Report

# What do we have to lose?

## Understanding and responding to climate-induced loss of biodiversity and ecosystem services

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**About this report**

This report is part of an ODI series on non-economic loss and damage, which includes a report on losses to cultural heritage and a report on losses to life and health.

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# Acronyms

| | |
|---|---|
| **AF** | Adaptation Fund |
| **AOSIS** | Alliance of Small Island States |
| **CBD** | Convention on Biological Diversity |
| **CMA** | Conference of the Parties serving as the meeting of the Parties to the Paris Agreement |
| **COP** | Conference of the Parties |
| **EU CICES** | European Union's Common International Classification of Ecosystem Services |
| **ExCom** | Executive Committee of the WIM |
| **DALYs** | disability-adjusted life years |
| **GCF** | Green Climate Fund |
| **GEF** | Global Environment Facility |
| **GDP** | Gross domestic product |
| **GHG** | Greenhouse gas |
| **IPBES** | Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **LDCF** | GEF Least Developed Countries Fund |
| **MA** | Millennium Ecosystem Assessment |
| **NELD** | Non-economic loss and damage |
| **QALYs** | Quality-adjusted life years |
| **SCCF** | GEF Special Climate Change Fund |
| **SIDS** | small island developing State |
| **TC** | Transitional Committee on the operationalization of the new loss and damage funding arrangements and fund |
| **TEEB** | The Economics of Ecosystems and Biodiversity |
| **UNCC** | United Nations Compensation Commission |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **UNESCO** | United Nations Educational, Scientific and Cultural Organization |
| **WIM** | Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts |

# Executive summary

Human societies and economies are embedded in natural systems. Nature provides a suite of benefits, services and contributions that improve people's quality of life and in many cases enable human survival. For decades, the global scientific community, Indigenous Peoples and local communities have been sounding the alarm on the decline in Earth's wealth of living organisms and non-living components. Throughout history, biodiversity and ecosystems have been damaged and lost through land use change, pollution, invasive species and direct exploitation, but now there is a new force driving their disappearance and degradation: anthropogenic climate change.

Biodiversity and ecosystems matter because biodiversity supports all life on earth, and reducing the range of genes, species and ecosystems affects the resilience of nature and the quality of services that it provides. If biodiversity loss reaches certain thresholds and tipping points (which are difficult to predict), biodiversity loss may trigger ecosystem collapse with profound effects for human health, dignity and productivity. This paper discusses the range of ecosystem services and functions that are at risk of loss and damage, along with examples where loss and damage is already a reality.

Climate change is already threatening biodiversity and ecosystems in varied and complex ways, and this is likely to increase as average global temperatures continue to rise. Some causes of climate change-induced loss and damage are relatively direct: extreme weather events or slow-onset events fuelled by higher average temperatures can destroy or damage biodiversity and ecosystems. As these events become more frequent and severe, biodiversity and ecosystems will consequently face greater risks.

Responding to damage or loss relating to biodiversity and ecosystems requires estimations of both the scale and the value of the loss, as without proper measurement it is more likely that losses will be ignored or neglected in decision-making. This paper outlines a range of metrics available from the physical and natural sciences to measure biodiversity and its loss or degradation and discusses tools to measure ecosystem services or nature's contribution to people. It also outlines techniques to estimate the monetary value of ecosystem services and their limitations.

The most effective way to avert or minimise further climate-induced loss and damage is to reach net-zero anthropogenic emissions as quickly as possible. The second most effective way is through actions to prepare for and adjust to the impacts of climate change. One option is in situ conservation, or the protection of biodiversity and ecosystems in their original location. This may involve the creation of protected areas with the express intention of maintaining species richness and ecosystem functions. Conservation and sustainable use of certain types of landscapes and seascapes can also contribute to climate change mitigation and adaptation.

Much loss and damage cannot be averted or minimised, and these unavoided or unavoidable impacts therefore need to be addressed. There is currently a lively debate around fair and appropriate ways to address non-economic loss and damage resulting from climate change. Options derived from transitional justice literature include:

1. Restitution: restoring those affected to their original situation (or as close as possible) before the loss and damage occurred. This can encompass measures to maintain biodiversity and restore ecosystems to something approximating their original state.
2. Rehabilitation: redressing or repairing the loss and damage through the provision of social services such as healthcare, education or legal support to help individuals or communities recover economically and socially from the trauma of the loss.
3. Satisfaction: symbolic measures to recognise loss and damage, such as truth-seeking, apologies or memorialisation.
4. Material compensation: the provision of money or other benefits in compensation for loss and damage.
5. Guarantees of non-repetition: commitments and measures to prevent similar loss and damage in the future, such as codes of conduct, training or governance reform.

These options vary in their relevance to climate-induced loss and damage to biodiversity and ecosystem services. They may also be deployed in different combinations depending on the nature and extent of biodiversity and ecosystem services loss, the value placed upon it by affected communities and others, the cost of response activity and the resources available.

A comprehensive response to biodiversity and ecosystem services loss will require collective, multilateral action.

There are several multilateral processes relevant to responding to biodiversity and ecosystem services loss, including the UN Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD). Financial support and fit-for-purpose funding arrangements are central to responding to loss and damage, and there have been major developments in this area under both of these regimes. The UNFCCC COP and CMA have established new loss and damage funding arrangements, including a new fund, and the CBD COP has requested the GEF to create a new special trust fund in 2023 to support implementation of the newly adopted Framework. These multilateral processes must ensure that the design and operationalisation of the mandates, structure, operating model and policies for the new funds (like the loss and damage fund and the Global Biodiversity Framework Fund) and funding arrangements are fit-for-purpose to respond to loss of biodiversity and ecosystems – whatever the cause.

# 1 Introduction

Human societies and economies are embedded in ecological systems. Nature provides a suite of benefits, services and contributions that improve people's quality of life and in many cases enable human survival: for example, water purification, food provision, construction material, cooking fuel and livelihoods[1].

Human degradation of earth systems and processes risks creating an environment that is likely to be less hospitable to human wellbeing,[2] jeopardising the development gains of the past and aspirations for the future. Throughout history, biodiversity and ecosystems have been damaged and lost through land use change, pollution, invasive species and direct exploitation, but now there is a new force driving their disappearance and degradation: anthropogenic climate change.

The concept of 'loss and damage' has its origins in international climate negotiations under the UNFCCC, and is now understood to refer to the impacts of climate change that cannot be avoided due to inadequate mitigation and the soft and hard limits to adaptation.[3] On its own, damage refers to climate change impacts that can potentially be restored, whereas loss refers to impacts that it is not possible to restore or repair.[4] Loss and damage can also be categorised into economic loss and damage, which refers to the loss of resources, goods and services that can easily be monetised, and non-economic loss and damage (NELD), which refers to loss that is far more difficult to quantify or measure solely in economic terms.[5]

Types of NELDs include loss of life, health, mobility, territory, biodiversity, indigenous knowledge, ecosystem services and cultural heritage.[6] However, the range of NELDs types is potentially endless as they are based on lived experiences and individual perceptions.[7] NELD is consequently more complex to measure and value than economic loss and damage,[8] and the resulting exclusion from monetary assessments can lead to underestimates of – and inadequate responses to – climate change-induced loss and damage.[9]

The international climate regime first began to pay substantial attention to NELD through the Warsaw International Mechanism (WIM) within the UNFCCC. At COP23, hosted by Fiji in Bonn, the five-year workplan of the Executive Committee was finalised with five workstreams, one of which focused on non-economic loss and damage.[10] This recognition of the importance of NELD, especially for developing countries,[11] significantly increased their visibility within negotiations and (more gradually) in policy-making among a number of countries.

This paper focuses on one subset of NELDs: loss and damage relating to biodiversity and ecosystems. Where NELD has been studied, loss and damage to biodiversity and ecosystem services has received less attention than other domains, such as loss of life and health. This paper reviews the nature and value of biodiversity and ecosystem services, the impacts of climate change on biodiversity and ecosystem services, and potential measures to respond to that loss and damage.

# 2 Understanding the nature and scale of loss of biodiversity and ecosystem services

## 2.1 Defining biodiversity and ecosystem services

Earth is home to a wealth of living organisms and non-living components that interact and create a rich diversity of genetics, species and ecosystems.[12] For decades, the global scientific community, Indigenous Peoples and local communities[i] have been sounding the alarm regarding the decline of this natural wealth and highlighting the need to rebalance people and nature through transformative change in human behaviour and activities.[13] This section articulates what is being lost when we speak of climate-induced NELDS relating to biodiversity and ecosystems.

Biological diversity (or 'biodiversity' as it is commonly known) is defined as the 'variability among living organisms from all sources'.[14] This diversity can be within species, among species and at the ecosystem level. When living organisms (i.e. plants, animals and micro-organisms) and their non-living environment interact with each other, the functional unit that this creates is known as an ecosystem.[15]

Ecosystems can be most simply categorised as terrestrial, freshwater or marine, but may also be defined more narrowly based on distinctive species compositions and environmental conditions. Ecosystems vary immensely in the level of species richness and therefore biodiversity. Some are exceptionally rich and have a high concentration of rare and endemic (native) species. These areas collectively host more than half of the world's species in approximately 1.4% of its land area, and are known as 'biodiversity hotspots'.[16] The tropical Andes in South America is a helpful illustration. This mountainous landscape is subject to large climate variability in a relatively small space because of its myriad levels of elevation. This results in a rich grouping of rare, range-restricted species, from the lake-dwelling Titicaca water frog to high-altitude Polylepis tree forests. Such biodiversity hotspots can be especially vulnerable, given the restricted range of species in question.

Another way of assessing or measuring ecosystems is through the concept of ecosystem function, the flow of energy and materials through living and non-living parts of the ecosystem.[17] These functions provide the necessary basis for ecosystem services.[18] At its most basic, the air we breathe, the water we drink and the food we eat all depend on these complex natural webs of life: the photosynthesis and transpiration of plants, the purification effect of wetlands and mangroves, the pollination services of birds and insects, and so on. Biodiversity levels and ecosystem function are closely linked.[19]

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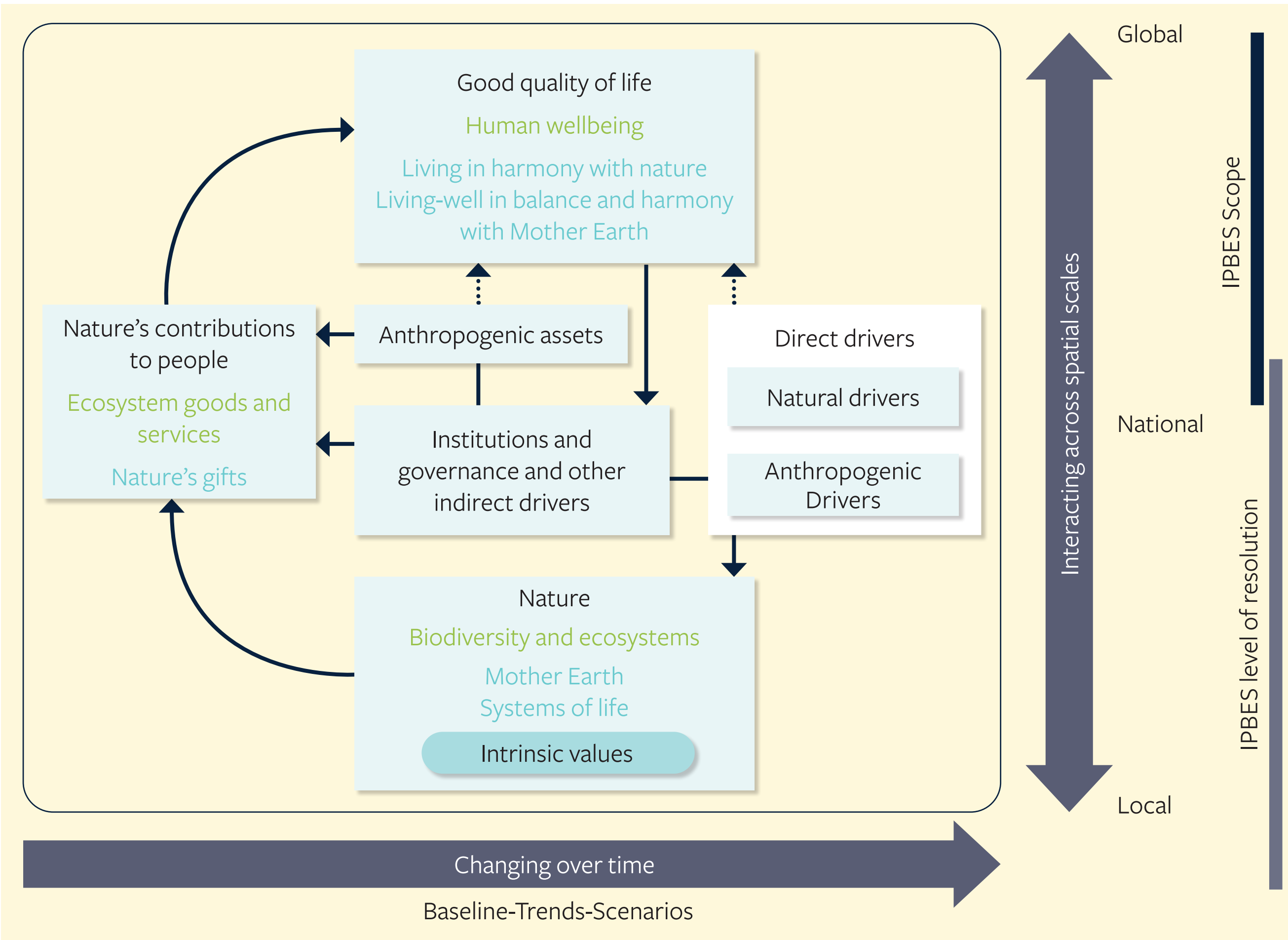
i The use of the term 'indigenous peoples' and 'local communities' is based off of its usage under the UNFCCC regime, specifically in its Paris Agreement 2018 and Decision 1/CP.21 (2015).

Ecosystem services were initially categorised as supporting services, regulating services, provisioning services and cultural services.[20] In an effort to evolve thinking around 'ecosystem services' towards a more pluralistic conceptualisation, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) developed a revised framework in 2013. This expanded framework involves concepts of nature, nature's contribution to people and good quality of life as umbrella categories that incorporate parallel scientific concepts including biodiversity and ecosystems, ecosystem services and human wellbeing (Figure 1), as well as concepts from other knowledge systems (including those from Indigenous Peoples and local communities), such as Mother Earth, nature's gifts and living well in balance and harmony with other species.[21]

The next section examines the causes or drivers of loss in biodiversity and ecosystems.

**Figure 1** IPBES conceptual framework representing the complex interactions between the natural world and human societies




Source: IPBES, 2019: 13[22]

Note: Text in green denotes scientific concepts, and text in blue denotes concepts originating in other knowledge systems. The solid arrows in the main panel denote influence between elements, and dotted arrows denote links that are acknowledged as important, but that are not the main focus of the Platform.

## Box 1 Choice of terminology in this paper

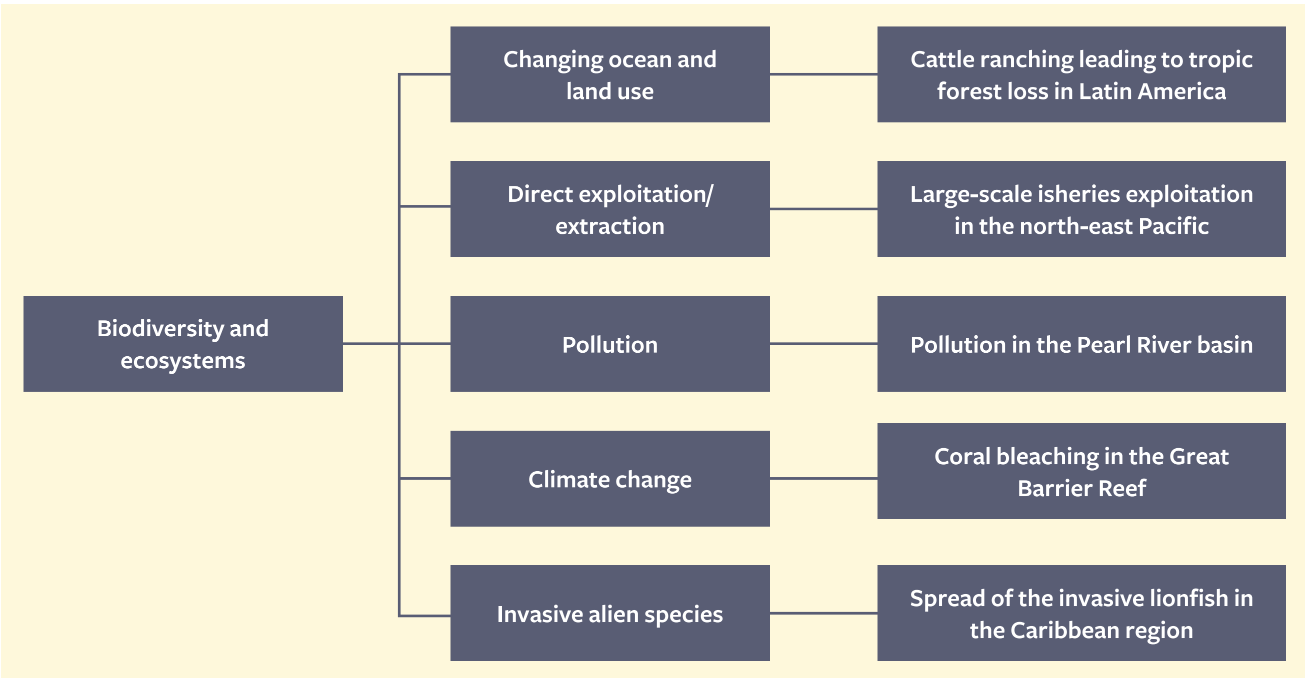
In this paper, the terms 'biodiversity' and 'ecosystem services' are used as a shorthand to encompass diverse understandings of nature, its intrinsic value and the contributions it makes to human individuals, economies and societies. This choice is based on the prevalent use of those terms in the international climate change regime, particularly the UNFCCC negotiations.

However, this is a rapidly evolving field and we note that the latest IPBES work has adopted the term 'Nature's Contribution to People' as an umbrella term to encompass the meanings attached to ecosystem services as well as those pertaining to different intellectual traditions and worldviews.[23]

## 2.2 Causes of loss of biodiversity and ecosystem services

The Earth has entered a sixth mass extinction event. Species are disappearing hundreds of times faster than the normal or background rate. Around a million species face extinction within decades. Loss of biodiversity and ecosystems at this scale is driven by human activity. The main direct drivers of such loss are pollution, direct exploitation/extraction of organisms or natural resources, changing ocean and land use, invasive alien species and the adverse effects of climate change (Figure 2).[24]

**Figure 2** The five direct drivers of biodiversity and ecosystem services loss with real-world examples



Since the 1980s, all five direct drivers of biodiversity and ecosystem loss have consistently increased globally.[25] Indirect drivers of biodiversity and ecosystem loss are social behaviours and values incompatible with environmental stewardship – production choices, consumption preferences, trade patterns, population growth and so on – that then fuel pollution, exploitation and the other direct drivers of loss.[26]

Among these direct drivers, changing ocean and land use is currently responsible for the largest share of global biodiversity loss, while invasive alien species account for the smallest share. Climate change is currently the fourth most significant direct driver, just ahead of invasive alien species and below pollution. When these drivers are broken down by ecosystem, climate change has its greatest documented effect on the marine ecosystem.[27] In absolute terms, climate-induced loss of biodiversity and ecosystems services is likely to increase as average global temperatures rise.

In the context of the new attention to climate-induced loss and damage, there are important questions to be asked about how robustly specific instances of biodiversity and ecosystem services loss can be linked to the more extreme weather or slow-onset events fuelled by higher average temperatures. Attribution is difficult given that many populations, species and ecosystems disappear amidst multiple drivers: for example, the Christmas Island forest skink recently went extinct, probably due to a combination of pollution (insecticides) and invasive alien species (including both competitors and predators).[28] In such instances, the specific impact of climate-related shocks and stresses is perhaps more difficult to evaluate than most of the other drivers. Moreover, the different drivers of biodiversity and ecosystem loss interact in a reinforcing feedback loop: for example, climate change is accelerated through land use change (for example the loss of carbon sinks such as forests, wetlands and mangroves) and pollution (such as the decomposition of organic waste products). Attribution science at the local and national level is further complicated in developing countries due to a lack of historical, granular data that can serve as a baseline (Indigenous and local knowledge can partially fill this gap).

Lastly, it is worth elaborating on the indirect drivers of biodiversity and ecosystem services loss, given that changing these forces will be necessary for transformative action. Indirect drivers encompass the social and economic values and behaviours of people, recognising how these in turn vary across communities and regions. Values and behaviours may manifest in governance arrangements at different scales, economic and financial structures (e.g. production and consumption choices or trade patterns) and demographics (e.g. population growth and wealth inequality).[29] Such indirect drivers shape the direct drivers of biodiversity and ecosystem services loss.

Financial system incentives offer a good illustration. Commercial banks in many countries have considerable experience of agricultural lending, and may indeed have formal incentives to do so (e.g. subsidies from finance ministries or priority sector lending requirements from central banks). Finance professionals in these institutions are therefore experienced in evaluating whether individual loans to – for example – expand cattle ranches or palm oil plantations will be repaid at agreed rates and timelines. However, regulatory frameworks may not require those finance professionals to consider the full social, economic and environmental costs of those loans as those ranches and plantations expand into tropical forests. The direct drivers of biodiversity loss therefore might include land use change, pollution (from pesticides, herbicides and fertilisers) and climate change (from the destruction of carbon sinks). The indirect drivers would include the governance of the financial sector alongside consumption choices such as demand for beef and palm oil, demographic changes like a larger and wealthier global population demanding these goods, and other governance factors such as the creation and enforcement of conservation areas. Addressing the direct drivers of biodiversity loss therefore requires attention to socio-economic values, behaviours and structures.

This section has unpacked the causes of biodiversity and ecosystem loss. The next section considers the impact of such losses.

### Box 2 Loss and damage on the Great Barrier Reef

The Great Barrier Reef in Australia is the world's largest reef system and is sometimes described as the largest structure made by living organisms. It is home to 400 species of coral, 1,500 species of fish, 4,000 species of mollusc and many other types of life, including endangered flagship species such as the dugong or green sea turtle.[30] The Great Barrier Reef has been a UNESCO World Heritage Site since 1981.

The Great Barrier Reef faces a number of threats that are being compounded by or can be attributed to climate change. Cyclones can physically damage or destroy reef structures, while heavy rainfall in Queensland can lead to large influxes of freshwater, sediments and pollutants. Both weather events are becoming more frequent and severe as global temperatures rise. Looking forward, rising sea levels will affect corals' access to light, while ocean acidification (caused by absorption of atmospheric carbon dioxide) will dissolve the calcium carbonate that they use to build their skeletons.[31] Other direct and indirect drivers of loss are also at play. Some of the freshwater reaching the reef is polluted from agricultural and industrial activities on land. Changing ocean and land use is affecting coastal habitats (on which many reef species depend), for example due to new ports, housing and tourist developments. Natural resource extraction is also having an impact, including both legal and illegal fishing/poaching. The Australian government has done much to manage many of these threats, most notably establishing vast marine parks that cover almost the entire reef system and adjacent coastal habitats. Within these boundaries, social and economic activities are closely managed. However, Australians produce among the highest per capita greenhouse gas emissions in the world, which contribute to the climate change that poses the largest threat to the Great Barrier Reef.

## 2.3 Impact of losing biodiversity and ecosystem services

Biodiversity supports all life on earth. Reducing the range of genes, species and ecosystems affects the resilience of nature and the quantity and quality of services it provides. If biodiversity loss reaches certain thresholds and tipping points (which are difficult to ascertain), biodiversity loss may trigger ecosystem collapse with profound effects for human health, dignity and productivity.[32] Beyond a certain point, decline in biosphere integrity risks destabilising fundamental Earth systems and therefore poses an existential threat to humanity.[33] Such losses have economic implications that can be quantified in monetary terms. In 2019, one calculation suggested that an estimated 50% of global gross domestic product (GDP) – equivalent to $44 trillion of economic value – was moderately or highly dependent on ecosystems.[34] Focusing on more specific examples of biodiversity or ecosystem services loss, the collapse of wild pollination, marine fisheries and timber provision by native forests would lead to a potential contraction of 3% of global annual GDP – worth $2.7 trillion as of 2021.[35]

There are limits to how robustly such economic assessments can be made (for more on valuation of biodiversity and ecosystem services loss, see Section 2.4), and indeed whether such analyses are even meaningfully relevant. Biosphere integrity and ecosystem function play a critical role in human economies and societies, irrespective of whether they are directly or indirectly traded on the market, or whether they can be consumed or not. All humans ultimately depend on biodiversity and ecosystems for survival. As such, the dichotomy between economic and non-economic loss is blurred in reality when applied to biodiversity and ecosystem services. Economic activities or indeed a good life are not possible in the absence of a sufficiently healthy natural world, where critical Earth systems have collapsed.The impacts of biodiversity and ecosystem loss can be hard to assess and manage at a global scale in part because they are borne so unevenly. There is great distributional variation in individuals' and communities' direct dependence on nature. Low-income and other marginalised groups tend to be more exposed to environmental degradation, and unequal power relations affect their ability to prevent or manage the associated impacts. Another challenge is that biodiversity loss is non-linear: when pollution, climate change or other threats pass often unknown thresholds (at either a local or global scale), they can trigger accelerated rates of loss and damage.[36] The large uncertainties as to the extent and reversibility of environmental degradation further disincentivise efforts to avoid it – a well-established challenge in tackling climate change, but one that is particularly stark with respect to biodiversity and ecosystems services.

Table 1 summarises the range of ecosystem services at risk from biodiversity loss and other forms of environmental degradation. This framework, developed by IPBES in 2019, seeks to bring together previous classification frameworks (i.e. the MA, UK National Ecosystem Assessment, TEEB and the EU CICES). The immense range of nature's contribution to people hints at the catastrophic threat that loss of ecosystem function and ecosystem services poses for humanity.

**Table 1** Services and functions at risk through biodiversity and ecosystem loss

| | Ecosystem services/ Nature's contribution to people | Description |
|---|---|---|
| Regulating services | Habitat creation and maintenance | The formation and continued production, by ecosystems, of ecological conditions necessary or favourable for living beings important to humans |
| | Pollination | Facilitation by animals of movement of pollen among flowers, and dispersal of seeds, larvae or spores of organisms beneficial or harmful to humans |
| | Regulation of air quality | Regulation (by impediment or facilitation) by ecosystems of atmospheric gases; filtration, fixation, degradation or storage of pollutants |
| | Regulation of climate | Climate regulation by ecosystems (including regulation of global warming) through effects on emissions of greenhouse gases, biophysical feedback, biogenic volatile organic compounds and aerosols |
| | Regulation of ocean acidity | Regulation, by photosynthetic organisms, of atmospheric $CO_2$ concentrations and seawater pH |
| | Regulation of freshwater quantity, location and timing | Regulation, by ecosystems, of the quantity, location and timing of the flow of surface and groundwater |
| | Regulation of freshwater and coastal water quality | Regulation of water quality by ecosystems through filtration of particles, pathogens, excess nutrients and other chemicals |
| | Formation, protection and decontamination of soils and sediments | Formation and long-term maintenance of soils including sediment retention and erosion prevention, maintenance of soil fertility and degradation or storage of pollutants |
| | Regulation of hazards and extreme events | Amelioration, by ecosystems, of the impacts of hazards; reduction of hazards; change in hazard frequency |
| | Regulation of detrimental organisms and biological processes | Regulation, by ecosystems or organisms, of pests, pathogens, predators, competitors, parasites and potentially harmful organisms |
| Material and assistance | Energy | Production of biomass-based fuels, such as biofuel crops, animal waste, fuelwood and agricultural residue |
| | Food and feed | Production of food from wild, managed or domesticated organisms on land and in the ocean; production of feed |
| | Materials and assistance | Production of materials derived from organisms in cultivated or wild ecosystems and direct use of living organisms for decoration, company, transport and labour |
| | Medicinal, biochemical and genetic resources | Production of materials derived from organisms for medicinal purposes; production of genes and genetic information |

| | Ecosystem services/ Nature's contribution to people | Description |
|---|---|---|
| Non-material | Learning and inspiration | Opportunities for developing capabilities to prosper through education, knowledge acquisition and inspiration for art and technological design (e.g. biomimicry) |
| | Physical and psychological experiences | Opportunities for physically and psychologically beneficial activities, healing, relaxation, recreation, leisure and aesthetic enjoyment based on close contact with nature |
| | Supporting identities | The basis for religious, spiritual and social cohesion experiences; sense of place, purpose, belonging, rootedness or connectedness, associated with different entities of the living world; narratives and myths, rituals and celebrations; satisfaction derived from knowing that a particular landscape, seascape, habitat or species exists |
| Regulating, material and non- material | Maintenance of options | Capacity of ecosystems, habitats, species or genotypes to keep human options open in order to support a later good quality of life |

Source: IPBES, 2019[37]

## Box 3 Loss and damage in the Himalayas

The Himalayas span five countries: Bhutan, China, India, Nepal and Pakistan. The mountain range runs in an arc that stretches over 2,400km and includes some of the highest peaks in the world. Its immense size and rugged nature have created a huge number of isolated micro-habitats, leading to exceptional biodiversity as species evolved down separate lines. The Himalayas is known for iconic species such as tigers, snow leopards, red pandas, elephants and rhinoceros, but it is also distinguished by the exceptional diversity of alpine flora.

Ten major rivers rise in the Himalayas, collectively providing water to over a billion people. Some of this water comes directly from precipitation, as the mountain range forces monsoon winds to rise; the air thins at higher atmosphere and loses its moisture. Rivers are further fed by the annual melting of snow and glaciers. While the amount of rain falling in the Himalayas is predicted to increase with rising global temperatures, it is also expected to fall in more unpredictable and intense patterns. While the rapid melting of glaciers due to climate change has increased the volume of run-off over recent decades, water flows are already diminishing in parts of the Hindu Kush due to glacier retreat.[38] Climate-induced changes to rainfall and glacial melt will affect Himalayan ecosystems' ability to regulate the quantity and quality of water, exposing the hundreds of millions of people living downstream to increased risks of both flooding and scarcity. Provisioning ecosystem services may also be affected: for example, the production of fodder, fuel and timber may be affected by glacial floods or water shortages.[39] Such climate-induced impacts are taking place in parallel with other threats to ecosystem function, such as the expansion of hydropower, tourism development and unsustainable groundwater extraction.

## 2.4 Measuring and valuing the loss of biodiversity and ecosystem services

Loss and damage to biodiversity and ecosystem services can have harmful impacts, as outlined in Section 2.3. However, without proper measurement of these losses it is more likely that they will be ignored or neglected in decision-making.[40] In order to avert, minimise and address loss or damage relating to biodiversity and ecosystems, there is a need for estimations of both the scale and the value of the loss.[41]

There are a wide range of metrics available from the physical and natural sciences to measure biodiversity and ecosystem services, including their loss or degradation. Such indicators typically measure individual components of biodiversity or ecosystem services, as it is difficult to develop a single metric that speaks to all facets collectively.[42]

Common indicators to assess biodiversity include genetic variation within a species, species abundance (the population of an individual species), species richness (the number of species within a region), the number or proportion of a threatened species (typically accompanied by data on that species' abundance), the number or proportion of endemic species (i.e. species that are only found in a particular region) and the range of ecosystems within a particular region.

In addition to measuring biodiversity, there is an array of tools to measure ecosystem services or nature's contribution to people.[43] Indicators in this category may capture material impacts, for example the extent to which ecosystems regulate air quality, decontaminate soils or provide food and materials. They may also capture aspects of non-material loss, although this is more difficult to quantify and measure.[44] Indicators in this category may capture, for example, loss to human health in terms of disability-adjusted life years (DALYs) or quality-adjusted life years (QALYs), or loss of cultural heritage by asking trained experts (such as historians, curators, linguists or psychologists) equipped with the specific tools of their disciplines.[45] IPBES provides an illustrative list of indicators that can be used to measure nature's contribution to people (Appendix 1).

Although non-monetary metrics are available to measure NELDS relating to biodiversity and ecosystems, they are unlikely to galvanise a robust response. Valuing NELDS in monetary terms is therefore important for implementing measures to prevent and respond to loss and damage.[46]

However, conducting an economic or financial valuation of biodiversity and ecosystem services is a challenging task. These items are not typically traded on the market, and therefore have no direct market price.[47] Biodiversity and ecosystem services also have intrinsic values, such as bequest, altruistic and existence values, which are much more difficult to estimate. The focus is usually on the instrumental value of biodiversity or ecosystem services, while their intrinsic value (both in their own right and to humanity) are neglected.[48]

Economic valuation techniques, such as revealed preference and stated preference, can be used to estimate the monetary value of ecosystem services. Revealed preference methods are based on the fact that, while some goods or services may not be traded on the market directly, they may be traded implicitly, and their value can be estimated by observing the values of similar goods or services.[49] Techniques include market price, productivity change, defensive expenditure, replacement cost, provision cost, hedonic pricing and travel costs.[50] Revealed preference methods typically measure the use value of ecosystem services, whereas stated preference methods can be used to measure use and non-use value. Stated preference methods rely on questionnaires and hypothetical markets to elicit individuals' preferences and willingness to pay for an ecosystem service, using methods such as contingent valuation, choice modelling and group valuation.[51] While these economic valuation techniques can provide a monetary value for ecosystem services, there are limitations. For instance, stated preference methods which rely on individuals' valuations of the good may be limited by the fact that individuals might have imperfect knowledge about an ecosystem's processes and functions which may affect the quantification and economic valuation of the service.[52] Contingent valuation methods may also suffer from biases in respondent behaviour that may affect the valuation estimations, including strategic biases, hypothetical biases and insensitivity to scope.[53] Other concerns surrounding the use of these techniques include the discounting rates that should be applied to compare present and future costs and benefits and uncertainties about whether the values obtained are representative of the service's true value.[54]

Such limitations play out very starkly when considering the loss of biodiversity and ecosystems. For example, it is difficult to assess the value of all pollinator species in monetary terms, given that their services in food production are fundamental for human survival. Avoiding the global loss of the bees, beetles, butterflies, birds and other animals involved in pollination is therefore logically worth a significant amount to global GDP – but no decision-maker would allocate all of their resources to this purpose unless and until those species pass a tipping point and collapse. It is similarly difficult to estimate the value of coral reefs, which protect entire nations from storms and erosion and serve as breeding grounds for huge numbers of commercially and culturally important species.[55] However, the vast majority of tropic coral reefs are likely to disappear even at 1.5°C of warming.[56] Assigning a monetary value to the future provisioning and regulating services of such reefs is extremely challenging; it is still more challenging to integrate estimates into the cost-benefit analyses being undertaken by decision-makers whose choices are indirectly driving the loss and damage of those reefs.

## Box 4 Loss and damage in the Mekong Delta

With over 20,000 plant species and over 1,300 fish species, the Mekong river system is renowned for its exceptional biodiversity. It is also home to many iconic animals such as the Irrawaddy dolphin, Mekong giant catfish, Asian elephant, the saloa, the siamang and – until recently – one of the last two populations of Javan rhinos.[57] People have inhabited the Mekong Delta for centuries, drawn by its rich natural resources. The abundant supply of water and rich sediments lend themselves to agriculture, while fish are plentiful. However, increasingly intensive human settlement and extraction are leading to diminishing levels of biodiversity – the local extinction of Javan rhino being one of the more high-profile examples – and declining quality of ecosystem services. For example, the construction of hydropower stations upstream has slowed the flow of sediment, affecting agricultural productivity and fuelling coastal erosion.[58] Downstream, the uprooting of mangroves to establish shrimp farms has removed an important line of defence against storm surges and soil erosion.[59]

Climate change poses an additional threat to both people and nature in the delta. Much of the region lies less than five metres above sea level, and the land itself is sinking due to subsidence. This means that much of the Mekong Delta risks inundation with even relatively small levels of sea-level rise; moreover, the whole region will be at risk from increasingly frequent and severe typhoons, storm surges and coastal flooding.

Increasing salinity within the Mekong Delta is a function of climate change, but also other anthropogenic factors including the destruction of coastal ecosystems and construction of hydropower plants. Salinisation is likely to enable marine species to move upstream, while reducing the habitat available for freshwater species. It is also likely to devastate rice production, the staple food and a major export crop of Vietnam. One study finds that 44% of land in the delta has already been affected by salinity intrusion, with saline concentrations above 4 grams per litre (the level which begins to affect rice yields) up to 40km upstream of the coast.[60]

# 3 Responding to climate-induced loss of biodiversity and ecosystems: a review of the options

There is a unique relationship between nature and climate change. The degradation and disappearance of ecosystems – particularly carbon-rich habitats such as wetlands, mangroves and tropical forests – releases greenhouse gases that fuel global warming, which in turn causes further habitat loss. However, the conservation and restoration of such ecosystems can sequester greenhouse gases from the atmosphere, helping to mitigate the extent of climate change. Moreover, healthy ecosystems can enhance resilience to climate-related shocks and stresses, for example through their regulatory and provisioning services.[61, 62] Biodiversity loss and climate change consequently need to be understood as mutually reinforcing with responses seizing cobenefits where possible.

The multilateral climate and biodiversity regimes use different terms to describe responses to loss and damage.

Within the UNFCCC regime, the term 'addressing' loss and damage was used from 2010;[63] from 2015, other terms like 'averting' and 'minimizing' were also included as objectives for responding to loss and damage.[64] At COP27 in 2022, 'responding, including a focus on addressing' was used in relation to funding arrangements for these actions.[65] ODI's companion report on NELDs relating to cultural heritage defines the term '*avert*' as 'to prevent or keep from happening', '*minimise*' as 'to reduce as much as possible' and '*address*' as 'to deal with, respond to, act upon or treat'.[66] In practical terms, averting and minimising loss and damage can be understood as climate change mitigation and adaptation, and implies attention to avoidable loss and damage. Addressing loss and damage describes managing the harm or impacts experienced, and implies attention to unavoided or unavoidable loss and damage.[67] Turning to the international biodiversity regime under the Convention on Biological Diversity (CBD), terms such as 'reduce', 'halt' and 'reverse' are used to describe objectives for responding to biodiversity loss.[68] Reducing and halting biodiversity loss can be understood as preventative measures in the context of avoidable loss and damage. Reversing such loss is a curative measure where losses were unavoided or unavoidable.[69] The key actions to achieve these objectives are 'conservation' and 'sustainable use' of biodiversity and ecosystems. *Conservation* more broadly includes saving, studying and using biodiversity though the management of human interactions with its components.[70] Conversation's ultimate aim is to provide maximum benefit to the present generation and sustaining potential benefit for future ones. *Sustainable use* of biodiversity is defined as the utilisation of different genes, species and ecosystems in a manner that does not lead to long-term biodiversity decline.[71] The foremost aim of sustainable use is to maintain biodiversity's benefit potential for present and future generations by not passing the component's threshold needed for its long-term viability.

Figure 3 provides a framework for comparing the terminology used in the climate and biodiversity regimes.

**Figure 3** Terminology for responding to loss and damage within the global climate and biodiversity regimes

| Loss and damage type | Avoidable | | Unavoided and unavoidable |
|---|---|---|---|
| Objective (climate change) | Avert and minimize loss and damage | | Addressing loss and damage |
| Action (climate change) | Mitigation | Adaptation | Addressing |
| Objective (biodiversity) | Reduce and halt biodiversity loss | | Reverse biodiversity loss |
| Action (biodiversity) | Conservation & sustainable use | | Restoring and redressing |

Source: Adapted from Schafer et al. (2021)[72]

The categories of loss and damage described above, i.e. 'avoidable', 'unavoided' and 'unavoidable', are useful, but the lines between them are blurred for several reasons. Human and natural systems face limits to adaptation. These may be soft limits, where adaptation or conservation measures are available but cannot be used because of prohibitive costs, inadequate implementation capabilities, political or cultural barriers or other factors. In such contexts, avoidable losses become unavoided. For example, large mammals living in grassland ecosystems may be able to survive climate-induced changes to rainfall patterns that affect the availability of food if this is the only threat they face. However, additional pressure from poaching may lead to population decline and ultimately extinction in their native habitat. Human and natural systems may also face hard limits to adaptation. In this instance, a threshold has been passed which means that losses are unavoidable.[73] For example, the disappearance of snow and glaciers in some mountain ranges may mean that some of the alpine species living at the

highest altitudes lose their ecological niche and therefore become extinct in their native habitat. Thus, both soft and hard limits to adaptation can mean that the climate regime moves from averting and minimising loss to addressing it, while the biodiversity regime moves from reducing and halting loss to reversing it.

This section has two parts. First, it considers options to avert and minimise avoidable loss of biodiversity and ecosystem services. Second, it considers options to address unavoided or unavoidable loss of biodiversity and ecosystems. Both sections draw heavily on experiences of biodiversity conservation, sustainable use, ecosystem restoration, redress and loss around the world. Although this section is structured in a way that separates averting/

minimising avoidable loss and damage from addressing unavoided/unavoidable loss and damage, it is important to recognise that on the level of implementation, loss and damage response actually takes place on a spectrum. Thus, a combination of tools and techniques may be deployed in response to specific examples of biodiversity and ecosystem services loss. In all cases, it is important to emphasise that all responses to loss and damage should begin with consultation and prior informed consent of the representatives of Indigenous Peoples and affected communities, and need to support their participation in actions taken to address climate-induced loss of biodiversity and ecosystems.[74]

## 3.1 Averting and minimising loss of biodiversity and ecosystems

Preventative measures are the first and best hope for responding to biodiversity loss given the typically irreversible nature of environmental damage.[75] The precautionary principle is therefore a cornerstone of successful environmental management.

The most effective way to avert and minimise climate-induced loss and damage is to reach net-zero anthropogenic emissions as quickly as possible. Earlier action to reduce greenhouse gases would have averted and minimised the extent of climate-induced loss and damage still further. In the absence of sufficient efforts to cut emissions, average global temperatures have increased by 1.1°C above pre-industrial levels[76] and will continue to rise due to historic emissions, even if humanity collectively achieved net-zero emissions tomorrow. A still hotter future is locked in.

Climate change will therefore pose an increasing threat to biodiversity and ecosystems, which will be compounded by the other anthropogenic drivers of loss outlined above: changing land and ocean use, direct exploitation and extraction of natural resources, pollution and invasive species. A range of additional measures are required to conserve natural systems, to ensure sustainable use and to facilitate their adaptation to a changing climate.

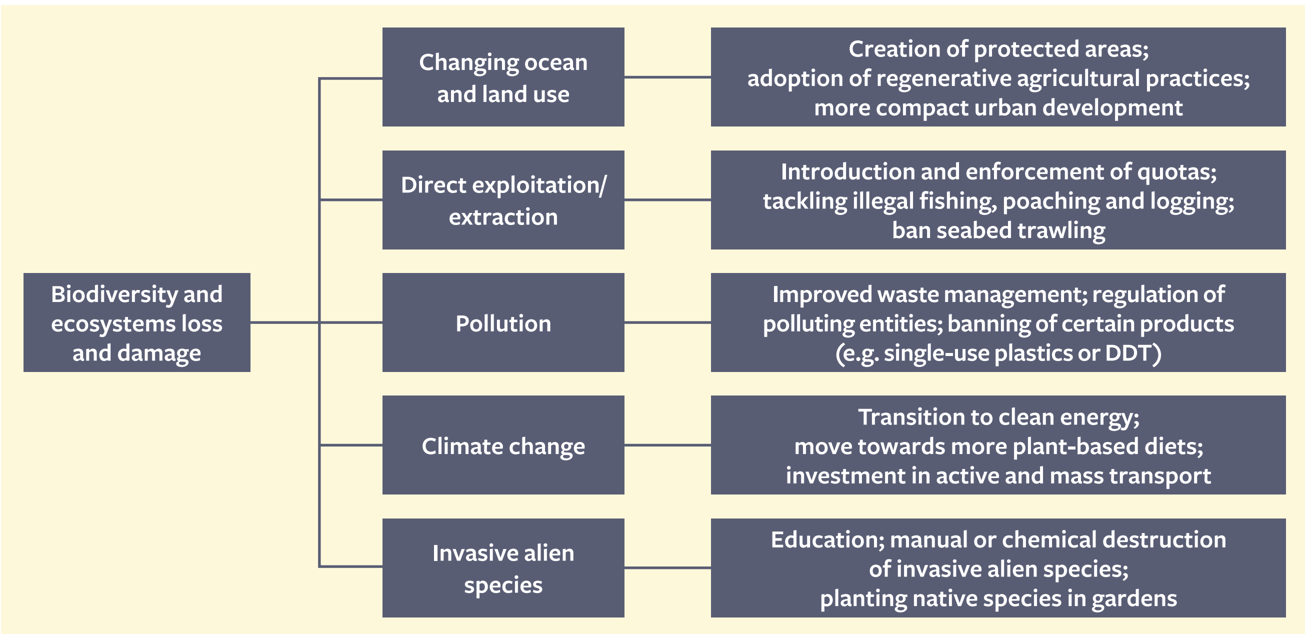
One option is through in situ conservation, i.e. the protection of biodiversity and ecosystems in their original location. This strategy may involve the creation of protected areas with the express intention of maintaining species richness and ecosystem functions. In some cases, these sites will be refuges for species or serve to maintain ecological processes that would not persist with more intensive management or use by humans. However, in situ conservation does not necessarily imply that a landscape or seascape must be pristine and exclude human use.[77] Controlled trophy hunting or carefully managed fishing, for example, can generate significant revenues and jobs; if those benefits are equitably shared, they can provide the resources and secure the public support necessary for successful conservation of terrestrial and aquatic ecosystems.[78] The effectiveness of in situ conservation depends on a wide range of factors, including the size of the area protected; the diversity of species and ecosystems within the area; its connectivity to other habitat fragments; and governance of the area (including adequate funding, staff training and local buy-in).

Conservation and sustainable use of certain types of landscapes and seascapes can contribute particularly to climate change mitigation and adaptation (and therefore averting and minimising climate-induced loss and damage while protecting biodiversity). Protection or sustainable use of carbon-rich ecosystems such as tropical forests, peatlands and seagrass meadows can prevent the release of the greenhouse gases stored in soil and plant matter.[79] Other ecosystems play important regulating functions that can enhance resilience to climate shocks: for example, mangroves and wetlands can both slow the flow of water and therefore reduce flooding in the event of storms or heavy rainfall. All of these ecosystems are home to unique species, and their protection can therefore help to sustain biodiversity.

As of May 2023, only 16% of terrestrial and inland waters were protected and just 8% of marine areas.[80] These protected sites are absolutely critical but clearly not sufficient for nature to thrive given the multiple threats it faces. A range of additional measures are needed to avert and minimise loss of biodiversity and ecosystems. Figure 4 presents some of the possible responses to the direct drivers of biodiversity and ecosystem loss. It is not intended to be a comprehensive list, but rather to illuminate the range of measures that are available and necessary to reduce the anthropogenic pressures facing the natural world.

The examples presented in this section make it clear that there are a wide range of responses to avert and minimise loss and damage. These are pertinent to negotiations about loss and damage finance within the UNFCCC, but sufficient financial resources and supportive governance arrangements are still required. Against this backdrop, the findings of a recent global literature review are highly relevant.[81] The analysis suggests that finance and governance are the two most common constraints to adaptation, a barrier which may lead to potentially unavoided loss and damage. Additionally, there are instances where losses are unavoidable despite the availability of adaptation options. All of this sits in the broader context of hard-to-reverse or irreversible thresholds or tipping points currently being exceeded, particularly for biodiversity and ecosystems, caused by the adverse effects of climate change.[82] Where these breaches occur, it is necessary to pivot from averting and minimising loss and damage to addressing it.

**Figure 4** Responding to the five direct drivers of biodiversity and ecosystem loss: an illustration of available measures



## 3.2 Addressing loss of biodiversity and ecosystems

Measures can be put in place to avert and minimise NELD to biodiversity and ecosystems, including through mitigation and adaptation to climate change, as outlined in the previous section. However, in some cases NELD cannot be averted or minimised, leading to unavoided or unavoidable impacts.[83] As a result, there are important questions related to fair and appropriate ways to address non-economic loss and who should be responsible for doing so.[84]

This subsection looks at five options to address loss and damage of biodiversity and ecosystems: (1) restitution; (2) rehabilitation; (3) satisfaction; (4) material compensation; and (5) guarantees of non-repetition. These options were introduced into climate debates by Klinsky and Brankovic (2018),[85] who suggested that the issues of responsibility and repair are separated, so that a non-punitive approach could be taken to ameliorate climate-related harms. The options were based on international experiences of and frameworks for transitional justice. However, similar measures have been proposed to address non-economic loss in other work, including recognition and repair of loss, remembrance, counselling and official apologies, which can all provide some remedy.[86, 87] Similar options under public international law should also be explored to inform the design of loss and damage response options, including lessons from literature and real-life application of remedies/response options contained in the International Law Commission's 2001 *Draft articles on responsibility of states for internationally wrongful acts*, and their 2006 *Draft principles on the allocation of loss in the case of transboundary harm arising out of hazardous activities* (specifically the principle on 'Response Measures'). The focus should be on effectiveness in responding to loss and damage, rather than liability or responsibility.

This section discusses the five options outlined above, and how they can be used to address non-economic loss relating to biodiversity and ecosystems. The options put forward may be used on their own or in combination. While material compensation is a potential measure in its own right, all of the other measures also require funding as they will incur costs. For example, translocation to reintroduce a species to its indigenous habitat (a form of restitution) will require funding to cover its capture, transport, care while captive and tracking after release. In Namibia, the translocation of large carnivores – leopards, cheetahs and hyenas – had a median cost of $2,393 per individual.[88] Such activities to address climate-induced loss and damage are rarely funded by those responsible, especially compared to activities to avert and minimise loss and damage.[89]

When considering the use of different mechanisms to address non-economic loss to biodiversity and ecosystems, the most appropriate choice of measure will depend on the nature and impact of the damage or loss. Measures can be put in place to address the impacts of the damage or loss to nature itself – for example, captive breeding programmes to preserve and increase the population of a species that has no material value to humans. However, measures should also address the impacts of the damage or loss on humans, as the diminution of biodiversity and degradation of ecosystems could lead to the violation of human rights to food, clean air and water, health and culture and the right to life, all of which depend on flourishing ecosystems (UNEP and OHCHR, n.d.). Under the *International Covenant on Economic, Social and Cultural Rights* and the *International Covenant on Civil and Political Rights*, Parties are to work towards fulfilling these rights. Because of the potential impacts on humans, any actions to address biodiversity and ecosystem loss should also protect human rights and consider human wellbeing. For instance, a bleached coral reef may be difficult to replace with its wealth of life and range of ecosystem services. However, given the importance of its contribution to human wellbeing, alternative measures such as engineering solutions can be constructed to protect low-lying coastal communities from storm surges and erosion.

## Restitution

In the context of international human rights, restitution aims to provide remedy to individuals by restoring them to their original situation before the loss and damage was experienced.[90] Restitution typically refers to restoration of liberty, human rights, identity, citizenship and employment following a violation of human rights law.[91] In the context of climate change, restitution can perhaps better be understood as repair of loss, similar to the mechanism outlined in Shawoo et al. (2021).[92]

We understand restitution in this context as encompassing measures intended to maintain biodiversity and restore ecosystems to something approximating their original state. Deployment of these measures can be motivated by the intrinsic value of nature, by the benefits accruing to humans or by a combination of both. It is important to distinguish restitution from rehabilitation (discussed in the next sub-section), which focuses particularly on measures to redress or repair the harm experienced by humans due to loss of biodiversity and ecosystems. In other words, rehabilitation in this context does not describe the rehabilitation of nature; rather, we use rehabilitation in the sense in which it is used in international frameworks for transitional justice.

This sub-section identifies three options for restitution: ecological restoration, conservation translocation and ex situ conservation. These three options are not mutually exclusive.

Ecological restoration describes activities that assist in the recovery of ecosystem structure and function.[93] Effective ecological restoration typically demands stopping activities that reduce biodiversity or degrade natural environments, such as overfishing, the use of pesticides/herbicides or covering the soil with impermeable surfaces (like concrete, asphalt or plastic). Such measures can also be understood as averting and minimising loss of biodiversity and ecosystems, discussed in Section 3.1. Ecological restoration typically goes further through measures that can actively enhance biodiversity and ecosystem function, primarily by facilitating the recovery of degraded habitats. Such measures might include:

- Seeding or planting degraded ecosystems with native plant species to recreate vegetation communities. For example, replanting a deforested area with native tree species can – over time – help regenerate a forest, though additional measures might be required to fully restore biodiversity and ecosystem function: for example, careful logging to prevent the dominance of pioneer species or the reintroduction of specific animal species.
- Changing the management of terrestrial ecosystems to diversify the species or age composition of vegetation communities. For example, leaving old trees instead of felling them can provide nest sites for birds to breed, decaying wood for invertebrates to feed and much more extensive mycorrhizal (fungal) root networks that nourish younger trees.
- Creating corridors to connect habitat fragments that support ecosystem function and larger, more connected populations. For example,

freshwater flows down a river can be restored by removing or adjusting barriers (such as dams), helping to restore key regulating services, while buffer strips of aquatic and terrestrial vegetation can be added to provide habitat for riparian species.

In some cases, the 'green' and 'blue' solutions described above may be combined with 'grey' solutions to more quickly replace or restore ecosystem services. For example, coastal communities may choose to construct smaller concrete breakwaters and simultaneously to replant mangroves, which together can provide more comprehensive protection against storm surges. Property developers may choose (or be required) to install green roofs on buildings, providing ecosystem services such as temperature regulation as well as benefits to humans such as improved insulation. Table 2 provides a non-exhaustive list of some of the ways in which grey, green and blue solutions may be combined to recreate or substitute for nature's contribution to people. These alternative measures can also ensure that human wellbeing and human rights are protected in the event of the degradation of ecosystems.

**Table 2** Services and functions at risk through biodiversity and ecosystem loss, including loss induced by climate change

| | Loss of NCP | Negative impacts of loss on quality of life | Alternative measures to address impacts |
|---|---|---|---|
| Regulating services | Pollination | • Shortages in foods reliant on pollination<br>• Health impacts due to food decline | • Artificial and mechanical pollination methods |
| | Regulation of air quality | • Health impacts and premature deaths due to air pollution | • Nature-based infrastructure such as urban forests and green roofs and walls to improve air quality |
| | Regulation of climate<br>Regulation of natural hazards and extreme events | • Increase in economic cost of climate-induced extreme events<br>• Natural hazards and extreme events leading to deaths, health impacts and other impacts on people | • Built and nature-based infrastructure to mitigate impacts of extreme events |
| | Regulation of ocean acidification | • Economic impacts of damage to coral reefs<br>• Impacts on provision of food, income, livelihoods<br>• Impacts on coastal protection | • Advances in geoengineering<br>• Nature-based infrastructure for coastal protection (e.g. living shorelines) |
| | Regulation of freshwater quantity, location and timing | • Increasing human water demand<br>• Increasing water scarcity | • More efficient use of water resources<br>• Desalination of seawater<br>• Wastewater recycling |
| | Regulation of freshwater and coastal water quality | • Decrease in water quality | • Desalination of fresh and seawater<br>• Water purification plants |
| | Formation, protection and decontamination of soils and sediments | • Declining soil fertility leading to reduced crop yield | • Greater use of chemical fertilisers<br>• Use of improved soil management techniques |
| Material and assistance | Energy | • Global decrease in forested area to provide fuelwood and timber | • Increase in access to alternative energy sources |
| | Food and feed | • Decrease in food quantity and quality<br>• Increase in malnutrition, hunger and negative health outcomes | • Increase in climate-smart agricultural practices<br>• Increase in climate-resilient food crops |
| Non-material | Learning and inspiration | • Reduced human-nature interactions<br>• Declining diversity of life from which to learn<br>• Reduced ideas and products mimicking or inspired by nature | • Increase in urban green spaces such as parks and community gardens |
| | Physical and psychological experiences | • Reduction in exposure and visits to natural terrestrial, coastal and marine areas<br>• Decrease in wellbeing from lack of exposure to nature | |

Source: Adapted from IPBES (2019)[94]

Ecological restoration requires significant time, resources and knowledge before it can be implemented to repair and restore damaged ecosystems.[95] Additionally, some habitats may be difficult to restore at all.[96] Before ecosystem restoration is used an assessment of the potential for the ecosystem to be restored and a cost-benefit analysis should be undertaken. There are frameworks that can be applied to consider the costs and benefits of restoration projects.[97] In some cases, climate change will mean that a habitat cannot be restored in the same place. For example, coral reefs may not be able to survive the increasingly warm and acidic waters where they once thrived, and alpine vegetation may not be able to compete in their previous altitudes given higher temperatures and reduced snowfall. In these cases, tools such as conservation translocation – the intentional movement and release of organisms[98] – and ex situ conservation may be used,[99] sustaining global levels of biodiversity even if local biodiversity is diminished.

Types of conservation translocation include reinforcement, which aims to improve population viability by increasing the number of individuals and diversifying the genetic stock; reintroduction, which aims to reestablish a viable population of the species within its natural range; assisted colonisation, which aims to establish populations in areas where current or future conditions are likely to be more suitable; and ecological replacement, which aims to replace the extinct species with a related species that will perform similar ecological functions.[100] One example where this measure has been implemented is Project Rewild Zambezi, which aimed to translocate over 3,000 animals facing population pressure due to issues such as climate change and resource scarcity.[101] For species such as coral, restoration measures can involve reef transplantation and coral gardening.[102] The Cozumel Coral Reef Restoration Program in Mexico aims to conserve and restore all 35 species of coral native to Cozumel through coral gardens and nurseries for rescued coral.

Measures such as translocation are not suitable for all species and can be expensive and resource-intensive.[103] Another strategy to maintain biodiversity is ex situ conservation. This refers to the conservation of genetic or species diversity away from their natural habitats.[104] The purpose of this type of conservation is primarily to complement in situ or on-site measures, ideally through the eventual reintroduction of the species into their natural habitat once conditions are suitable. These types of measures can be considered an 'insurance policy for humanity'.[105]

There are two primary options for ex situ conservation: caring for and breeding endangered species in constructed environments managed by people (such as botanic gardens, zoos and aquariums) or storing the species' genetic material to enable breeding in the future (for example in cryogenic facilities or seed banks). Seed banks allow for the preservation of diverse plant varieties that may otherwise be lost. There is increasing interest in seed banks given that they provide a potential pool of genes and species that may prove climate-resilient.[106] Seed bank projects in flood- and drought-prone communities in La Mojana, Colombia, are now reintroducing native varieties of rice, tamarind, loquat, annatto and cashews that were abandoned in the 1970s because of their low commercial value.[107] There are a wide range of strategies to enable restitution for climate-induced loss to biodiversity and ecosystems, including ecological restoration, conservation translocation and ex situ conservation. However, all of these presume that it is possible either for habitats to be restored or for species to recover. Yet climate change and other drivers of environmental degradation mean that ever-more biodiversity and ecosystem services are being lost forever. In these cases, restitution is not possible and other options for addressing loss and damage must be considered: rehabilitation, satisfaction, material compensation and guarantees of non-repetition. These responses address the impacts of climate-induced loss and damage on humans, but there is no way to respond to the loss and damage experienced by nature.

## Rehabilitation

In some cases, restitution of climate-induced biodiversity and ecosystem losses may not be possible. For some individuals or communities, nature may have provided them with values such as spiritual connections or benefits such as jobs, which are difficult to substitute for with measures such as ex situ conservation; given that effective ecological restoration takes time, these values and benefits may not be immediately replaced.

Where restitution is not possible, rehabilitation measures can be put in place. The aim of rehabilitation is to redress or repair harm through the provision of social services such as healthcare, education or legal support.[108] When humans are negatively impacted by loss of or damage to ecosystems, rehabilitation is intended to help individuals or communities recover economically and socially from the trauma of the loss. The scope for rehabilitation depends on the impacts, which can be assessed through extensive dialogue with those individually and collectively experiencing the loss and damage.

Some species and ecosystems provide spiritual and socio-psychological services, and many cultural and amenity services are essential to individuals' wellbeing and mental health.[109] Loss of personally important places, and by extension ecosystems and species, can lead to feelings of loss, emotional distress and disorientation.[110] The loss of livelihoods that were dependent on these ecosystems can give rise to feelings of helplessness as people lose their sense of autonomy and control.[111] Mental health support can be used to help individuals and communities minimise their suffering and build resilience.[112] Tools like trauma counselling could be used to facilitate grieving and boost emotional resilience.[113] For instance, following Typhoon Haiyan in the Philippines in 2013, investments were made to address the mental health impacts by building a better mental health system, training health workers to provide mental health care and improving access.[114]

Some individuals may lose livelihoods and sources of income related to specific ecosystems, and therefore may be harmed economically. While it may not be possible to restore them to their original ways of life, rehabilitation measures such as education and training can help people adjust to new ways of life and alternative livelihoods. In the case of ecosystem damage, restoration projects can be two-fold: restitution of the ecosystem and job creation and education for people living in and around it. The Green Gicumbi Project in Rwanda, for example, has rehabilitated 377 hectares of degraded forest, created 21,000 green jobs, and trained 1,500 local authorities and community representatives on climate change causes and effects and mitigation measures.

## Satisfaction

Satisfaction can be used alone or alongside other responses to loss and damage. Satisfaction uses symbolic measures where financial or material solutions do not prove sufficient on their own.[115] This includes actions such as recognition, official apologies, truth-seeking and memorialisation. These actions are usually combined with the more tangible measures of compensation, restitution and rehabilitation.[116] The action of memorialisation refers to forms of collective remembrance, such as museums, monuments, incorporation in school curricula or remembrance days.[117] Memorialisation aims to provide redress and reflection to those experiencing the loss, but also to raise broader awareness, ensure empathy for the victims and prevent future losses.[118] Memorialisation can be used to provide representations or activities that recognise specific species or ecosystems that have been lost. Remembrance Day for Lost Species, an international initiative that takes place annually on 30 November, encourages people to gather to remember and mourn extinct species,[119] and start their own public or private events to recognise species and grieve their losses.[120] Researchers and non-profits are using technologies such as 3D modelling, laser scanning and high-resolution images to provide video streams, panoramic views, virtual tours, documentaries and museum exhibitions of ecosystems for people who would otherwise not be able to see them.[121] In the event that these ecosystems are lost, this material can be used to memorialise them and continue to share information about them. For example, the Kaua'i 'ō'ō bird went extinct in 1987, but a recording of its mating call helps keep the memory of the species alive. Based on this, Danish artist Jakob Kudsk Steensen has used Virtual Reality to bring the bird back to life in a virtual world.[122]

## Material compensation

Material compensation refers to the use of financial resources to address loss and damage. It aims to improve the well-being of those most affected and can be applied to several types of loss or damage, including to territory and property, loss of means and loss of life.[123] In theory, individuals who lose benefits, for example livelihoods, due to lost ecosystems can be financially compensated for these losses. Compensation is typically in the form of direct contributions or insurance.[124]

There is precedent within the UN system for compensation to be provided for environmental loss and damage (see Box 5). However, the language accompanying the adoption of the Paris Agreement states that 'Article 8 of the Agreement does not involve or provide a basis for any liability or compensation'.[125] This suggests that the likelihood of material compensation within the climate regime is low. That does not mean that there can be no provision of resources to respond to climate-induced loss and damage of biodiversity and ecosystems. In fact, all the other options outlined above – from ecosystem restoration to mental health counselling to memorialisation – require significant resources. As a result, financial resources should be provided on the basis of need – which is now possible given the new loss and damage fund and funding arrangements currently being operationalised under the UNFCCC regime. This funding will be a key part of addressing loss and damage.

### Box 5 The United Nations Compensation Commission and its response to environmental damage

The Iraqi invasion and occupation of Kuwait in 1990–1991 led to large-scale environmental damage within Kuwait and neighbouring Gulf countries, primarily due to the burning of oil wells and subsequent efforts to put the fires out, direct pollution from military activities and piping of oil into the Persian Gulf. Areas such as Bubiyan Island, Khiran Inlets and Sulaibikhat Bay were severely contaminated, leading to long-term impacts including a decline in provisioning services (food and water), as well as loss of wildlife habitats.

After the war, the United Nations set up a Compensation Commission (UNCC) and an accompanying Fund to process and pay claims resulting from the conflict. The main source of financing for the Fund came from the proceeds generated by exports of Iraqi oil and oil products from 1991 to 2020. The UNCC created different claims categories that ranged from individual claims for forced departure from Kuwait or Iraq and loss of income and business to government and international organisation claims for losses including 'environmental loss and damage'.

However, instead of providing funding for primary restoration to address the loss, the UNCC deemed that funding for establishment of a coastal preserve would be a reasonable, feasible and cost-effective approach. This included, inter alia: development of management system to ensure the type and quality of ecological services provided equal those lost (inclusive of needed facilities, vehicles, enforcement and maintenance personnel) as well as the provision of education.

The UN Security Council officially declared the work of the UNCC complete in December 2022 and terminated its mandate.

Source: Farber (2007)[126]

## Guarantees of non-repetition

The purpose of guarantees of non-repetition is to prevent similar loss and damage in the future. However, in the context of climate change it is difficult to implement this measure due to the time lag between the production of greenhouse gas emissions and the experience of loss and damage. Guarantees of non-repetition of loss and damage therefore temporally and technically can be considered as the implementation of climate change mitigation and adaptation policies.

This section has highlighted a range of measures that could be used to address loss of or damage to biodiversity and ecosystem services, and the impacts of these losses on people. Many of these options can be deployed in different combinations. However, the measures that are used are dependent on the nature and impacts of the losses, and the value of the losses to affected communities. Hence, before any of these measures are implemented, there is again a need for meaningful participation from the community.

## 3.3 The multilateral architecture and responding to the loss of biodiversity and ecosystems

### Multilateral processes

While several multilateral processes are relevant to responding to biodiversity and ecosystem services loss, only two will be discussed in this paper given their centrality in the discourse on this topic: the UNFCCC and CBD. These two environmental conventions have concurrently begun charting and implementing parallel processes of 'governing loss' through international solidarity underpinned by the concept of environmental justice.

The international regimes seeking to govern climate change and biodiversity were born out of the 1992 United Nations Conference on Environment and Development in Rio de Janeiro (the 'Earth Summit').[127] With this common point of origin, the UNFCCC and CBD along with the United Nations Convention to Combat Desertification[ii] are collectively and commonly known as the 'Rio Conventions'. The concept underpinning all three regimes was a simple one: the 'common concern of humankind'. As the phrase suggests, the prospect of destabilising critical earth systems and creating a less rich and hospitable world is one that should worry all of humankind and requires collective action to remedy it.[128] And because of their international significance and adverse effects on humanity, these issues could not be considered only within the national, bilateral or regional context.

Both the UNFCCC and CBD aspire to find and advance solutions to the respective causes of these environmental problems.[129] Nevertheless, the harm already being faced demanded the inclusion and operationalisation of treaty provisions, subsequent agreements and decisions of State Parties focused on responding to that harm. On this matter, both Conventions in some way refer to the duty on the international community to cooperate to develop rules on ensuring that, when activities within a state cause transboundary harm, that state remedies these adverse effects. This duty had previously been codified in the Stockholm Declaration on the Human Environment 1972 (Principle 22); it was reiterated almost exactly in the Rio Declaration on Environment and Development 1992 (Principle 13). The level of prominence of this duty to cooperate varies between the UNFCCC and CBD. The former only includes it in a preambular paragraph as interpretative context recalling the pertinent provisions of the Stockholm Declaration.[130] The CBD includes it as an obligation of conduct on the COP to examine the issue 'liability and redress, including restoration and compensation' on international level only.[131]

This sub-section outlines the processes seeking to remedy loss and damage, specifically relating to biodiversity loss, under the UNFCCC and CBD. While both regimes address biodiversity loss associated with the adverse effects of climate change, the CBD covers all biodiversity and ecosystem services loss including loss caused by non-climate drivers such as direct human exploitation or pollution. The UNFCCC focuses on responding to loss associated with other adverse effects beyond biodiversity and ecosystem services loss, such as cultural heritage and human health.

ii It should be noted that, due to scoping constraints, this paper was not able to include a consideration of the desertification multilateral process which is also relevant to biodiversity and ecosystem services loss.

## UNFCCC

Although small island developing States (SIDS) had highlighted the need to address loss and damage due to climate change from the beginning of the UNFCCC negotiations in the early 1990s, it was not until the Bali Action Plan of 2007 that loss and damage was mentioned in decision text from the Conference of the Parties (COP). It was only in the 2010 Cancun Agreements that an official work programme on loss and damage was established. The first mention of biodiversity loss was in a footnote listing examples of adverse effects including sea level rise and glacial retreat.[132]

During the work programme period (2010–2013), NELD was first referenced in the decision text of the Doha COP in 2012.[133] This was to acknowledge that further work and understanding were needed on the topic and to request the Secretariat to publish a dedicated technical paper (its notable 2013 NELDs technical paper). This manifested in the establishment of the Warsaw International Mechanism for Loss and Damage (WIM) and its Executive Committee (ExCom) at COP 19 in 2013.[134] With the WIM's three main functions of enhancing knowledge, coordination, and enhancing action and support, NELDs was included as an action area for enhancing data and knowledge on that matter through awareness-raising and the establishment of a dedicated expert group.[135]

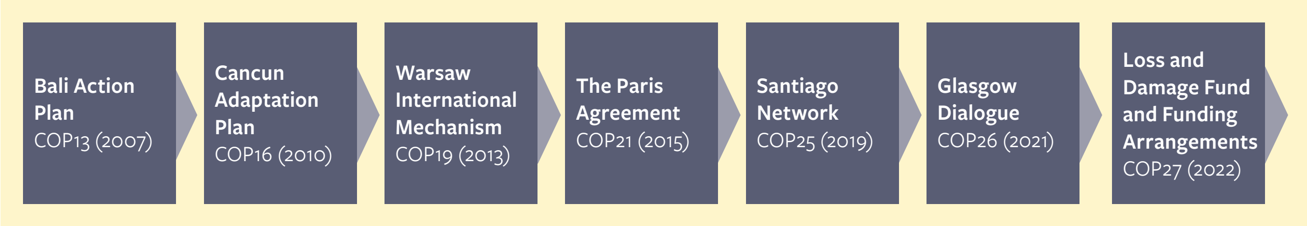
In 2015, loss and damage was explicitly codified in a treaty under the UNFCCC regime via Article 8 of the Paris Agreement. NELDs and the resilience of ecosystems were included under the loss and damage provision as examples of areas of international cooperation for enhanced understanding, action and support.[136]

The Santiago Network was established at COP 25 in Madrid as the operational arm/component of the WIM. The Network's main function is to catalyse technical assistance in developing countries in preparation for loss and damage responses.[137] At COP26 in 2021, the Glasgow Dialogue was established to explore potential arrangements for funding related to loss and damage. In Sharm El-Sheikh in 2022, Parties agreed to establish new funding arrangements including a fund with a mandate that includes addressing loss and damage. A Transitional Committee (TC) was also created to make operationalisation recommendations to the COP and CMA for consideration and adoption at their 2023 session.

Since COP 26 there has been more focus on the need for loss and damage response support for vulnerable populations and the ecosystems on which they depend.[138] The 2022 decision mandates the TC, in elaborating its recommendations to operationalise the new fund and funding arrangements, to take account of 'the most effective ways in which to address the gaps, especially for the most vulnerable populations and the ecosystems on which they depend'. This provides an entry point for operationalisation of these funding arrangements to address gaps in support for responding to biodiversity and ecosystem services loss.

Figure 5 summarises key milestones for the incorporation of loss and damage within the UNFCCC.

**Figure 5** Key loss and damage milestones within the UNFCCC




## CBD

In comparison to the decades under the UNFCCC attempting to incorporate and develop an international system of rules and institutional arrangements to respond to loss and damage, the CBD had a clear legal basis in the treaty to examine appropriate responses to biodiversity loss. The negotiation history of this Article highlights that a number of countries also wanted an international liability regime to redress transboundary biodiversity loss, similar in spirit to the 1990 AOSIS proposal for an insurance fund for sea level rise damage under the UNFCCC.[139] However, they ended up with an Article provision requiring the COP to examine the issue, as highlighted above, with no specified timeline and modalities for the examination or a requirement to come to a conclusion on its basis.[140]

Consequently, the COP only started to consider the matter at its fourth session in 1998.[141] Discussions on the redress regime gradually progressed into a 2001 workshop in Paris, which recommended the creation of a Legal and Technical Expert Group on Liability and Redress to COP 6. At COP 6 in The Hague, States and relevant international organisations were urged to cooperate to strengthen national capacities and provide financial resources to prevent biodiversity damage, and establish and implement national legislative regimes as well as measures on liability and redress.[142] In 2005, the Expert Group received funding for its first and sole meeting, in Montreal.[143] In advance, the COP made numerous attempts at information gathering with several invitations for national, regional and international case studies on liability and redress. These received limited responses. In its 2005 report to the COP, the Expert Group deemed that it 'may be premature at this time' to determine whether an international regime on damage to biodiversity should be developed.[144] They suggested to the COP that they first develop guidance on damage to biodiversity, its valuation and restoration using, among other things, the Expert Group's element points. One of its points on restoration is helpful to this paper's discussion on options for loss and damage response, and states: '*where primary restoration is not possible or reasonable, other methods of redress should be considered, such as complementary methods of restoration and/or monetary compensation for irreversible damage on the basis of criteria to be developed*'.[145]

At its eighth session, in 2006, the COP welcomed the Expert Group's report, requested the Secretariat to compile a synthesis report with the technical information requested by the Expert Group, and called for relevant examples of legislation and case studies from countries. In 2008 at its ninth session, the COP welcomed the Secretariat synthesis report and requested it be made available by the CBD clearinghouse mechanism, as well as decided to consider whether there was need for future work in context of its 2011–2020 Strategic Plan.

Less attention has been given to the issue since, as evident in its absence from the 2011–2020 Strategic Plan. At its 12th session the COP simply took note of recently developed guidance on the issue and actions of national regimes,[146] and at COP 14 Parties were invited to continue addressing liability and redress through national regimes.[147] A cycle of examination through information-sharing and requests for national regimes to take the information into account has been the recent pattern in this area. There appeared to be little appetite for establishing an international regime. So, despite the matter being anchored in the treaty, discussion on an CBD international liability and redress regime remains at the information-gathering and -sharing stage.

In 2022 at the Kunming/Montreal COP, the purpose and theory of change of the post-2020 Global Biodiversity Framework made reference to 'reversing' biodiversity loss in addition reducing and halting for the first time.[148] It also introduced a specific target for the restoration of at least 30% of the world's degraded ecosystems by 2030.[149] While these are important steps in the CBD regime enabling responses to biodiversity loss, they do not acknowledge that solutions are needed to respond to permanent and irreversible loss that range from the instituting alternatives to attempt to substitute the lost ecosystem services to coping with the mental trauma of losing the culturally significant biodiversity.

Reflecting on progress under both regimes, the climate change regime appears to have made greater strides on establishing international institutional structures to respond to loss and damage. This could in part be due to its comparative global popularity and attention relative to biodiversity;[150] alternatively, it could be linked to the use of framings focused on cooperation and facilitation as opposed those explicitly on liability and compensation like those entrenched under the biodiversity regime. That said, whatever the reason(s) that has brought the climate change regime to this point, it has yet to be seen if it brings results and impact on the ground by responding to loss and damage through the new fund and funding arrangements.

**Figure 6** Key loss and damage related milestones within the CBD

## Multilateral funds

Multilateral finance for addressing biodiversity and climate change, among other things, was arguably born out of the creation of the Global Environment Facility (GEF). The GEF was established as an 'experimental' pilot in 1991, where funding provided for addressing these environmental challenges 'would be additional to regular development assistance and provided as untied grants or on highly concessional terms'.[151] The GEF's creation and rapid operationalisation was intended to garner global political endorsement at the 1992 Earth Summit, where the UNFCCC and CBD were also adopted.[152] As a result, the GEF was included in both Conventions as one of the interim institutional structures or entities entrusted with the operation of their respective financial mechanisms. This designation was subject to the GEF being reformed in line with a number of principles from the Conventions, most notably universal membership and participation.[153]

The Green Climate Fund (GCF) is the only other fund designated as an operating entity of the UNFCCC financial mechanism, while the GEF is the sole institutional structure for the CBD financial mechanism. Both regimes have other specifically focused/thematic funds, i.e. the UNFCCC's Least Developed Countries Fund (LDCF) and Special Climate Change Fund (SCCF) created under the GEF, and the Adaptation Fund (AF), which serves the Kyoto Protocol and Paris Agreement. There is also the Nagoya Protocol Implementation Fund under the CBD.

Gaps exist in the mandates, business models and investment and results frameworks of these and other funding arrangements, limiting their ability to address loss and damage, in particular biodiversity and ecosystem services loss. For example, with the GEF the results framework for climate change mitigation only focuses on, and tracks results that reduce, GHG emissions.[154] For tracking adaptation results, the GEF LDCF and SCCF concentrate squarely on facilitating 'transformational adaptation' (or reducing the risk of future loss and damage) to achieve the adaptation goal of the Paris Agreement, with core indicators focused on building climate resilience.[155] The GEF's biodiversity focal area focuses on conserving biodiversity to achieve global environmental benefits, especially through protected area management. One of its integrated programmes on 'ecosystem restoration' is germane to addressing unavoided/unavoidable damage, but this is concentrated on potentially reversible damage.[156] The programme's funding is limited at around $117 million for a four-year period. The GCF has similar mandate and structural issues. There is no explicit mandate to address loss and damage in its Governing Instrument, Investment and Results Management Frameworks or quadrennial Strategic Plan.[157] For example, the criteria that the GCF uses to decide whether it will fund a project/programme prescribe that there must be 'impact potential', but this only covers 'mitigation impact' and 'adaptation impact' not loss and damage response impact.[158]

At a minimum, the current structures of these funds are not built to deal with a number of issues on loss and damage response. This includes most notably scenarios where there has been permanent biodiversity loss. Support for activities that address the actual value of the ecosystem services that are lost is needed. And these activities can range completely replacing lost biodiversity components(s) with an alternative to memorializing the loss and/or address associated mental trauma from the loss.

During 2022 there were major developments with regard to funding arrangements under both regimes which seek to address these gaps.

As highlighted above, the UNFCCC COP and CMA established new loss and damage funding arrangements, including a new fund. In the wake of the newly adopted post-2020 Framework, the CBD COP also requested the GEF to create a special trust fund in 2023 to support the framework's implementation.[159]

These multilateral processes must ensure that the mandates, structure, operating model and policies for the new funds (the loss and damage fund and the Global Biodiversity Framework Fund) and funding arrangements are fit-for-purpose to respond to the loss of biodiversity and ecosystems – whatever the cause.

# 4 Conclusion

Climate change is impacting the world's natural systems including biodiversity and ecosystem services in the worst ways imaginable. International regimes and national systems focused on climate change and biodiversity have over the past 30 years made limited progress on mitigating the causes of climate change, and adapting to its adverse effects

The UNFCCC's ultimate objective, framed in 1992, speaks to the 'stabilization' of GHGs to 'allow ecosystems to adapt naturally to climate change'. The science and reality in 2023 speak of the limits to adaptation for those very same ecosystems. With 'baked in' loss and damage and these limits to what can be prepared for, systems and arrangements for addressing the unavoidable and unavoided must be developed and adequately supported alongside those for mitigation and adaptation. This is because the age of 'natural' adaptation has slowly slipped away from with the breach of these limits.

The impact of biodiversity and ecosystem services loss blurs the lines between economic and non-economic loss and damage. The natural system provides the foundation for human systems, especially economies and the fabric of society. While the measuring and valuing of this type of loss has advanced, decision-making on action and support related to the non-economic value of biodiversity and ecosystem services continues to be overshadowed by the economic value that is lost. Solutions and support for these solutions must be tailored in a manner that appreciates the non-economic value of biodiversity in order to ensure that the intended results are not solely focused on alleviating loss expressed in economic terms. As with cultural heritage, this paper highlights the typically irreversible nature of environmental damage. Recreating an ecosystem and its biodiversity is exponentially more difficult than reconstructing buildings, for example. Application of the precautionary principle in responding to biodiversity loss is critical. Actions that focus on tackling causes and preparing for impacts are the most effective way to avert and minimise climate-induced loss and damage. Conservation and sustainable use measures ranging from protected areas to quotas to education and awareness fall within this category of action.

Where biodiversity and ecosystem services loss has occurred, it is necessary to address it. Options include developing and implementing activities that take inspiration from these processes: (1) restitution, whereby an ecosystem is restored to its original condition to the extent possible; (2) rehabilitation, whereby those affected are provided with legal, medical, educational and other services to support their recovery; (3) satisfaction, whereby symbolic actions such as truth-seeking processes, apologies and memorials recognise both the loss itself, and responsibility for that loss; (4) material compensation, whereby those who have experienced loss and damage receive money or other benefits; and (5) guarantees of non-repetition, whereby measures are taken to avoid further harm. These five options vary in their relevance to biodiversity and ecosystems services loss due to climate change.

These and other options do not operate in a vacuum. Climate-induced biodiversity loss is part of two common concerns of humankind, climate change and biodiversity conservation. As such, these options or responses should be considered on a multilateral level in relation both the relative processes and support arrangements.

On this, the paper notes that the climate regime appears to be making some progress on creating institutional spaces to discuss and develop these and other options, including through expert committees and a technical assistance network. This is especially the case when compared to the biodiversity regime that appeared to have been taking what could deemed as a hiatus on developing an international regime focussed on redressing actual biodiversity loss. .

All that said, these international regimes have acknowledged gaps with regard to both funding and funding arrangements for responses to biodiversity loss. By learning from other sectors, processes and arrangements, as well as adopting inclusive approaches, much more can be done to respond to biodiversity and ecosystem services loss in an equitable and just manner for those vulnerable populations and ecosystems most in need.

# Appendix 1

**Table A1** Potential indicators to measure nature's contribution to people

| | Nature's contribution to people | Indicators |
|---|---|---|
| Regulating Services | Habitat creation and maintenance | • Extent of suitable habitat<br>• Biodiversity intactness |
| | Pollination and dispersal of seeds and other propagules | • Pollinator diversity<br>• Extent of natural habitat in agricultural areas |
| | Regulation of air quality | • Retention and prevented emissions of air pollutants by ecosystems |
| | Regulation of climate | • Prevented emissions and uptake of greenhouse gases by ecosystems |
| | Regulation of ocean acidification | • Capacity to sequester carbon by marine and terrestrial environments |
| | Regulation of freshwater quantity, location and timing | • Ecosystem impact on air-surface-ground water partitioning |
| | Regulation of freshwater and coastal water quality | • Extent of ecosystems that filter or add constituent components to water |
| | Formation, protection and decontamination of soils and sediments | • Soil organic carbon |
| | Regulation of hazards and extreme events | • Ability of ecosystems to absorb and buffer hazards |
| | Regulation of detrimental organisms and biological processes | • Extent of natural habitat in agricultural areas<br>• Diversity of competent hosts of vector-borne diseases |
| Material and assistance | Energy | • Extent of agricultural land – potential land for bioenergy production<br>• Extent of forested land |
| | Food and feed | • Extent of agricultural land – potential land for material production<br>• Abundance of marine fish stocks |
| | Materials and assistance | • Extent of agricultural land – potential land for material production<br>• Extent of forested land |
| | Medicinal, biochemical and genetic resources | • Fraction of species locally known and used medicinally<br>• Phylogenetic diversity |
| Non-material | Learning and inspiration | • Number of people in close proximity to nature<br>• Diversity of life from which to learn |
| | Physical and psychological experiences | • Area of natural and traditional landscapes and seascapes |
| | Supporting identities | • Stability of land use and land cover |
| | Maintenance of options | • Species' survival probability<br>• Phylogenetic diversity |

Source: IPBES (2019)[160]

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