Economics of Peatlands Conservation, Restoration and Sustainable Management

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Economics of Peatlands Conservation, Restoration and Sustainable Management policy report

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Global Peatlands Initiative

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

INTERNATIONAL CLIMATE INITIATIVE (IKI)

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Executive Summary

Peatlands in decline

Global peatlands are in decline with an estimated 11-15% of these ecosystems having been drained for agriculture, grazing, peat mining and forestry. A further 5-10% are degraded through vegetation removal or alteration (see Tables 1 and 2). Peatland decline has slowed somewhat in temperate and boreal regions, but the loss of tropical peatlands continues at a high rate. If unchecked, the area of peatland converted in tropical regions could increase to around 300,000 square kilometers (km^2) by 2050 (Leifeld *et al*. 2019). This is almost double today's drained peatland area in the tropics.

A triple win for people, the climate and biodiversity

The conservation, sustainable management and restoration of peatlands worldwide provides an important socio-economic and environmental opportunity. Peatlands are particularly vital for combatting the climate crisis. They are one of the largest terrestrial organic carbon stocks globally, storing twice as much carbon as the world's forests (Anisha *et al*. 2020).[1] If undisturbed, peat layers are an effective permanent store of carbon. Peatlands can be part of an effective climate change mitigation strategy, and they could help countries meet Nationally Determined Contributions (NDCs) to global climate action. In addition, parties to the Paris Agreement have acknowledged the importance of promoting gender equality and the empowerment of women when taking actions to address climate change (United Nations Women 2016).

Peatlands also provide a wide range of other important ecological, economic and cultural benefits. They represent a habitat for many unique and threatened species while also supporting water cycles, controlling pollution and sediments, serving as a source of locally harvested products, and existing as an inspiration for art, religion, and other cultural values (see Table 3).[2] Economic assessments confirm that the benefits of these ecosystems are considerable. Investment in peatlands conservation, restoration and sustainable management is a triple win for people, the climate, and biodiversity.

Undervalued and underinvested

The principal cause for the mismanagement of global peatlands is that their economic contributions are *undervalued*. Commercial activities and policies that degrade and convert these high-carbon ecosystems often ignore or fail to account adequately for their benefits to society. In addition, global peatland conservation and restoration suffer from chronic *underinvestment*. Current public and private funding directed towards peatlands falls well short of what is needed to save such valuable ecosystems.

Although the economic and environmental benefits of peatlands are often considerable, the cost of restoring degraded or drained peatlands can be high, especially in tropical regions (see Annex 2). To rewet 40% of drained peatlands by 2050, annual global investments in peatland restoration must rise from nearly US$19 billion annually to US$31 billion by 2030, to US$39 billion by 2040, and then in excess of US$46 billion by 2050 (see Figure 1). Investing in cost-effective tropical peatland conservation and restoration for carbon mitigation would reduce global greenhouse gas emissions by 800 million tonnes per year (equivalent to Germany's emissions), requiring an annual investment of US$28.3 billion for conservation and US$11.7 billion more for restoration (see Table 4).

[1] See also Crump (2017), Joosten *et al.* (2012) and (2016), Leifeld and Menichetti (2018), and Page and Baird (2016). The Global Peatlands Initiative (GPI), established in 2016 at the United Nations Climate Change Conference (UNCCC), aims to promote the conservation of the world's peatlands in order to prevent further emission of this carbon into the atmosphere.

[2] See also the various studies cited in Annex 1.

Because these irrecoverable stores of carbon are disappearing quickly, the bill for saving peatlands will only rise further if we fail to invest now. The opportunity cost of delaying action on peatland conservation and restoration as part of a greenhouse gas mitigation strategy could be substantial (Glenk *et al*. 2021).

Some governments have begun to recognize the socio-economic importance of peatlands and are adopting better policies for their conservation, restoration and sustainable management (see Annex 3). But overcoming the current widespread problems of peatland undervaluation and underinvestment requires a range of innovative policy and financing initiatives. These actions should form the basis for a global strategy for promoting peatlands as a nature-based solution.

Ending the undervaluing of peatlands

All countries with significant peatland areas should ensure that the values provided by these ecosystems are adequately considered in reference to land use decisions that have the potential to inflict damages, degrade or destroy peatlands. Ending the undervaluing of peatlands requires countries to adopt policies, regulations and other actions that improve conservation, restoration and sustainable management of their peatlands. Such a policy strategy should comprise six key elements:

- Mapping, monitoring and ongoing assessment of peatland areas, including determining the status and condition of intact peatlands.
- Imposing moratoria, regulations, controls and incentives to prevent additional drainage, conversion and damage to remaining intact peatlands.
- Removing subsidies and other forms of financial support to agricultural, forestry, mining and other economic activities that excessively degrade or convert peatlands.[3]
- Using taxes, tradable permits and market-based incentives to further control economic activities, their resource use and resulting pollution that adversely impact peatlands.
- Allocating revenues generated or saved from subsidy removal, market-based instruments and other pricing reforms to free up or generate revenue for investment in improving peatland conservation, restoration and sustainable management. This is particularly important in the aftermath of the COVID-19 pandemic, which has placed significant fiscal burdens on governments worldwide.
- Increasing funding for conservation, restoration and sustainable management of peatlands, especially to rejuvenate substantially drained peatland areas.

Ending the underfunding of peatlands

Global peatland protection and restoration suffers from chronic *underinvestment*. The current public and private funding of peatlands falls well short of what is needed to save these valuable ecosystems. If they are to be part of a global strategy of nature-based solutions to prevent climate change, biodiversity loss and other environmental threats, then much more needs to be done to invest in peatlands, especially in tropical regions.

[3] OECD (2020a) estimates that public and private spending on nature protection and conservation over 2015-2017 averaged US$78 to US$91 billion. In comparison, environmentally harmful agricultural subsidies averaged US$112 billion per year over 2017-2019 just in OECD countries, and in 77 countries, fossil fuel subsidies were US$478 billion in 2019 (OECD 2020b). These estimates suggest that public subsidies to agriculture and fossil fuels that are environmentally harmful are more than five times the amount spent globally by the public and private sector on nature conservation and protection. Additional subsidies to the forestry sector and for water use further exacerbate excessive peatland conversion. Governments also provide environmentally beneficial subsidies to nature, but over 2012-2016 they averaged less than US$1 billion per year (OECD 2019).

In order to transform global peatlands from a net source of greenhouse gas emissions to a net sink, as much as 40% of drained peatlands will need to be rewetted by 2050. To achieve this goal, annual investments in peatland restoration worldwide must more than double within the next two decades, from current levels of just under US$19 billion annually to over US$46 billion by 2050 (See Figure 1). Funding support is especially urgent for eight countries that could potentially account for 97% of the carbon mitigation from tropical peatland investment - Indonesia, Malaysia, Papua New Guinea, Uganda, Brazil, Democratic Republic of Congo, Peru and Republic of Congo (see Table 4).

Averting the worldwide crisis of peatland mismanagement requires much more investment in these ecosystems than current levels. Given the urgency of addressing global peatland loss, a key challenge is broadening the sources and scale of financing for the conservation and sustainable management of peatlands worldwide.

First, wealthy countries that contain peatlands should unequivocally adopt policies, regulations and other actions that are needed to improve protection, restoration and sustainable management of their peatlands. Wealthy countries should not only increase the amount of their own private and public spending on peatlands but also assist poorer countries in doing so. The latter could be done through more bilateral and multilateral aid while also encouraging more innovative public and private financing mechanisms.

Second, many low- and middle-income countries, especially those with significant tropical peatlands, need technical and financial assistance to undertake some of these policies, especially the restoration of degraded peatlands. Countries seeking support from the international community for peatlands as a nature-based solution should demonstrate their "sustainable peatlands readiness" by devising national strategies of policy actions for conservation, restoration and sustainable management of peatlands and by establishing accurate and transparent monitoring, reporting and verification of results-based actions under their national strategies. The international community should provide adequate financial and technical support to those low- and middle-income countries that adopt policies and actions for improved peatland conservation, restoration and sustainable management.

This additional assistance can be provided by a consortium of donors, including public-private partnerships, and should be conditional on verifiable policies and actions by recipient countries that have developed long-term policy and management plans for peatlands. Such an approach has been adopted within the REDD+ framework, where potential recipient countries must demonstrate their "REDD readiness" by first creating a national strategy or action plan for reducing emissions from deforestation and forest degradation and guaranteeing accurate and transparent monitoring, reporting and verification of results-based actions.

Third, in a post-COVID world of limited financial resources, there is a need to develop new sources of private and public funding for protection of peatlands globally. There are many possible options, including biodiversity offsets, payments for ecosystems services, voluntary carbon markets, REDD+, debt-for-nature swaps and green bonds. In addition, the agricultural, forestry, mining, food and beverage, and other global industries must invest in product certification and in making their supply chains "peatland friendly" by ensuring that they result in no additional loss of peatlands. These industries should also support and invest in these valuable ecosystems.

A global strategy for peatlands

Peatland conservation, restoration and sustainable management should be a central consideration within the global effort to invest in nature-based solutions and avert climate change, biodiversity loss and other environmental threats. This requires a global strategy for peatlands that motivates collective action by all countries and stakeholders that will end the underpricing and underfunding of these important ecosystems worldwide. Investment in peatlands is a triple win for people, the climate, and biodiversity.

Main Report

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Introduction

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Because of global climate change and rising environmental risks, upcoming international summits concerned with these threats are focusing on the promise of nature-based solutions. These are broadly defined by the International Union for Conservation of Nature (IUCN) as "actions to protect, sustainably manage, and restore natural or modified ecosystems, while also addressing societal challenges, such as food security, climate change, water security, human health, disaster risk, social and economic development".[4]

Most current discussions concerning nature-based solutions focus on high-carbon ecosystems, such as primary forests, agroforests, wetlands, mangroves and other coastal habitats. Considerably less attention has been devoted to peatlands. This is a serious omission. One positive development has been the Global Peatlands Initiative (GPI), which was established in 2016 at the United Nations Framework Convention on Climate Change Conference (UNFCCC). The GPI promotes the conservation of peatlands as the world's largest terrestrial organic carbon stock and to prevent further emission of this carbon into the atmosphere. Furthermore, the adoption of the resolution for the conservation and sustainable management of peatlands at the fourth United Nations Environment Assembly (UNEA-4) strengthens the work of the GPI, as does the recently established International Tropical Peatlands Center (ITPC) (2021).

This policy report examines the current status of peatlands globally, assesses the benefits and costs of peatlands, and identifies policies for peatlands conservation, restoration and sustainable management. This report concludes that much more needs to be done to conserve, sustainably manage and restore peatlands worldwide. They are an economically important nature-based solution, and they are vital to any global strategy to combat rising environmental threats. Investment in peatlands conservation, restoration and sustainable management is a triple win for the climate, biodiversity and people, more so for those left furthest behind, including poor people, women, and children who face increased vulnerability from depleted natural resources. It is essential that peatlands are recognized as high priority for urgent action by policymakers.

A *peatland* is "an area with or without vegetation with a naturally accumulated peat layer at the surface" (Joosten and Clarke 2002, p. 24). Commonly called peat swamp forests, fens, bogs or mires, peatlands are the most widespread of terrestrial wetland ecosystems. Peat is "partially decayed plant material that accumulates under waterlogged conditions over long time periods" (Ramsar Convention on Wetlands 2018). They represent 50 to 70% of global wetlands and are found in boreal, temperate and tropical zones (Joosten and Clarke 2002, p. 6). They cover over 4 million km^2 or 3% of the land area of the planet (Xu *et al*. 2018b; Humpenöder *et al*. 2020).

Peatlands provide important ecological, economic, social, and cultural benefits. They are particularly vital in combatting and mitigating the effects of climate change. If undisturbed, peat layers are an effective permanent store of carbon. Consequently, peatlands are one of the most carbon-dense terrestrial ecosystems globally, storing twice as much carbon as all of the world's forests (Anisha *et al*. 2020).[5] In addition, peatlands provide habitat for many unique and threatened species, while also supporting water cycles, controlling pollution and sediments, serving as a source of locally harvested products, and existing as an inspiration for art, religion, and other cultural values (Bullock and Collier 2011; Bullock, Collier and Convery 2012; Martin-Ortega *et al*. 2014; Page and Baird 2016; Crump 2017; Evers *et al*. 2017; Medrilzam *et al.* 2017; Dargie *et al*. 2018; Schulz *et al*. 2019; Faccioli *et al*. 2020; Simangunsong *et al*. 2020).[6]

[4] Based on IUCN's definition of nature-based solutions. See https://www.iucn.org/sites/dev/files/content/documents/wcc_2016_res_069_en.pdf.

[5] See also Joosten *et al.* (2012), Joosten *et al.* (2016), Page and Baird (2016), Leifeld and Menichetti (2018) and Crump (2017).

[6] See also studies listed in Annex 1.

Peatlands are under significant threat globally from drainage, fires, overgrazing and other human impacts. Over 650,000 km^2 of peatlands may have been affected by human activity, and drained or burning peatlands contribute around two billion tonnes of carbon-dioxide emissions per year – about 5% of all anthropogenic emissions (Joosten *et al*. 2016; Günther *et al*. 2020; Humpenöder *et al*. 2020). Drained peatlands are also a significant source of other greenhouse gases, such as methane and nitrous oxide, as well as a source for the formation of acid sulfate soils (Wong *et al*. 2020). Local communities frequently depend upon peatlands for their livelihoods. Local women and men derive economic gain from peatlands based on their gender roles, and documenting these roles is crucial to developing policies that are more inclusive (Marlina *et al*. 2021).

The ongoing loss and degradation of global peatlands result from two principal causes:

- First, the reason we collectively fail to adequately conserve, restore and sustainably manage peatlands is that their important socio-economic benefits are *undervalued*. Commercial and policy land use decisions that degrade and convert these high-carbon ecosystems often ignore or fail to account for these benefits.
- Second, global peatland conservation and restoration efforts suffer from chronic *underinvestment*. Current public and private funding of peatlands falls well short of what is needed to save these valuable ecosystems.

This policy report explains why it is essential to address these two shortcomings by ending the undervaluation of peatlands and overcoming underinvestment in these ecosystems as a nature-based solution. As background, the current status of global peatlands is summarized and available studies on the benefits from intact and restored peatlands are examined. Furthermore, assessments of the net benefits from peatland conservation and restoration activities are outlined. These studies indicate that peatlands offer relatively high returns as a nature-based solution. They deliver considerable benefits through conservation, restoration and sustainable management at relatively low expense.

Two important benefits provided by peatlands – storing carbon and maintaining unique and threatened species – are globally important. Yet, it is the countries that contain peatlands that fund the costs of conserving and restoring them. These costs are especially burdensome for tropical peatland countries, which are mainly low- and middle-income economies with limited financial resources. This is a critical reason illustrating how global peatlands are underfunded. Current private and public financing that tropical countries receive from the rest of the world inadequately compensates them for the costs of conserving, restoring and sustainably managing sufficient peatlands for the myriad global benefits they provide.

We therefore need global investment to promote peatlands as a nature-based solution. Such a **policy approach** should have **three key elements**:

- First, all countries with significant peatland areas should ensure that the values provided by these ecosystems are adequately considered in the land use decisions that inflict damages upon, degrade or destroy peatlands. This requires adopting inclusive policies, regulations and other actions that will improve conservation, restoration and sustainable management of their peatlands. For example, peatlands can be part of an effective climate change mitigation strategy and make an important contribution to Nationally Determined Contributions (NDCs) to global climate action (Anisha *et al* 2020). Additionally, inclusive stakeholder engagements with the participation of youth, women, indigenous peoples, local communities and other vulnerable groups ensures that the concerns of local communities are also taken into account. Giving voice to those historically left behind who play critical roles as primary land managers and resource users is an effective way to address societal complexities that may adversely impact both people and planet, thereby embedding appropriate safeguards into polices, regulations and other conservation actions (Palmer 2018).
- Second, the international community should provide adequate financial and technical assistance to low- and middle-income countries that adopt such policies and actions to support peatlands as nature-based solutions. This additional assistance can be provided by a consortium of donors, including public-private partnerships, and should be conditional on verifiable policies and actions by recipient countries that have developed long-term policy and sustainable management plans for peatlands.
- Third, in a post-COVID world of limited financial resources, there is a need to develop new and innovative sources of private and public funding of peatlands globally. This paper discusses a number of possible options, including payments for ecosystems services, biodiversity offsets, voluntary carbon markets, REDD+, debt-for-nature swaps and green bonds, and the need for the private sector to invest in peatland-friendly supply chains and product certification.

Status of Peatlands

Peatlands occur on every continent and currently cover 4 million km^2, or approximately 3% of the global land area (see Table 1). They are, however, distributed unevenly across the world. In addition, the human activities impacting peatlands vary significantly across the globe, by climatic zone and by type of peatland. Both the distribution of peatlands and their differing rates of loss are important to consider when formulating a global strategy for peatland conservation, restoration and sustainable management.

Asia contains just under 40% of all peatlands, and North America around 32% (see Table 1). Canada alone contains 27% of all peatlands, and Russia (Asian plus European) comprises 32%. But there are significant peatland areas in other countries, too, such as the United States, Indonesia, China and Finland.

The temperate and boreal climatic zones of the Northern Hemisphere account for nearly two-thirds of peatland area worldwide (Joosten *et al*. 2002). Peatlands are also found across the tropics, but their distribution varies significantly by region. The most extensive areas are in Southeast Asia, where just four countries - Indonesia, Malaysia, Papua New Guinea and Brunei - account for 56% of the global tropical peatland area and 77% of tropical peat carbon storage (Page and Baird 2016; Humpenöder *et al*. 2020). In Africa, considerable peatlands are in the central Congo Basin, and in Latin America the largest peatland areas are in the Amazon Basin, especially in Brazil and Peru (Page and Baird 2016; Humpenöder *et al*. 2020).

	Land area	Peatland area	Peatland share (%) of land area	Share (%) of global peatland area
North America	**24,709,000**	**1,339,321**	**5%**	**32%**
Canada	9,084,977	1,132,614	12%	27%
United States	9,161,923	197,841	2%	5%
Others	6,462,100	8,866	0%	0%
Asia	**44,579,000**	**1,623,182**	**4%**	**38%**
Asian Russia	9,784,930	1,180,358	12%	28%
China	9,326,410	136,963	1%	3%
Indonesia	1,811,569	148,331	8%	4%
Malaysia	326,657	22,398	7%	1%
Others	23,327,434	135,132	1%	3%
Europe	**10,180,000**	**528,337**	**5%**	**12%**
European Russia	6,592,812	185,809	3%	4%
Finland	303,815	71,911	24%	2%
Ireland	68,883	16,575	24%	0%
Sweden	410,335	60,819	15%	1%
United Kingdom	241,930	22,052	9%	1%
Others	2,562,225	171,171	7%	4%
South America	**17,840,000**	**485,832**	**3%**	**11%**
Africa	**30,370,000**	**187,061**	**1%**	**4%**
Oceania	**7,692,024**	**68,636**	**1%**	**2%**
World	***148,647,000***	***4,232,369***	***3%***	***100%***

Table 1. Global distribution of peatlands (km^2). Source: Xu et al. (2018b).

Several human activities are responsible for peatland loss and degradation worldwide, with the largest impacts arising through drainage and land conversion for agriculture, including livestock raising, and commercial forestry. Other important causes of peatland decline are mining of peat for fuel and other purposes, road building and infrastructure development (Crump 2017).

Overall, close to 11-15% of global peatlands have been drained for agriculture, grazing, peat mining and forestry and a further 5-10% are degraded due to removal or alteration of vegetation (Joosten *et al*. 2012; Leifeld and Menichetti 2018; Leifeld *et al.* 2019; FAO 2020; Humpenöder *et al*. 2020). Between 1850 and 2015, temperate and boreal regions lost 267,000 km^2 and tropical regions 203,000 km^2 of natural peatland. Although drainage and degradation of peatlands has slowed in the temperate and boreal regions, peatland loss in the tropics continues at a high rate. By 2050, the area of peatland converted in tropical regions might increase to around 300,000 km^2, and by 2100 to as much as 363,000 km^2 (Leifeld *et al*. 2019).

Current estimates indicate that there are just over 500,000 km^2 of drained peatlands worldwide (see Table 2). Roughly one-third are in the tropics, and two-thirds in boreal and temperate zones. Agricultural drainage and conversion of peatlands is increasing in the tropics, especially in Southeast Asia. Commercial forestry and plantations, such as oil palm, are also responsible for much tropical peatland loss. Although the pace of agricultural drainage in temperate and boreal zones has slowed in recent years, commercial forestry is a major cause of peatland decline in these regions (Paige and Baird 2016; Crump 2017). Since 1850, 8% of boreal and temperate peatlands have been drained, whereas in the tropics 29% have been drained, mainly in recent decades (see Table 2).

Drained peatlands are highly prone to fires (which are difficult to control), increase the release of greenhouse gas emissions, and generate smoke, particulate matter pollution and other toxic substances. Each year, the world's drained peatlands emit around 2 billion tonnes of carbon dioxide (CO_2) through peat oxidization or fires, a figure representing about 5% of all anthropogenic greenhouse gas emissions (Joosten *et al*. 2016; Leifeld and Menichetti 2018; Günther *et al*. 2020; Humpenöder *et al*. 2020). Currently, tropical peatland loss accounts for around 1.2 to 1.5 billion tonnes of CO_2 emissions, with about half of these emissions coming from peatland loss in Southeast Asia (Leifeld *et al*. 2019).[7] Clearance of vegetation, draining and burning of peatlands is a major source of biodiversity loss, water quality deterioration and land degradation (Crump 2017).

Given these trends and the impacts of global peatland loss and degradation, conserving, restoring and sustainably managing these critical high-carbon ecosystems has become essential. The high rates of tropical peatland conversion and the associated environmental risks are of particular concern. Conservation of remaining intact peatlands, alongside substantial rewetting and restoration of drained and degraded peatlands, is urgently required to keep peatland carbon stored in the ground and to reduce future greenhouse gas emissions (Leifeld and Menichetti 2018; Leifeld *et al*. 2019; Günther *et al*. 2020; Humpenöder *et al*. 2020). As the remainder of this policy report makes clear, this will not happen without addressing the two main causes of peatland mismanagement: peatland undervaluation and underinvestment in their conservation and restoration.

	Forest	Cropland	Deep-drained grassland	Shallow-drained grassland	Agriculture	Peat extraction	Total	% Global
Boreal	54,740	2,620	4,260	0	34,200	3,330	**99,150**	20%
Temperate	63,150	25,280	34,050	24,220	83,890	6,620	**237,210**	47%
Tropical	72,350	3,050	700	0	93,140	80	**169,320**	33%
Global	**190,240**	**30,950**	**39,010**	**24,220**	**211,230**	**10,030**	**505,680**	

Table 2. Areas of drained peatland (km^2) by climate zone and land use category. Source: Günther et al. (2020).

Notes: Leifeld et al. (2019) estimate that peatland area in 1850 was 4,045,000 km^2 in temperate and boreal regions, and 587,000 km^2 in tropical regions, or 4,632,000 km^2 globally. The above table therefore indicates that 8% of 1850 boreal and temperate peatlands have been drained, 29% of tropical peatlands, and 11% globally.

[7] For comprehensive reviews of the threats and impacts to peatlands in Southeast Asia, see Dohong, Aziz and Dargusch (2017) and Mishra *et al.* (2021), in Congo Basin see Dargie *et al.* (2018), and in Amazon Basin Lilleskov *et al.* (2019) and Roucoux *et al.* (2017).

Assessing the Benefits and Costs of Peatlands

Peatlands provide several important ecosystem services and benefits. The three key services most often associated with peatlands are carbon sequestration, water quality and wildlife habitat (Glenk and Martin-Ortega 2018).[8] However, in many developing countries, peatlands are also a source of harvested products central to the livelihoods of local communities. In some regions, recreation is also an important benefit. Other regulatory services of peatlands include erosion control, nutrient uptake and water supply. Peatlands may also serve as an inspiration for art, religion, and other cultural values held by both current and future generations.

Because of their wide-ranging and important benefits, peatlands are one of the most valuable ecosystems on our planet. Among all global inland wetlands, forested peatlands in Latin America, the Caribbean and Oceania have the highest ecosystem service values, followed by non-forested peatlands in Asia and North America. However, due to their rapid decline in recent years, both forested and non-forested peatlands exhibit the greatest decline in annual ecosystem service values when evaluated alongside all types of coastal and inland wetlands globally (Davidson *et al*. 2019).

Given the rapid loss of these valuable ecosystems, it is imperative that any decision to convert, degrade or drain peatlands includes an assessment of the various benefits that may be lost through such land use changes. Similarly, there should be adequate assessment of the costs and benefits of the drained and degraded peatland areas targeted for restoration.[9] Such assessments must also consider the unique features of the ecosystem services provided by peatlands. Many of these ecosystem services are not transacted in markets, and their values must be assessed explicitly through a range of *non-market valuation techniques*. Such techniques are well-known in economics and have been applied to value similar services for ecosystems that share certain attributes with peatlands, such as other aquatic, coastal and wetland habitats.[10]

One of the primary benefits of peatlands is that they are an important store of carbon. In fact, among all major ecosystems globally, peatlands have the most *irrecoverable carbon*. Not only does drainage and conversion of peatlands release much of its carbon, but once lost, it may take decades – if not hundreds of years – to restore the carbon. After 30 years, drained tropical peatlands are still unable to recover 450 tonnes of carbon per hectare (ha) that they had previously stored. Converted boreal and temperate peatlands have less irrecoverable carbon (135 tonnes per ha) after 30 years, but only because they store less carbon initially compared to tropical peatlands. Full carbon recovery in converted boreal and temperate peatlands takes more than a hundred years, and more than two hundred years for drained tropical peatlands (Goldstein *et al*. 2020).

The high irrecoverable carbon in converted peatlands means that carbon storage is effectively an irreversibly lost ecosystem service once peatlands are drained. When assessing land use options that lead to the conversion of peatlands, such as agricultural, forestry or mining activities, it is therefore necessary to include the irrecoverable carbon loss as a permanent cost to the alternative use of peatlands. Taking full account of the cost of irrecoverable carbon emissions from peatland conversion may mean that the alternative land use option is no longer economically attractive or viable.

[8] See also Martin-Ortega *et al*. (2014), Page and Baird (2015), Crump (2017) and studies in Annex 1.

[9] For example, see Hanley and Barbier (2009). Glenk *et al*. (2014) provide a cost-benefit framework for assessing spatially targeted peatland restoration. For an application of this framework to peatland restoration scenarios in Scotland, see Glenk and Ortega-Martin (2018). See also Annex 1 for economic assessments of peatland restoration in other regions.

[10] See, for example, National Research Council (2005), Barbier (2007), Barbier *et al*. (2011), Freeman III, Herriges and Kling (2014) and Barbier, Mensah and Wilson (2021).

Equally, in assessing the benefits and costs of restoring drained or damaged peatlands, one must compare the net gains in carbon dioxide and other emitted greenhouse gases from rejuvenating peatlands compared to the various agricultural, forestry or mining use of previously converted peatlands (see Table 2). For example, the immediate benefit of restoring peatlands is that the net greenhouse gas emissions from rewetted peatlands are significantly lower as compared to alternative drained land uses, even though rewetting may initially lead to higher methane levels (Günther *et al*. 2020; Humpenöder *et al*. 2020). As a result, taking the net reduction in greenhouse gas emissions into account can make peatland restoration more economically attractive and viable relative to alternative options, such as maintaining agriculture, forestry or mining activities on previously converted peatlands. The opportunity cost of delaying action on peatland restoration as part of a greenhouse gas mitigation strategy could be substantial (Glenk *et al*. 2021).

Because peatlands are waterlogged areas classified as wetlands, many of their ecosystem services are related to water quality. These include the supply of drinking and industrial water, filtration of toxic metals and pollutants, erosion control, maintaining nursery populations and habitats, recreation, scientific and educational benefits, and cultural values including art and religion (Martin-Ortega *et al*. 2014).

The role of peatlands in supporting potable water supply will become increasingly important with the growing risk of climate change, freshwater scarcity and periodic drought. Over 2,300 km^2 of peatlands deliver potable water to 71.4 million people globally. In Ireland and the United Kingdom, peatlands supply around 85% of all drinking water. However, only around 650 km^2 (28%) of the world's peatlands important for water supply are protected (Xu *et al*. 2018a). Assessments of the costs and benefits of peatland conservation and restoration should take account of the implications for potable water supply, especially in regions where water security is an increasing concern.

The benefit of peatlands as wildlife habitat and areas of high biodiversity is also becoming increasingly important, particularly as the economic and ecological consequences of global biodiversity loss are becoming more apparent (Dasgupta 2021). Peatlands have a unique structural and functional integrity that is central to both peat formation and the richness of their biota. They support a large proportion of species that are adapted to waterlogged, acidic and nutrient-poor conditions, including a range of rare, threatened or declining animals and plants. This biological diversity in turn underlies many of the key water-related ecosystem services described above, as well as the role of peatlands as permanent stores of carbon (Minayeva *et al*. 2017). In addition, the biological resources and wildlife found in peatlands have traditionally been exploited through hunting, fishing, harvesting and gathering. They continue to support the livelihoods and subsistence needs of many populations, especially in developing countries (Crump 2017; Evers *et al*. 2017; Dargie *et al*. 2018; Medrilzam *et al*. 2017; Schulz *et al*. 2019; Simangunsong *et al*. 2020). Sustainable management of tropical peatlands and their wildlife could also substantially mitigate the potential risks and severity of future zoonotic diseases (Harrison *et al*. 2020). Supporting local communities in the pursuit of sustainable ways of living is also crucial. Women and men from local communities have varied interactions with peatlands due to their gender roles. Examining and analyzing these interactions can engage communities in peatland conservation and restoration, whilst safeguarding their livelihoods and wellbeing (Goib *et al*. 2018).

Table 3 summarizes the key ecosystem services of peatlands. Many of these services are not marketed and require explicit valuation to assess their benefits. Increasingly, recent assessments of the costs and benefits of conserving, restoring and sustainably managing peatlands are including estimates of various peatland benefits. Annex 1 lists and summarizes a selection of these assessments from different regions of the world.

Ecosystem Service	Description	Value
Carbon sequestration	Carbon sequestered and stored in peat layer and any above ground biomass.	Non-marketed, valued by social cost of carbon or the trading price of carbon.
Water supply	Potable drinking water and non-potable water for domestic and industrial use.	Non-marketed, valued by reduction in treatment costs or willingness to pay (WTP) for additional supply.
Erosion control	Water retained in peatlands leads to less erosion and soil runoff.	Non-marketed, valued by reduction in off-site costs of soil erosion.
Flood control	Water retained in peatlands leads to less risk and severity of downstream flooding.	Non-marketed, valued by reduction in risk and severity of flood damages.
Water pollution and sediment control	Increased retention and filtration of sediment, toxic substances and pollution by peatlands.	Non-marketed, valued by reduction in downstream damages or WTP for reduction in health impacts.
Supports fishing, hunting and foraging	Peatlands provide plants, animals and habitats for resources harvested for subsistence and commercial activities.	Marketed and non-marketed, valued by surrogate market prices, production function and household production function methods.
Tourism, recreation, education, and research	Peatlands support diverse and unique species, some of which are rare or threatened.	Non-marketed, valued by WTP for wildlife viewing and other recreational benefits, educational or scientific value.
Religious, spiritual and other cultural values	Peatlands may have considerable spiritual, religious and cultural significance to nearby communities.	Non-marketed, elicited through qualitative surveys.
Existence and bequest values	Some may wish to preserve unique peatland ecosystems in their own right, especially for future generations.	Non-marketed, valued by WTP for preserving peatlands irrespective of an individual's current or future uses of their services.

Table 3. Key peatland ecosystem services

The case studies listed in Annex 1 confirm that assessing the benefits and costs of peatland conservation, restoration and sustainable management is critical to their wise use and conservation in many regions of the world. The case studies show that conserving, restoring and sustainably managing peatlands often result in considerable economic and environmental benefits, and decision makers should not ignore such benefits. Local communities are key stakeholders, and examining the social and cultural linkages between peatlands, their communities and other actors can lead to inclusive and sustainable solutions (Goib *et al*. 2018).

The indicative list of case studies in Annex 1 reinforces the concerns that reliable studies are available for only a small group of countries and are mainly dominated by assessment of carbon sequestration benefits of peatlands. More economic studies are needed for a broader range of countries, especially those with tropical peatlands threatened by land use changes, mining and other human impacts. Further investigation and study should concentrate on other ecosystem services indicated in Table 3, especially with the increasing importance of potable water supply by peatlands in water-scare areas.

The assessments in Annex 1 also indicate that the distributional impacts of peatland loss can be significant. Those who benefit from the commercial agricultural, forestry and mining activities that negatively impact peatlands are different economic actors than local communities and individuals who value the ecosystem services that undisturbed peatlands provide. Even within communities, some individuals may gain at the expense of others. For example, in Central Kalimantan in Indonesia, smallholders who have expanded palm oil cultivation on peatlands have profited significantly, whereas households that depend on subsistence and extra cash income from fishing, hunting and collecting non-timber forest products such as berries, bark, medicinal plants, rattan, sago and honey have lost out from smallholder expansion on peatlands (Evers *et al* 2017; Medrilzam *et al*. 2017; Schoneveld *et al*. 2019). People in Ireland, Scotland and Finland widely perceive peatland conservation to be important to biodiversity preservation, carbon sequestration and water quality services, and restricting commercial forestry and peat mining is considered preferable to limiting household cutting of peat for energy and horticultural use, even though activities and the household level also damage peatlands (Bullock and Collier 2011; Bullock, Collier and Convery 2012; Heli *et al*. 2019; Faccioli *et al*. 2020; Juutinen *et al*. 2020).

Restoration also has important distributional impacts. Assessing who wins and who loses is especially critical given that the costs of restoration vary significantly and that such costs depend not only on the types of restoration activities implemented but also on the initial peatland condition, which has been affected by historical land use. In addition, rewetting drained peatlands is expensive and often requires considerable initial capital outlays as well ongoing costs over long periods of restoration.

Annex 2 summarizes the costs of restoration for various peatland options in a representative temperate location (United Kingdom) as opposed to a tropical location (Indonesia). The estimates illustrate how restoration costs are especially high for tropical peatlands and can be wide-ranging for different methods and conditions. The outlays listed mainly relate to labor, equipment materials and other operating and capital costs related to peatland restoration. Importantly, information on opportunity costs is not included. Such costs can be considerable, especially those related to water for rewetting in water-scarce regions and in terms of foregone commercial land uses on drained and converted peatlands.

In sum, peatlands provide an important, viable option as a nature-based solution, and they offer a triple win for the climate, biodiversity and people. The failure to recognize these facts is leading to irrecoverable losses of carbon and other ecosystem services that are vital to the wellbeing of millions of people around the world, thereby exacerbating the climate and nature crises.

Policies for Peatlands

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Annex 3 provides an overview of peatland policies from five countries (Finland, Indonesia, Malaysia, Peru and the United Kingdom) and one major region (Congo River Basin). Governments in these countries and region are increasingly cognizant of the economic importance of peatlands and the need to adopt better policies for conserving, restoring and sustainably managing them. For example, Scotland (UK) has already started restoring drained peatlands and has set goals for additional restoration. Elsewhere, Indonesia has "prohibited the conversion and clearing of peatlands for oil palm, pulpwood and logging concessions".[11] Furthermore, the governments of the Democratic Republic of Congo and the Republic of Congo have agreed to cooperate to sustainably manage a large portion of the central Congo River Basin peatlands.

The conservation, restoration and sustainable management of peatlands provides a unique opportunity to align peatlands protection with national climate strategies. For example, the net reduction of greenhouse gas emissions resulting from peatland conservation, restoration and sustainable management could represent a significant part of national climate change mitigation strategies, thereby making a significant contribution to country-level Nationally Determined Contributions (NDCs) (Anisha *et al*. 2020).

Although such policy developments are encouraging, they stop short of a comprehensive strategy. For one, governments need to reconcile the tradeoffs between sustainably managing peatlands and development pressures that stem from the expansion of agriculture, forestry, mining and other commercial activities. Such a reconciliation is especially urgent for regions and countries where very few peatland areas have adequate protection, and for regions and countries where the status of peatlands is poorly monitored, evaluated and regulated.[12] Many countries and regions have found that restoring drained and damaged peatlands is expensive, difficult and time consuming. Such peatland management priorities represent a challenge for low- and middle-income countries in tropical regions, whose limited public finances have been stretched even further by the health and economic crises caused by the COVID-19 pandemic.

To overcome these challenges, countries need a more comprehensive strategy for managing these high-carbon and biologically rich ecosystems. Ending the undervaluation of peatlands requires countries to adopt policies, regulations and other actions that will improve peatland conservation, restoration and sustainable management. Such a policy strategy should comprise six key elements:

- Mapping, monitoring and assessment of peatland areas, including determining the status and condition of intact peatlands.
- Imposing moratoria, regulations, controls and incentives to prevent additional drainage, conversion and damage to remaining intact peatlands.
- Removing subsidies and other forms of financial support to agriculture, forestry, mining and other economic activities that excessively degrade or convert peatlands.
- Using taxes, tradable permits and market-based incentives to further control economic activities, their resource use and pollution that adversely impact peatlands.
- Allocating revenues generated or saved from subsidy removal, market-based instruments and other pricing reforms to invest in improving peatland conservation, restoration and sustainable management.
- Increasing funding for conservation, restoration and sustainable management of peatlands, especially to rejuvenate substantially drained peatland areas.

[11] A clear and operable definition of peatland in Indonesia is required to improve management and to enable comparison with other countries worldwide (Osaki *et al* 2016).

[12] See Annex 3 and FAO (2020).

Conservation policies require better mapping, monitoring and assessment of remote peatland areas, including determinations of the status and condition of intact peatlands.[13] Putting adequate policies in place for the conservation of remaining intact peatlands is essential. Designating more pristine peatland ecosystems as protected areas and imposing moratoria on land use activities that degrade, drain and burn peatlands are important first steps, but such policies must be sufficiently comprehensive and need to be supported by effective programmes of monitoring and enforcement. When combined with strict sanctions and penalties on non-compliance, these policies could also reduce illegal peatland conversion.

In many countries, agriculture, forestry, mining and water supply benefit from substantial publicly funded subsidies. Such subsidies include tax exemptions, consumption support, government-funded research, and lowered costs of labor, equipment, capital financing and other inputs. Such financial support not only uses up scare government revenues but can also damage the environment. Public subsidies to agriculture and fossil fuels that harm the environment amount to almost US$600 billion per year – a figure more than five times the amount spent globally by the public and private sector on nature conservation and protection.[14] The forestry subsidies most damaging to biodiversity may represent an additional US$28 to US$55 billion per year worldwide (Deutz *et al*. 2020). Annual subsidies provided through public water utilities are estimated at about US$456 billion globally, encouraging wasteful use, exacerbating scarcity and leading to more infrastructure development and extraction (Kocchar *et al*. 2015).

By subsidizing these economic activities, governments are essentially paying the aforementioned industries to continue with existing practices, such as land conversion and water abstraction, ecosystem degradation and pollution, rather than switch to more sustainable land and water management. This increases the incentives for degrading the environment, including draining, converting and damaging peatlands. Such subsidies not only perpetuate the undervaluation of peatlands, they essentially put a "negative price" on these ecosystems and their economically important services.[15] Consequently, the review of current financial support to agriculture, forestry, mining and other economic activities that excessively degrade or convert peatlands should form an important element of any country's strategy to manage peatlands more sustainably. Such a review could help governments identify and remove those subsidies that contribute to harmful environmental outcomes. Redirecting some of these subsidies to the poorest local communities is also crucial to ensure that those left furthest behind – including women – have opportunities to improve their livelihoods, not only via healthier ecosystems but also through economic empowerment and inclusive conservation efforts (United Nations Development Programme [UNDP] 2020).

Eliminating subsidies may not on their own end the underpricing of peatlands. It may also be necessary to tax pesticides, fertilizers, forest products and timber harvests, mining, and infrastructure developments that cause additional damage to peatlands. Such taxes can help ensure that agriculture, forestry and other land uses do not excessively degrade, over-exploit or unnecessarily convert peatlands. Furthermore, revenue from these taxes can be used for community initiatives, thereby enhancing the adaptive capacities of local women and men.

[13] For example, Sari *et al*. (2021) demonstrate how the difficulty of auditing the effectiveness of countrywide government policies may be overcome by auditing at landscape scales, using the example of peatland forests on the Kampar Peninsula landscape, Indonesia.

[14] OECD (2020a) estimates that public and private spending on nature protection and conservation over 2015-2017 averaged US$78 to US$91 billion. In comparison, environmentally harmful agricultural subsidies averaged US$112 billion per year over 2017-2019 just in OECD countries, and in 77 countries, fossil fuel subsidies were US$478 billion in 2019 (OECD 2020b). Governments also provide environmentally beneficial subsidies to nature, but over 2012-2016 they averaged less than US$1 billion per year (OECD 2019).

[15] Environmentally harmful subsidies act as a "negative price", because they do not only price the services of peatlands and other ecosystems too cheaply – they effectively pay some economic activities to destroy nature. As pointed out by Dasgupta (2021, p. 234), "The current structure of market prices works against our common future; the biosphere is precious but priced cheaply, if it is priced at all. Worse, owing to a wide range of government subsidies, some services come with a negative price."

Increasingly, countries use taxes, tradable permits and other market-based instruments to control harmful impacts on ecosystems and biodiversity. Since 1980, such *biodiversity-relevant taxes* have risen steadily in 59 countries, where they currently generate US$7.5 billion a year in revenue (Organization for Economic Cooperation and Development [OECD] 2020b). As part of their peatland policy strategies, governments should consider employing biodiversity-relevant taxes and other market-based instruments to control economic activities, their resource use and pollution that adversely impacts peatlands.

Removing subsidies and adopting biodiversity-relevant taxes will also free up or generate revenue that governments may invest in improving peatland conservation, restoration and sustainable management. This is especially important in the aftermath of the COVID-19 pandemic, which has placed significant fiscal burdens on governments worldwide. These burdens represent a challenge for low- and middle-income countries, which need to reconcile sustainability, nature-based solutions and development objectives in their post-pandemic recovery plans (Barbier and Burgess 2020).

Some emerging and developing countries may also decide to pursue innovative "win-win" financial mechanisms for funding peatlands as a nature-based solution. One possibility is a *tropical carbon tax* (Barbier *et al*. 2020). This is a levy on fossil fuels, where some of the revenues generated are invested in conserving, restoring and improving land management to protect biodiversity and services from a variety of ecosystems, including peatlands. Costa Rica and Colombia have already adopted tropical carbon tax strategies. If India put a similar policy in place, it could raise US$916 million to invest in peatlands and other natural habitats annually. Brazil could also fund US$217 million, Mexico US$197 million and Indonesia US$190 million per year with the same approach.

More ambitious policies for taxation and revenue allocation could yield nearly US$6.4 billion each year for peatlands and other nature-based solutions in India, US$1.5 billion for Brazil, US$1.4 billion for Mexico and US$1.3 billion for Indonesia. Other countries with tropical peatlands could also benefit from such a strategy.[16] All countries, despite the perceived burden, should increase funding for conservation, restoration and sustainable management of peatlands, especially to rejuvenate substantial drained peatland areas.

While all countries need to increase funding for peatlands as nature-based solutions, the growing gap between current spending on peatlands in low- and middle-income countries and what is needed represents an important reason for tropical peatland decline. Current private and public financing from the rest of the world to tropical countries inadequately compensates them for the costs of conserving, restoring and sustainably managing sufficient peatlands for all the climate, biodiversity and other environmental benefits they provide to the world. Tackling the underfunding of global peatlands therefore needs to be urgently addressed.

[16] For example, Barbier *et al*. (2020) estimate that if 12 other megadiverse tropical countries roll out a policy similar to Colombia's, they could raise US$1.8 billion each year between them to invest in natural habitats such as peatlands. A more ambitious policy of taxation and revenue allocation for these countries could yield nearly US$13 billion each year for natural-based solutions.

Funding for Peatlands

Global peatland conservation and restoration efforts suffer from chronic *underinvestment*. Current public and private funding devoted to peatlands falls well short of what is needed to save these valuable ecosystems. Because peatlands must be central part of any global strategy for nature-based solutions to prevent climate change, biodiversity loss and other environmental threats, much more needs to be done to invest in these valuable ecosystem services, especially in tropical regions.

Recent studies shed some light on how much additional funding should be allocated in the coming decades.

Figure 1 illustrates the challenges that underfunding poses for global peatland restoration. The scenario assumes that 40% of drained peatlands will be rewetted by 2050, which represents a necessary step to transform global peatlands from a net source of greenhouse gas emissions to a net sink (Leifeld and Menichetti 2018; Leifeld *et al*. 2019; Günther *et al*. 2020; Humpenöder *et al*. 2020). To achieve this goal, restored area must increase steadily over the next three decades from about 20,000 km^2 currently to around 204,000 km^2 by 2050. Consequently, annual investments in peatland restoration worldwide must rise from nearly US$19 billion annually to US$31 billion in 2030, US$39 billion in 2040 and over US$46 billion by 2050. In other words, global annual funding for rewetting and restoring drained peatlands must more than double within the next two decades.

An alternative scenario examines the funds needed for conserving and restoring tropical peatlands as a cost-effective nature-based solution for greenhouse gas mitigation. Table 4 provides one such estimate for 79 tropical countries.

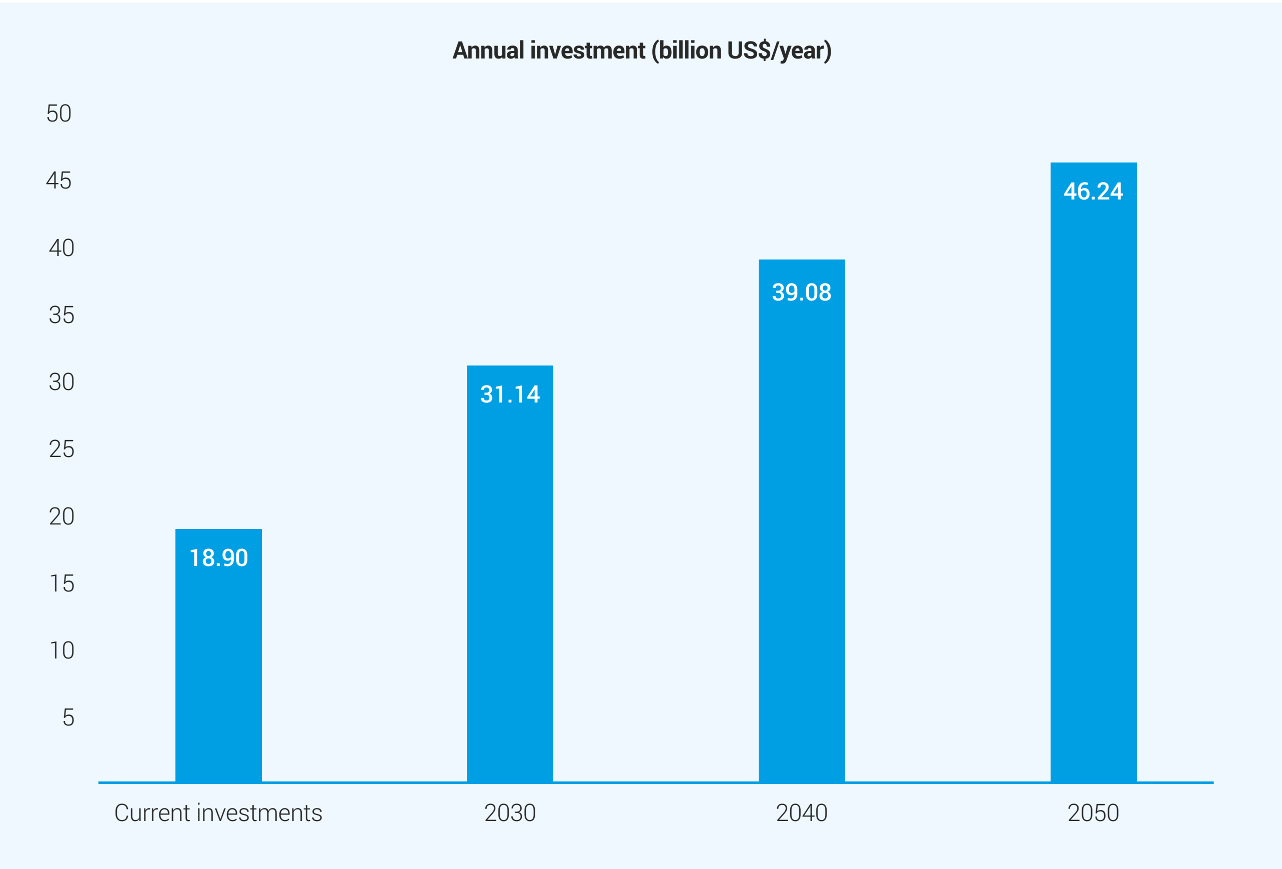

Figure 1. Projected annual investments for global peatlands restoration. Source: Based on Humpenöder et al. (2020) and United Nations Environment Programme [UNEP] (2021a).

Notes: Assumes rewetting and restoration of around 204,000 km^2 of drained peatlands by 2050 (ca 40% of global total, see Table 2), with 20,400 km^2 restored currently, rising to around 149,000 km^2 by 2030 and 182,000 km^2 by 2040.

Investing in cost-effective tropical peatland conservation and restoration for carbon mitigation would reduce global greenhouse gas emissions by 800 million tonnes per year, a figure larger than the annual emissions of Germany and just under 3% of the global total.[17] However, attaining this mitigation potential requires an annual investment of US$40 billion per year in tropical peatland conservation and restoration (US$28.3 billion for conservation and US$11.7 billion for restoration).

The estimates in Table 4 illustrate the current challenge of underinvestment in global tropical peatland restoration and conservation. The challenge is especially urgent for eight countries that could potentially account for 97% of the carbon mitigation outcomes from investing in tropical peatlands – Indonesia, Malaysia, Papua New Guinea, Uganda, Brazil, Democratic Republic of Congo, Peru and Republic of Congo.

Indonesia currently holds around US$200 million in domestic and international funds for annual spending on peatland restoration. Given the high costs of tropical restoration, such funds support the restoration of only 1,000 km^2 of peatlands annually, which is well below the government's stated targets.[18] To realize these targets, as well as to achieve the carbon mitigation potential estimated in Table 4, Indonesia requires much more funding for conserving and restoring its peatlands. The same is true for many other tropical countries.

	Peatland conservation		Peatland restoration		Total	
Country	**Annual carbon mitigation $MtCO_2e$/year**	**Annual cost US$M/year[a]**	**Annual carbon mitigation $MtCO_2e$/year**	**Annual cost US$M/year[a]**	**Annual carbon mitigation $MtCO_2e$/year**	**Annual cost US$M/year[a]**
Indonesia	462.82	23,141.0	174.65	8,732.5	637.47	31,873.5
Malaysia	51.31	2,565.5	16.77	838.5	68.08	3,404.0
Papua New Guinea	24.5	1,225.0	6.98	349.0	31.48	1,574.0
Uganda	7.92	396.0	6.98	349.0	14.9	745.0
Brazil	1.58	79.0	4.2	210.0	5.78	289.0
Dem Rep of Congo	0.85	42.5	0.84	42.0	1.69	84.5
Peru	0.05	2.5	0.14	7.0	0.19	9.5
Republic of Congo	0.01	0.5	0.01	0.5	0.02	1.0
Total 8 countries	**549.0**	**27,452.0**	**210.6**	**10,528.5**	**759.6**	**37,980.5**
Global share (%)	(97%)	(97%)	(90%)	(90%)	(95%)	(95%)
Other countries	**17.2**	**861.0**	**23.6**	**1,179.5**	**40.8**	**2,040.5**
Global total	***566***	***28,313***	***234***	***11,708***	***800***	***40,021***

Table 4. Carbon mitigation potential and costs of peatland conservation and restoration in tropical countries at cost-effective levels (< US$100 per tonne of CO_2e). Source: Based on Griscom et al. (2020).

Notes: a Following Griscom et al. (2020), annual cost estimate is US$50 per tonne of carbon dioxide equivalent (tCO_2e) multiplied by annual cost-effective mitigation, which is an approximation of the area under the marginal cost curve up to the cost-effective level of mitigation. Peatland conservation and restoration is considered cost-effective mitigation if it costs less than US$100 per tonne of carbon dioxide equivalent (tCO_2e) mitigated. M = mega or million (106). Estimates are for 79 tropical countries.

[17] See https://www.ucsusa.org/resources/each-countrys-share-co2-emissions.

[18] See Hansson and Dargusch (2017) and Annex 3. Budiharta *et al.* (2018) that offsetting the carbon emissions attributable to the existing 46,000 km^2 of industrial oil-palm plantations in Kalimantan, Indonesia requires restoring 4,000 to 16,000 km^2 of degraded peatlands, including failed agricultural projects, at a cost of US$0.7–2.9 billion. Offsetting biodiversity losses would require at least 47,000 km^2 of degraded areas to be restored at a cost of US$7.7 billion.

Table 4 only indicates the investment needed for tropical peatland conservation and restoration that achieves cost-effective carbon mitigation. It does not take into account the additional investments needed for the vast regions of tropical peatlands that currently remain largely intact but which are likely to face future development threats and conversion. This includes the Amazon peatlands found in Peru and the central Congo Basin peatlands in the Democratic Republic of Congo and the Republic of Congo, which are largely unprotected (see Annex 3). All three countries will require considerably more funding in the coming years to conserve these high-carbon and biodiversity-rich peatland regions from overexploitation and land use changes.

Finally, current funding for all nature-based solutions, including peatlands, relies heavily on public sources of financing. Around 86% of global nature-based solutions comes from domestic government funds, bilateral and multilateral assistance or other public funds (UNEP 2021a). Peatlands may be even more dependent on domestic and international public financing. Consequently, the challenge for ending global peatland underinvestment is not only to increase the scale of funding but also to find new sources, especially through additional private sector financing.

Innovative Financing of Peatlands

Given the urgency of addressing global peatland loss, broadening the sources and scale of financing for conserving and sustainably managing peatlands worldwide represents a key challenge. This involves wealthier countries not only increasing the amount of their own private and public spending on peatlands but also assisting poorer countries in doing the same. The latter could evolve through increases in bilateral and multilateral assistance while also encouraging more innovative public and private financing mechanisms. Financing mechanisms that centrally embed gender equality and other socio-economic factors will help advance the attainment of the SDGs. Countries seeking assistance from the international community for peatlands as a nature-based solution should demonstrate their "sustainable peatlands readiness" by devising national strategies and policy actions for peatland conservation, restoration and sustainable management and by establishing accurate and transparent frameworks for monitoring, reporting and verifying results-based actions under their national strategies.

In the case of peatlands, such investments have a high global return, as documented by many social and economic peatland assessments (see Annex 1). There is also a strong socio-economic case for assisting poor countries in improving the sustainable management of these unique ecosystems. Such assistance not only benefits the environment but also has the potential to improve the lives of the poorest people in local communities where conservation efforts impact them as well (UNEP 2021b). Increasingly, investments in conserving natural systems, such as peatlands, are proving to yield significant social and economy-wide benefits. Based on data from 16 low- and middle-income countries, researchers from the International Monetary Fund find that, for every dollar spent in conservation, almost seven dollars more are generated in the overall economy after five years (Batini *et al*. 2021). The authors attribute these high returns to three factors. First, conservation spending sponsored by donors supplements domestic resources in developing countries rather than crowding them out. Second, conservation actions in these countries are highly labor-intensive and create jobs. Finally, as discussed previously, the services of peatlands and other nature-based solutions support the economic livelihoods of the rural poor, by providing water, food, fodder, resource harvests and protection from extreme events (Batini *et al*. 2021).[19]

One way that richer nations could expand funding for peatland conservation and restoration in their own countries – as well as in poorer economies – is by increasing their investments in biodiversity offsets, payments for ecosystem services, voluntary carbon markets, and the global climate initiative Reducing Emissions from Deforestation and Forest Degradation (REDD+).

Biodiversity offsets

Biodiversity offsets are conservation actions, such as conserving or restoring ecosystems, which are used mainly by the private sector to compensate for unavoidable losses to natural habitats caused by investments elsewhere in the economy.

Biodiversity offsets aim to ensure at least a no net loss of biodiversity and, where possible, a net gain. Globally, US$6.3 to US$9.2 billion is spent annually on biodiversity offsets, which represent a large component of private sector funding related to biodiversity conservation. It should be noted that much of these offsets occur domestically within wealthier economies and that the amount funding peatland conservation is small.[20]

[19] The sixteen countries are Burkina Faso, Burundi, Cambodia, Cameroon, Central African Republic, Chad, Ghana, Guatemala, Malawi, Mozambique, Niger, Senegal, Sierra Leone, Madagascar, Tanzania and Uganda.

[20] The global estimates are from Deutz *et al*. (2020). According to OECD (2020a), US$2.6 to US$7.3 billion annually is spent on biodiversity offsets across 33 countries. The United States accounts for US$1.6 to US$6.3 billion of this spending. OECD (2020a) estimates that total annual private expenditure on biodiversity is US$6.6 to US$13.6 billion, and UNEP (2021a) estimates that annual private spending on all nature-based solutions is US$18 billion. These estimates suggest that biodiversity offsets are a large component of private spending on biodiversity and nature-based solutions.

Biodiversity offsets represent a potentially important source of funding for rewetting and restoring degraded peatlands in all regions.[21] By cooperating with the private sector, wealthier countries should encourage increased use of biodiversity offsets to fund peatland conservation, restoration and protection. Richer countries and multilateral agencies should also offer increased assistance to low- and middle-income countries when it comes to funding biodiversity offsets, as well as expanding their use for peatlands. This could be especially important for tropical peatland restoration efforts, which are disproportionately costly for most emerging and developing economies.

For example, offsetting the biodiversity impacts from existing oil palm plantations in Kalimantan, Indonesia would require rewetting at least 47,000 km^2 of degraded peatlands, incurring a cost of US$7.7 billion (Budiharta *et al*. 2018).

Payments for ecosystem services (PES)

Payment for ecosystem services are market transactions, usually direct cash or credit payments, made by those who benefit from ecosystem services to landowners who have agreed to provide these services through specific actions, such as habitat conservation or restoration. The type of ecosystem services generated include watershed protection, carbon sequestration, water quality benefits, biodiversity conservation and wildlife habitat benefits.

Ten large, publicly funded payments for ecosystem services programs account for around $10 billion of global funding annually. Estimates indicate that total public PES funding amounts to US$36-42 billion per annum. In addition, private schemes that pay for watershed protection services provide financing of around $15 million each year (Salzman *et al*. 2018; OECD 2020a; OECD 2020c).

Peatlands are currently under-represented in global PES. Expanding the use of payments for ecosystem services to conserve and restore peatlands may be especially viable for the water services that they provide. In many regions, peatlands are responsible for supplying drinking and industrial water, but only 28% of water-supplying peatlands are protected globally (Xu *et al*. 2018a).[22] This is an important opportunity to expand PES schemes worldwide for watershed conservation and other water services to include peatlands. Already, water utilities and other public entities are engaged in paying for such services that enhance water availability and quality, which are the focus of many PES schemes worldwide. Peatlands need to be included as priority ecosystems for PES schemes funding water trading services.

Voluntary carbon markets

Voluntary carbon markets support de-carbonization and carbon mitigation by allowing companies and other institutions to voluntarily set emissions reductions targets and purchase carbon offsets in markets for carbon credits. These credits increasingly fund the conservation and restoration of carbon-sequestering natural systems including forests, peatlands, grasslands, mangroves and other coastal systems.

[21] See, for example, Bonn *et al*. (2014), Crump *et al*. (2017), Budiharto *et al*. (2018), Renou-Wilson *et al*. (2019) and UNEP (2021a).

[22] See also Table 3 and Martin-Ortega *et al*. (2014)

Carbon projects supported by voluntary markets exist in 83 countries, and those financing nature-based solutions have expanded significantly in recent years. However, the overall value of this funding remains relatively small, at around US$780 to US$950 million annually (Deutz *et al*. 2020).[23]

Considerable potentials exist for voluntary carbon markets to expand in coming years, providing an increasing opportunity to support peatland conservation and restoration.

> One of the first programs to use carbon credits for peatland rewetting and restoration is MoorFutures in Germany.[24] Other countries in Europe and across the world could model their efforts on the MoorFutures approach, especially given the difficulty of raising funds for peatland restoration.[25] One study estimates that more than half of carbon mitigation schemes over a range of peatland rewetting costs and vegetation scenarios were profitable when funded through a hypothetical carbon credit scheme (modeled on MoorFutures) (Günther *et al*. 2018).

REDD+

REDD+ is a voluntary climate change mitigation approach created by the Parties to the United Nations Framework Convention on Climate Change (UNFCCC). It aims to channel investments that reduce emissions from deforestation and forest degradation, and to foster better conservation and sustainable management of forests.

Although several tropical countries have been working on developing national and sub-national REDD+ programs, very few have established verifiable emissions reductions to produce credits and qualify for payments. The largest multilateral assistance funds under REDD+ are UN-REDD, which has disbursed US$316 million to 35 projects worldwide, the Forest Investment Program, and the Forest Carbon Partnership Facility, which have disbursed around US$250 million each to 48 projects and 46 projects, respectively.[26] It is estimated that annual REDD+ payments globally are around US$40 million to US$500 million (Deutz *et al*. 2020).

The scale and scope of REDD+ projects must expand if it hopes to become a more effective tool for peatland conservation and restoration, especially for forested peatlands in tropical countries. Countries should start incorporating forested peatlands in their REDD+ national strategies and emission reference levels.

> For example, in its national REDD+ strategy, the Republic of Congo mandates that "agro-industrial concessions are not granted near wetlands or forests with high biodiversity value, and includes peatland carbon stocks in the country's forest reference emission levels for REDD+" credit assessment (Miles *et al*. 2017).[27]

[23] This estimate consists of US$200 million per year in 2019 from the California voluntary forest carbon market, US$500 to US$600 million per year in the Australia forest carbon market, and US$80 to US$150 million for all other voluntary forest and land use carbon markets.

[24] See https://www.moorfutures.de/ and https://www.globalcement.com/news/item/10530-holcim-deutschland-announces-partnership-with-moorfutures.

[25] See Bonn *et al*. (2014), Cadman *et al*. (2019), Cortina-Sagarra *et al*. (2021) and Günther *et al*. (2018). For example, peatlands are eligible for carbon credits under existing standards for the voluntary market, i.e. the Verified Carbon Standard (VCS) and the Climate Community and Biodiversity Standard (CCBS) operated under Verra (https://verra.org/about-verra/who-we-are/).

[26] As of December 2020, see https://climatefundsupdate.org/the-funds/. Approximately 80% of REDD+ projects are supported by public finance, and only 20% by private sector funding (UNEP 2021).

[27] Dargie *et al*. (2019) notes that the Democratic Republic of Congo also includes peatlands into reference carbon emission levels for REDD+.

In addition, countries implementing REDD+ projects for forested peatlands located in remote regions will require supplementary financial support to develop and implement protocols for measuring, reporting and verifying carbon stocks for results-based payments (Köhl *et al*. 2020).

Donors and countries must also develop more innovative ways of employing REDD+ payments to conserve and restore tropical peatlands. In Southeast Asia, it is suggested that REDD+ should be used to finance sustainable management of peatlands by local communities, to compensate smallholders to avoid palm oil expansion on peatlands, and to fund programs for relocating smallholders from peat to mineral soils, preferably on abandoned cultivated areas (Cacho *et al*. 2014; Evers *et al*. 2017; Medrilzam *et al*. 2017). Additionally, more effective use of fiscal instruments, such as fees, charges and funds, could encourage smallholders and concessionaires located in peatland areas to participate in REDD+ programs. Incentives could secure formal land tenure on existing land in exchange for reducing the expansion onto forested peatlands or deduct land and building taxes for license holders who conserve or restore peatlands within their concessions (Cadman *et al*. 2019).

Debt-for-nature swaps

Debt-for-nature swaps involve restructuring or cancelling some of a nation's foreign debt in exchange for investment in greater conservation of natural areas.

The COVID-19 pandemic has caused rising debt levels and budget strains in low- and middle-income countries which, in turn, limit their fiscal capacity to increase investment in nature-based solutions including peatland conservation and restoration. These financial strains also represent opportunities for donors to assist poorer countries by providing debt relief in exchange for increased peatland investment. Lender countries could offer lower interest rates and principal repayments in return for improved and sustainable peatland management in borrowing countries. Agreements that restructure or cancel some of a nation's foreign debt in exchange for investment in greater conservation of natural areas are called debt-for-nature swaps. Since 1990, debt-for-nature swaps by the United States cancelled approximately US$1.8 billion of debt owed by 21 low- and middle-income countries, generating US$400 million for conservation. These swaps also corresponded with lower rates of deforestation or forest loss in borrowing countries. In total, all other high-income countries carried out US$1 billion of debt cancellation and generated about US$500 million for nature conservation (Sommer *et al*. 2019).

If debt-for-nature swaps are to be effective in providing more global financing of peatland management, clearly more deals need to be made and key shortcomings addressed. Research on debt-for-nature swaps has highlighted various shortcomings, observing that "they often fail to deliver additional resources to the debtor country or to the government budget; often fail to deliver more resources for conservation purposes; often have a negligible effect on overall debt burdens; and are often in conflict with principles of alignment with government policy and institutions" (Cassimon, Prowse and Essers 2011). One option is to expand the range of conservation actions in any deal to include a commitment by participating low and middle-income countries to embark on the policy strategy outlined above, especially the commitment to removing subsidies and other forms of financial support to agricultural, forestry, mining and other economic activities that excessively degrade or convert peatlands. Such commitments not only signal the willingness to stop undervaluing peatlands but also reduces government spending. By undertaking such subsidy reforms in exchange for debt relief, participating countries can re-establish their credit worthiness with financial investors and markets. This could represent a win-win strategy for addressing both the debt crisis and the underfunding of peatlands – two problems that many developing countries face.

Green bonds

Green bonds are "debt instruments where the proceeds are used exclusively to finance or refinance projects with environmental benefits" (Cordon 2020).

Expanding the use of green bonds for peatland conservation, restoration and sustainable management represents another way to close the global funding gap. The European Investment Bank first issued green bonds in 2007 and the World Bank in 2008, reaching a market value of US$258 billion in 2019. The Luxembourg Stock Exchange established the first dedicated Green Exchange (LGX) that includes trading in green bonds in 2016 (Chahine and Liagre 2020; World Bank 2020).[28] The issuers of green bonds are typically local and national governments, corporations and multilateral development agencies and banks.

While the global market for green bonds is growing, they primarily relate to renewable energy, energy efficiency, green transport and other climate change mitigation investments. Green bonds are rarely used to finance biodiversity conservation and sustainable land use, let alone peatland conservation or restoration. Climate change, energy and transport have accounted for around 80% of green bonds; land use projects only 3% (Chahine and Liagre 2020).

The main issuer of green bonds for investments in low- and middle-income economies is the World Bank. Since 2008, the Bank has issued green bonds to raise US$17 billion for eligible projects worldwide. Of these commitments, nearly US$12 billion in green bond proceeds have been disbursed to support 106 projects in 31 developing countries. But 63% of the projects funded have focused on renewable energy, energy efficiency and clean transportation. Only 15% have related to agriculture, land use, forests and ecological resources and 4% to biodiversity, with a total allocation of just over US$1.6 billion (World Bank 2020).

If greens bonds are to catalyze more peatland investments, especially in developing countries, several limitations need to be overcome. Two key challenges are the relatively small scale of many ecological restoration and conservation projects compared to clean energy and transport investments, and as a result, the perceived relative low returns and significant risk of investing in nature-based solutions, such as peatlands. The average value of issued green bonds is US$150 million, but most restoration and conservation projects in low- and middle-income countries are unlikely to reach such a scale, unless they are bundled into larger investment opportunities (Chahine and Liagre 2020).

Developing country governments, working with multilateral agencies issuing green bonds, local governments and NGOS, could identify and combine individual peatland projects from various localities and regions into a single nation-wide investment portfolio. A green bond could then be issued for the entire portfolio of projects, and then disbursed to individual regional and local investments. Green bonds could also be issued to support other scalable peatland actions, such as a country-wide program of payments for ecosystem services, biodiversity offsets, ecological restoration, or for expanding conservation areas, their policing and monitoring.

[28] Note that, as traded assets, the market valuation of green bonds does not necessarily reflect the amount of money raised by issuers of green bonds to finance environmental projects. Chahine and Liagre (2020, p. 1) comment upon the rapid expansion in the market value of green bonds in recent years: "A lot of this growth has been captured by different stock exchanges where Green Bonds are listed."

Corporate contributions

Corporate contributions to fund peatlands conservation, restoration and sustainable management will play an important role in ending the underfunding of global peatlands. Few businesses are aware of the environmental costs within their supply chains. Still fewer make any attempt to account for these costs or understand how their business may depend on biodiversity or ecosystem services, such as those derived from peatlands.

The World Economic Forum estimates that US$44 trillion of global value added across 163 global industrial sectors and their supply is moderately or highly dependent on nature and its services. This is more than half of the world's GDP and is possibly even higher for sectors such as forestry and agriculture (World Economic Forum 2020).

It follows that the supply chains of some industries are environmentally destructive. Between 2000 and 2012, beef, soy, forest products (timber and pulp) and palm oil accounted for over 1 million km^2 of tropical forest loss (40% of global deforestation), including forested peatlands, with 31% of this loss attributed to exports and supply chains to the European Union and China (Haupt *et al*. 2020). On the other hand, consumer, shareholder and investor pressure has begun to motivate companies to invest in making their supply chains more sustainable. One global estimate indicates that corporate sustainable supply chains currently allocate US$5.5 to US$8.2 billion annually toward biodiversity conservation (Deutz *et al*. 2020).

Corporate initiatives

Corporate initiatives can enable a coordinated effort by the agricultural, forestry, mining and other global industries affecting peatlands to invest in improving the sustainability of their supply chains while also safeguarding that their activities result in no additional peatland losses.

For example, the *No Deforestation, No Peat, No Exploitation* (NDPE) initiative ensures that production does not involve any forest loss, conversion of peatlands or exploitation of indigenous communities or unjust labor practices. The NDPE approach has already gained ground in certain industries that have harmed peatland environments, such as palm oil, but the outcomes have been mixed. For example, in Indonesia and Malaysia, NDPE policies cover "83% of palm oil refining capacity, which also includes their plantations and the plantations of any third-party suppliers. However, non-cooperating refiners continue to leak unsustainable palm oil into the market thus undermining the effectiveness of the policies" (ten Kate *et al*. 2020). A survey of 79 of the world's most significant producers, processors and traders of palm oil found that, while 57 companies have committed to no planting on peat via NDPE, only 14 reported on their implementations of the commitment. Similarly, 59 companies have committed to no burning of peat, but only 43 companies disclose details of fire management and monitoring practices.[29]

[29] From https://bioenergyinternational.com/feedstock/many-palm-oil-companies-failing-to-meet-2020-zero-deforestation-targets.

Voluntary certification programs

Voluntary certification programs, such as the Roundtable on Sustainable Palm Oil (RSPO), have also encouraged more sustainable palm oil production, but not necessarily reduced peatland loss. An analysis comparing RSPO certified and non-certified oil palm plantations in Indonesia found that certification had little noticeable impact on reducing forested peatland loss or active fires (Carlson *et al*. 2018).[30]

In addition to ensuring that their supply chains do not cause additional loss of intact peatlands, businesses should also engage with and actively support government efforts to reform and redirect subsidies away from activities that are harmful to peatlands. Furthermore, they should proactively invest in developing sustainable supply chains and support producers to transition to sustainable production practices that will lead to no additional damage to or conversion of peatland ecosystems. Those activities that were historically based on peatland conversion, such as palm oil production, could also take responsibility for previous carbon emissions and make financial contributions to future peatland restoration and carbon sequestration programs. Finally, businesses should financially support and partner with public programmes to rewet and restore degraded peatlands, including through the various innovative financial mechanisms discussed above – biodiversity offsets, payment for ecosystem services, voluntary carbon markets, REDD+, debt-for-nature swaps and green bonds.

[30] See also Evers *et al*. (2017), Lyons-White and Knight (2018), Ayompe, Schaafsma and Egoh (2020), Degli Innocenti and Osterveer (2020). As summarized by Evers *et al*. (2017), p. 544, although "RSPO is an internationally recognized certifying agency for sustainable palm oil….joining the scheme is not compulsory and even if adhering, having existing concessions on peat does not currently disqualify growers from being certified as sustainable, and thus, further promoting the 'cake-and-eat-it' narrative that peat-based palm oil can be sustainable."

Towards a Global Peatland Strategy

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Global peatlands are in crisis. Their continuing losses from drainage, fires, mining and other human impacts pose profound implication for climate change, biodiversity loss, water supply and other important economic benefits worldwide.

Our global failure to conserve, restore and sustainably manage peatlands proves that their benefits are *undervalued* in our commercial and policy land use decisions that impact these high-carbon ecosystems. Global peatlands also suffer from chronic *underinvestment*, whereby the current public and private funding of peatlands falls well short of what is needed to save or restore these valuable ecosystems.

This report has outlined several **policy strategies** and **innovative financing initiatives** that could overcome these two shortcomings. Averting the worldwide crisis of peatland mismanagement requires us to address the problems of undervaluation and underinvestment, which should form the basis for **a global strategy for promoting peatlands as a nature-based solution**. Such a strategy requires three key elements:

- First, all countries with significant peatland areas should ensure that the values provided by these ecosystems are adequately considered in the land use decisions that inflict damages, degrade or destroy peatlands. They should adopt policies, regulations and other actions that will improve peatland conservation, restoration and sustainable management, whilst taking into account the wider gender-differentiated and socio-economic impacts faced by local communities. To end the undervaluation of peatlands, actions such as prohibiting additional loss of peatlands, removing subsidies that are harmful to peatlands, using market-based incentives and regulations to control peatland damages, and allocating any revenues generated or saved from subsidy and pricing reforms to improve peatland conservation, restoration and sustainable management should be pursued.
- Second, wealthy countries that contain peatlands should adopt these actions unequivocally. Many low- and middle-income countries, especially those with significant areas of tropical peatland, may need technical and financial assistance to undertake some of these policies, especially for restoring degraded peatlands. The international community should provide adequate financial and technical support to low- and middle-income countries that adopt gender-responsive policies and actions for improved peatland conservation, restoration and sustainable management.

  This additional support can be provided by a consortium of donors, including public-private partnerships, and should be conditional on verifiable policies and actions by recipient countries that have developed long-term policy and management plans for peatlands. Such an approach has been espoused by the REDD+ framework, where potential recipient countries have to demonstrate their "REDD readiness" by creating a national strategy or action plan for reducing emissions from deforestation and forest degradation and by guaranteeing accurate and transparent monitoring, reporting and verification of results-based actions. In a similar way, countries seeking assistance from the international community for peatlands as a nature-based solution should demonstrate their "sustainable peatlands readiness" by:

  - Devising a national strategy of policy actions for conservation, restoration and sustainable management of peatlands.
  - Establishing accurate and transparent frameworks for monitoring, reporting and verifying results-based actions under the national strategy.

- Third, in a post-COVID world of limited financial resources, there is a need to cultivate new potential sources of private and public funding for peatlands globally. This policy report has discussed several possible options, including biodiversity offsets, payments for ecosystems services, voluntary carbon markets, REDD+, debt-for-nature swaps and green bonds. In addition, the agricultural, forestry, mining, food and beverage, and other global industries must invest in product certification and in making their supply chains "peatland friendly" by ensuring that they result in no additional loss of peatlands. Industries should also partner with public programmes to rewet and restore degraded peatlands.

Conserving, restoring and sustainably managing peatlands must be a central aim in global efforts to invest in nature-based solutions to avert climate change, biodiversity loss and other environmental threats. This requires a global strategy for peatlands (Figure 2) that motivates collective action by all countries and stakeholders to end the worldwide underpricing and undervaluing of these important ecosystems. It is essential that policymakers recognize peatlands as a high priority for urgent action.

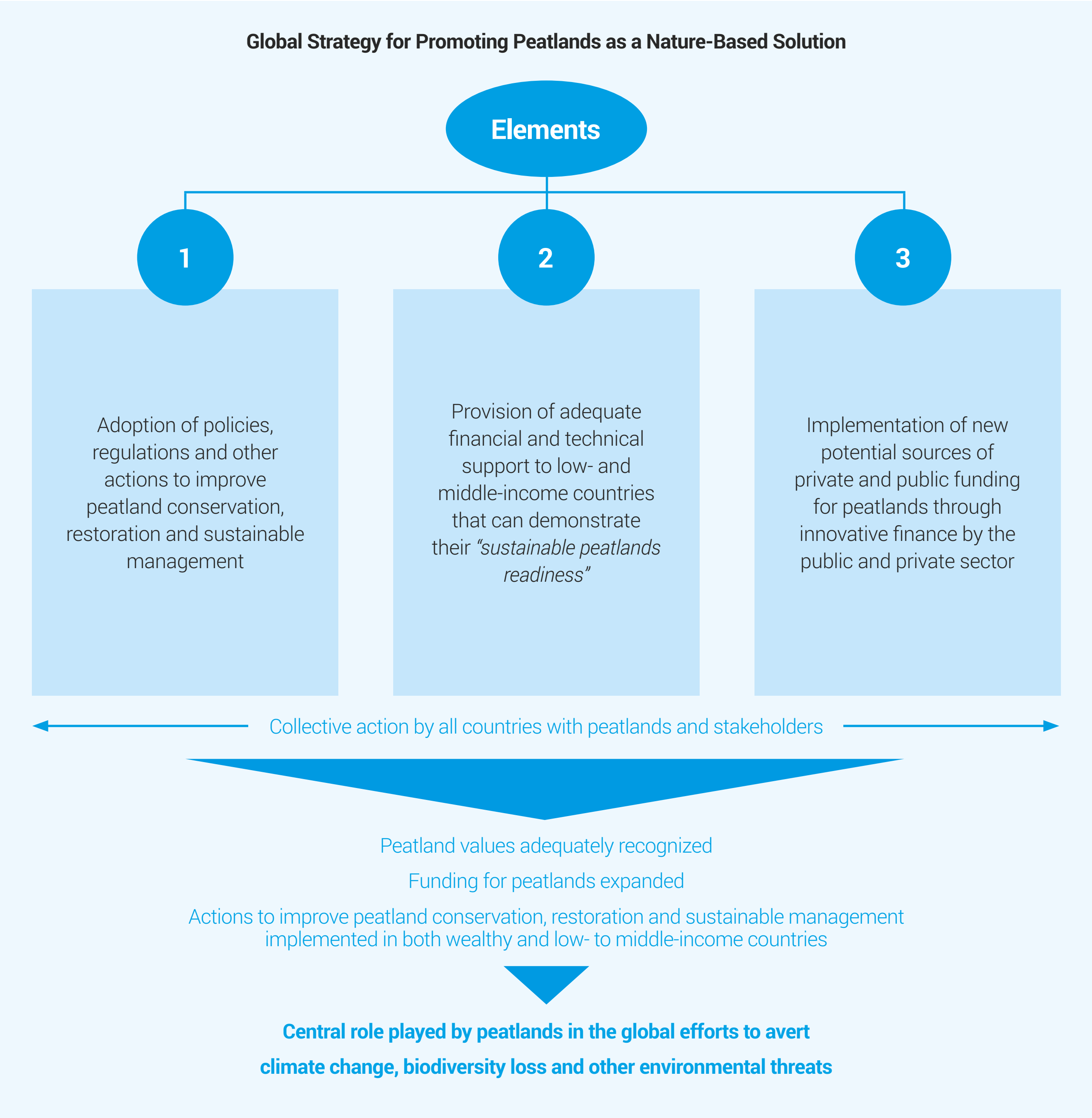

Figure 2. Global Strategy for Promoting Peatlands as a Nature-Based Solution

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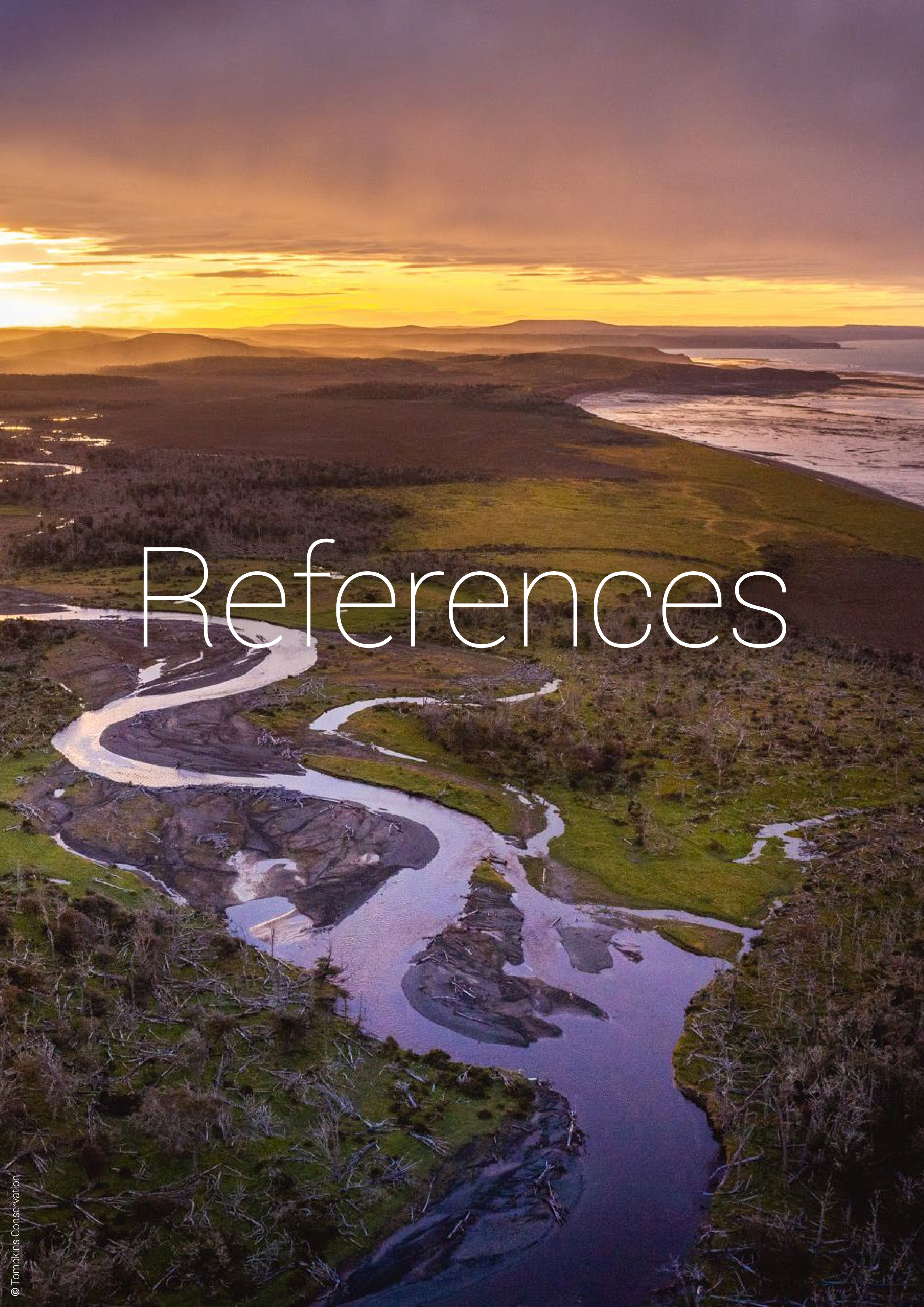

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Annexes

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Annex 1. Selective Examples of Peatland Economic Assessments

Source and Location	Description	Key Assessment Results
Glenk and Martin-Ortega (2018), Scotland, United Kingdom	Estimates the willingness to pay (WTP) of survey respondents to different peatland restoration scenarios in Scotland and compares the benefits to the costs of restoration.	The three-year Peatland Action Programme which restored 10,000 ha of peatlands has a benefit-cost (B/C) ratio ranging from 0.9 to 1.88 (mean 1.39). Subsequent restoration of 10,000 hectares (ha) in 2017 and 20,000 ha over 14 years has a B/C ratio ranging from 0.75 to 1.56 (mean 1.15).
Faccioli *et al.* (2020), Scotland, United Kingdom	Uses discrete choice experiments to explore the influence of environmental attitudes and place identity on the WTP for peatland restoration.	Respondents have a positive WTP for an improvement in peatland restoration, and those with more positive environmental attitudes and greater attachment to peatlands and Scotland tend to display higher WTP for restoration.
Moxey and Moran (2014), United Kingdom	Uses different estimates of carbon sequestration values and non-carbon benefits to determine whether the capital and ongoing costs of peatland restoration are justified.	For even low carbon sequestration value scenarios, capital costs of £200 to £10,000/ha for peatland restoration are generally justified given ongoing costs of between £25 to £400/ha/year over 20 to 40 years.
Bullock and Collier (2011), Ireland	Uses contingent valuation and discrete choice experiments to determine public preferences for protecting peatlands as opposed to industrial and household mining.	Respondents value peatlands as a cultural landscape, and are WTP on average €56/person/year. Although respondents favor halting industrial mining, there is a reluctance to stop extracting peat for domestic fuel even though it damages peatlands.
Bullock, Collier and Convery (2012), Ireland	Compares the carbon and other benefits of intact peatlands versus industrial mining, household mining and forestry.	Finds a substantial social cost associated with the business-as-usual scenario in which peatlands continue to be degraded through commercial and household extraction.
Miettinen *et al.* (2014), Finland	Examines alternative forested peatland harvesting regimes when ecosystem services in terms of water quality, biodiversity conservation and climate change mitigation are included.	Under a carbon neutral bioenergy policy, whole-tree harvesting with stump removal produces the highest net social benefits. However, if a carbon non-neutral bioenergy policy is assumed, the net social benefits are greater under stem-only harvesting.
Heli *et al.* (2019), Finland	Uses participatory multi-criteria decision analysis to evaluate five peatland policy scenarios that involve various tradeoffs between peat extraction and peatland protection.	While peat extraction for horticultural and energy use can be reconciled with preserving the most important biodiversity values, the conflict between peat extraction and carbon stock as well as water quality impacts and the related amenity values is irreconcilable. Conservation of all pristine peatland sites over 10 ha requires directing all new extraction sites to drained peatlands.
Juutinen *et al.* (2020), Finland	Uses an integrated biophysical-economic modeling approach with multi-objective optimization to investigate different alternative land-use and land-management options for peatlands.	Maximization of net present value (NPV) for peat extraction and forestry has significant tradeoffs with biodiversity, climate impact and water quality. Inclusion of restoration options maximized ecosystem services but also reduced NPV given the high costs of restoration (€800/ha).
Günther *et al.* (2018), Germany	Estimates the profitability of including direct greenhouse gas (GHG) measurements of project emissions for a range of peatland rewetting costs and vegetation scenarios based on a hypothetical carbon credit scheme.	Including direct GHG measurements was lucrative in more than 50% of all vegetation scenario/rewetting cost combinations. Profitability was achieved at rewetting costs of ca. €5400/ha and upwards.

Annex 1. (continued)

Source and Location	Description	Key Assessment Results
Ferré *et al*. (2019), Switzerland	Compares the present value of opportunity costs of Farmers switching to sustainable organic soils in Seeland peatlands to the present value of carbon benefits and payments for sustainable peatland management.	Current carbon offset policies and prices compensate for only half of the opportunity cost of switching to sustainable land use on organic soils used for intensive vegetable farming. There is a need for a long-term policy for sustainable management of cultivated peatlands and for eliciting society's willingness to invest in preserving organic soils.
Pindilli *et al*. (2018), Great Dismal Swamp National Wildlife Refuge, United States	Compares the carbon sequestration benefits of existing management regime to no management (with and without catastrophic fires) and improved management.	No management results in 2.4 million tonnes of CO_2 emissions with a net present value (NPV) of –US$67 million. No management with catastrophic fires emits 6.5 million tonnes of CO_2 with an NPV of –US$232 million. Current management avoids 9.9 million tonnes of emissions (via sequestration) with an NPV of US$326 million. Increased management avoids 16.5 million tonnes of emissions with an NPV of US$524 million.
Schaafsma *et al*. (2017), Central Kalimantan, Indonesia	Uses focus group discussions and a choice experiment to assess the compensation needed by local communities of farmers to forego peat burning for crops and cooperate in peatland restoration programs.	Farmers were willing to accept micro-credit as compensation for a ban on fire, as long as substitute methods of land-clearing and fertilization were offered; and farmers required a minimum level of income and food security as well as support for cultivating and marketing local species to accept the scheme.
Sumarga *et al*. (2016), Central Kalimantan, Indonesia	Compares hydrological and economic effects of conversion of peatlands to oil palm to mixed land use of oil palm plantations, rubber plantations and natural forest.	The oil palm scenario is the most profitable only in the short term and when the costs of CO_2 emissions are ignored, and is unsustainable in the medium and long term on two-thirds of drained peatland because of the risk of flooding. The social costs of carbon emissions considerably outweigh the benefits of oil palm production even at the first plantation cycle.
Sumarga and Hein (2016), Central Kalimantan, Indonesia	Compares the economic impacts of oil pam expansion on forests and peatlands to 2025 under three scenarios: business as usual (BUA), continuation of the peatland conversion moratorium and sustainable production.	Under BAU, the social costs of carbon emissions and the loss of other ecosystem services far exceed the benefits from increased oil palm production. The moratorium scenario increases the carbon and ecosystem benefits, but there is still considerable net loss of benefits from conversion. Sustainable production leads to the highest net benefits, including gains from oil palm.
Cacho *et al*. (2020), Sumatra, Indonesia	Derives marginal abatement cost (MAC) curves for oil palm clearing by farmers of peatland versus mineral soils, and compares the results with farmers' stated willingness to accept payment not to clear forests and peatlands.	Comparison of MAC curves suggests that a land-swap policy that offers farmers on peat soils the option to move to land on mineral soils, before they clear the forest, could save a considerable amount of carbon emissions without reducing oil palm production.

Annex 2. Costs of Peatland Restoration

Source and Location	Category	US$/hectare (ha)
Hansson and Dargusch (2017), Indonesia	Drained peatland with high-intensity fires of high-frequency fires	3,225 – 25,075
	Drained peat with low-intensity fires or clearing	2,315 – 24,725
	Drained peat with selectively logged peat	2,235 – 23,815
	Drained unlogged peat	2,000 – 23,500
	Drained small-scale agricultural peat	1,625 – 2,775
	Undrained selectively logged or agricultural peat	400 – 1,200
Artz *et al*. (2018), United Kingdom[a]	Drain blocking	720
	Reprofiling hags/peat banks	958
	Removal of normal-age forestry harvesting	2060
	Whole-tree mulching	3375
	All restoration types combined	1,225 – 2,088
Okumah *et al*. (2019), United Kingdom[a]	Reprofiling hags/peat banks	1,324 - 1,591
	Normal-age forestry harvesting	5,994
	Whole-tree mulching	3,480 – 5,345
	Whole-tree harvesting	7,837
	Felling to waste	747 – 4,939
	Ground smoothing/stump flipping	155 – 1,740
	Brash crushing	174 – 2,316
	Damming plough furrows	390 – 951
	Damming drains	143 – 8,189
	Introducing/replanting peat plants	658 – 1,688
	Cutting and clearing for regeneration	337 – 1,052
	All restoration types combined	103 – 8,189

Annex 3. Policy Overview for Major Peatland Countries and Regions

Country	Peatland area, km²	Status and trends	Current policies/programmes	Policy challenges
United Kingdom	22,052	About 77% of UK's peatlands are located in Scotland. More than 2/3 are degraded (over 80,000 km^2 drained).	Between 2013 and 2016, grants through the Peatland Action Programme have restored ca. 10,000 ha. Current peatland restoration target of 200 km^2/year (2,500 km^2 by 2032). In 2021, Scottish government announced £20 million for peatland restoration and a commitment to invest £250 million over the next 10 years.	Voluntary reductions in peat use by distilleries and horticulturists, and some fundraising from private sources. But need for more private financing and participation in peatland restoration.
Finland	71,911	One-third of land area is peatlands. 70% of Southern Finnish peatlands lost. Around 48,000 km^2 drained in country.	National peatland strategy enacted in 2009 to reconcile agricultural/fuel needs and environmental protection and to identify sites for protection. State-owned land of about 6,000 ha is already under protection status. About 30,000 ha more will be protected in the future. Private property protection is on a voluntary basis with support of a state compensatory budget.	Annual commercial timber harvesting is expected to increase from 60 to over 80 million m3 and a large proportion of this increase will come from peatlands. New energy peat extraction sites are likely to be established in coming decades. Inadequate restoration and conservation funding.
Indonesia	148,331	Third largest area of peatlands globally. Much peatland area has been drained (124,900 km^2) for agriculture and forestry, especially oil palm.	Moratorium prohibiting the conversion of primary natural forests and peatlands for oil palm, pulpwood and logging concessions, ban on peatland clearing on existing concessions and use of fire, and mandates concession-holders to fully restore peatlands in priority areas. Established a Peatland and Mangrove Restoration Agency (BRGM), with the goal of restoring 24,000 km^2 of degraded peatlands by 2020 and an additional 12,000 km^2 by 2024. Increased government investment in protecting and restoring peatlands, and incentives for private capital.	Reconcile continued expansion of oil palm, especially by smallholders, with peatland conservation and restoration. Lack of incentives for restoring degraded and burnt peatlands. Insufficient mapping and monitoring of priority areas. Lack of consistency among the ministries and institutions that govern peatlands. Given high costs of restoring tropical peatlands, more funding from public and private sources is insufficient to meet targets.
Malaysia	22,398	27.5% of peatlands are fully drained, mainly for oil palm and timber (pulp) (8,440 km^2), while most others are heavily damaged. Only 6% are intact.	Palm oil plantations monitored for environmental impacts, including on peatlands. Voluntary certification of sustainable oil palm production encouraged. National Action Plan for Peatland Management (NAPP) provides management strategies and targets for protecting peatlands. Limited regulatory policies for peatland conservation and restoration.	Continued unsustainable use of peatlands for agriculture and forestry, involving clearing and drainage. Conflicting government policies of promoting oil palm expansion and conservation and restoring peatlands. NAPP is not legally binding, so landowners or managers are not required to implement the policy.

Annex 3. (continued)

Country	Peatland area, km^2	Status and trends	Current policies/programmes	Policy challenges
Central Congo Basin	145,500	World's biggest tropical peatland complex. 90,800 km^2 in Democratic Republic of Congo (DRC), and 54,700 km^2 in Republic of Congo (ROC). Most areas relatively undisturbed, but agricultural and forestry use a threat.	DRC and ROC have agreed to cooperate on sustainable management of three Ramsar sites comprising 45% of peatland area. DRC government has established a Peatland Unit to define priority needs for mapping and monitoring peatlands. ROC considering additional protection of forested peatlands. Both DRC and ROC are facilitating technical dialogues within and across technical groups and sectors to advance national processes related to peatlands including capitalizing on ongoing sectoral reforms underway in each country.	Only 11% of the peatland region is protected. Highly vulnerable to land use change. Most of the region is under proposed or current concessions for logging, mining and oil and gas development. Expansion of the road network could increase access to previously remote locations and accelerate agricultural expansion.
Peru	49,990	Mostly intact (190 km^2 drained). Covers 11% of Peruvian Amazon.	Early in 2021, the Supreme Decree on the Multisectoral and Decentralized Management of Wetlands was approved. It recognizes the importance of peatlands and promotes their sustainable management. Additionally, the government has publicly announced its interest to incorporate peatlands into their Nationally Determined Contributions (NDCs) in order to address and mitigate the effects of climate change. The government has been promoting oil palm expansion in Amazon. Formal assignment of land tenure to indigenous communities and extensive protected areas in Amazon affords protection to some peatland areas.	Mostly intact but threatened by intensification of traditional management strategies and by agricultural, logging, mining, and infrastructure expansion. Oil and gas extraction is permitted in peatlands. Improved road access likely to increase agricultural expansion. Palm oil expansion and illegal logging are growing threats.

Sources: Peatland area and drained area (except Congo River Basin): Humpenöder et al. (2020), Xu et al. (2018b). United Kingdom: Glenk and Martin-Ortega (2018), Glenk et al. (2020), IUCN (2018), UNEP (2021a), Whitfield et al. (2011). Finland: Cortina Segarra et al. (2021), Heli et al. (2019), Juutinen et al. (2020), Salomaa et al. (2018). Indonesia: Budiharto et al. (2018), Cacho et al. (2014), Dahong et al. (2018), Evers et al. (2017), Hansson and Dargusch (2017), Hergoualc'h et al. (2018), Lilleskov et al. (2019), Medrilzam et al. (2017), Ministry of Environment and Forestry, Republic of Indonesia (2018), Sari et al. (2021), Schoneveld et al. (2019), Sumarga and Hein (2016), Sumarga et al. (2016). Malaysia: Cole, Willis and Bhagwat (2021), Dohong, Aziz and Dargusch (2017), Evers et al. (2017), Miettinen et al. (2016), Parish et al. (2021), Wan Mohd Jaafar et al. (2020). Congo River Basin: Crump et al. (2017), Dargie et al. (2017) and (2019), Miles et al. (2017). Peru: Crump et al. (2017), FAO (2020), Lilleskov et al. (2019), Roucoux et al. (2017), Schulz et al. (2019), Republica del Peru. (2021).