State of Finance for Nature 2022

Annex: SFN 2022 data and methodology

A1. Nature-based Solutions included in SFN 2022

Table 1: NbS categories included in SFN 2022

NbS category	Description
Reforestation	Conversion from non-forest (less than 25 per cent tree coverage) to forest (more than 25 per cent tree coverage) in previously forested areas
Agroforestry (silvopasture and silvoarable)	A land use system in which trees are grown with agriculture on the same land. SFN 2021 focused on silvopasture, which is the combination of trees and livestock; SFN 2022 includes silvoarable agroforestry, which is the planting of trees in croplands. Following Wilkinson (2020), two silvoarable types are considered: tree intercropping and multistrata agroforestry.
Restoration of mangroves	Restoration of damaged and degraded global mangrove forests.
Restoration of peatlands	Rewetting of damaged and degraded global peatlands.
Restoration of seagrass	Restoration of damaged and degraded global coastal seagrass meadows.
Restoration of saltmarshes	Restoration of damaged and degraded global coastal saltmarshes.
Grazing – optimal intensity	Grazing optimisation is the offtake rate that leads to maximum forage production (Henderson et al. 2015). This prescribes a decrease in stocking rates in areas that are overgrazed and an increase in stocking rates in areas that are under-grazed, with the net result of increased forage offtake and livestock production.
Cover crops	Cultivation of cover crops in fallow periods between main crops. Prevents losses of arable land while regenerating degraded land.
Avoided deforestation	Avoidance of conversion, destruction or degradation of forests, where forests are defined as areas with more than 25 per cent of tree coverage, in line with the global study conducted by the University of Maryland (Tyukavina et al., 2012).

Avoided grassland conversion	Avoidance of the conversion of temperate grasslands, tropical savannas and shrublands; the focus is placed on the conversion of grasslands to croplands.
Avoided mangrove impact	Avoidance of the conversion, destruction or degradation of global mangrove forests.
Avoided seagrass impact	Avoidance of the conversion, destruction or degradation of global seagrass.
Avoided peatland impact	Avoidance of the conversion, destruction or degradation of global peatlands.
Avoided saltmarshes impact	Avoidance of the conversion, destruction or degradation of global saltmarshes.
Protected area	Area closures that can help reduce deforestation, grazing pressure management and avoid destruction or degradation of marine and terrestrial ecosystems.

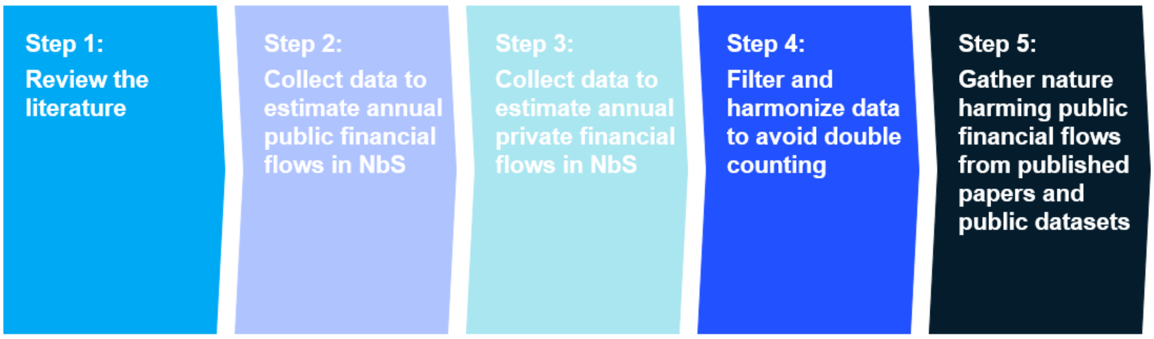
Note: Definitions based on FAO (2021), https://www.fao.org/3/cb3140en/cb3140en.pdf, UNEP (2021), Nature-based Solutions for climate change mitigation

A2. Current public and private sector financial flows in NbS

The estimation of current public and private financial flows in NbS builds on the methodology employed in SFN 2021 and consists of five steps, see

Exhibit 1. Step 1 was a review of closely related studies on biodiversity and conservation finance and reports on harmful environmental financial flows. Steps 2 and 3 involved collecting public and private financial flow data to estimate global levels of NbS finance. For these steps, the data sources from the SFN 2021 were used, preferably updated, and if available, new data sources were incorporated to capture a more diverse account of global NbS finance. In step 4, data sources were aligned to harmonise estimates and avoid double counting. Finally, step 5 drew evidence from published studies and public datasets to illustrate the size of potentially nature-harming public financial flows.

Exhibit 1: Methodology to estimate current financial flows in NbS



Step 1: Review the literature

The team conducted desk-based research and reviewed secondary sources related to finance for nature. The most closely related studies were identified below, with their estimates presented in 2022 prices:

1. **Financing Nature Report (Deutz et al. 2020):** A global review of financing in biodiversity conservation. It uses a narrow definition of NbS, which is climate finance channeled through carbon markets, totaling USD 0.9 to 1.6 billion per year in 2019. Finance into biodiversity protection amounted to USD 147 to 170 billion in 2019. It does not distinguish between private and public flows.

2. **A Comprehensive Overview of Global Biodiversity Finance (OECD 2020):** A global review of financing in biodiversity conservation. No specific NbS definition. Total expenditure in biodiversity conservation USD 90–105 billion per year (2015–2017 average). Private flows: USD 7–15 billion/year and potentially harmful flows to biodiversity from governments: USD 577 billion/year

3. **Global landscape of climate finance (Climate Policy Initiative 2021) :** A Review of global climate finance, updated in December 2021. No specific NbS definition. Estimates of climate finance flowing into the land use sector in 2019/2020: USD 16 billion, water and waste 19 billion and others and cross-sector, which includes disaster-risk management and biodiversity, land and marine conservation, were USD 24 billion. No figure for private flows into NbS.

4. **Protecting Nature by Reforming Environmentally Harmful Subsidies: The Role of Business (**Earth Track 2022)**:** A review of environmentally harmful subsidies across industries. The scale of subsidies is measured at least USD 2 trillion (2021 USD), including USD 560 billion/year in Agriculture and USD 166 /year in Forestry.

5. **A Decade of Ocean funding: Landscape Trends 2010-2020** (Our Shared Seas 2021): A review of the state of marine conservation funding across philanthropy, development aid, NGO discretionary funding, and private finance. In 2019, USD 3.3 billion in funding was allocated to marine conservation globally. No specific marine NbS definition.

Step 2: Collect data to estimate annual public financial flows in NbS

The study estimates public financial flows in NbS using the latest data available from the same sources selected for SFN 2021, updated where available, and incorporates public flows in marine NbS and protected areas by adding new data sources. The data was collected across seven sources to estimate domestic government expenditure and Official Development Assistance in NbS:

1. **Domestic government expenditure was collated for a total of 60 countries, which represent 76 per cent of global GDP.** The OECD Classification of Functions of Government was used to gather second-level domestic expenditure of government functions in 2019.[1] Moreover, domestic expenditure in 2017 for 28 non-OECD countries was obtained from the International Monetary Fund (IMF) COFOG database. In addition, domestic expenditure in NbS in China was estimated using the country's CBD Financial Reporting Framework in 2015 and its Gross Domestic Product in 2019. For the United States, the US National Accounts in 2021 were used to estimate domestic government expenditure in NbS. For all countries, the data is based on actual expenditure and excludes pledged or budgeted figures.

   SFN 2022 also estimates an approximate share of domestic expenditure in marine NbS by including government subsidies that support fisheries management and fishery research and development. The data was obtained from SubsidyExplorer.org, an online tool that compiles subsidy data for 152 countries using three sources and adjusts them to 2018 USD. The sources include: Sumaila et al (2019), the OECD fisheries support estimates database (2019), and Schuhbauer et al (2018) which collects data on small-scale fisheries subsidies from 2009.

2. **ODA was collected from the OECD Creditor Reporting System (CRS).** The CRS tracks gross disbursements of bilateral and multilateral aid in support of environment sustainability and aid to biodiversity, climate change mitigation and desertification from the DAC. The data is from 2019 and covers 138 recipient countries.

   The share of ODA towards marine NbS is obtained from the OECD Sustainable Ocean data platform. The platform extracts project-level data of ODA commitments for the sustainable ocean economy from the CRS. Sustainable Ocean economy is referred by the OECD as ocean conservation activities as well as support for ocean-based industries that integrates

[1] The Classification of Functions of Government (COFOG) data sets provide first- and second level COFOG on government expenditure data from the System of National Accounts by the purpose for which the funds are used. First-level COFOG splits expenditure data into 10 "functional" groups or sub-sectors of expenditures (such as defence, education and social protection), and second level COFOG further splits each first-level group into up to nine subgroups. For the purpose of this report, we have extracted the second-level data and triangulated these against both OECD sectoral guidance on inclusions and exclusions within each category and subcategories, and other major reports and studies in each of the sectors that can potentially contribute to NbS, including those on biodiversity, peatland and agriculture.

sustainability concerns. For instance, projects in support of mangrove restoration would be captured, as would projects promoting sustainable coastal tourism and sustainable fisheries projects. SFN 2022 uses 2019 data, which covered 1,174 projects. The team further screened those projects against the UNEA definition of NbS to identify those that were NbS only.

In addition, global expenditure allocated to protected area networks were included in this edition. These flows were estimated by Waldron et al. (2020) using primary data sources. The estimates include the management cost of terrestrial and marine protected areas in 2020 of 124 countries. Moreover, the flows could not be disaggregated between public and private sources, although private flows are typically small.

Table 2: Summary of public financial flows

Public financial flow	Source	Description	Year in SFN 2021	Year in SFN 2022
Domestic government expenditure	OECD Classification of the Functions of Government (COFOG)	An international standard that breaks down government expenditure from the System of National Accounts according to the different purposes or functions in which the funds are used.	2018	2019
	IMF Classification of COFOG		2016	2017
	Convention on Biological Diversity – China's Financial Reporting Framework	The framework is used by countries to report their contribution to global financial targets, under Aichi Biodiversity Target 20. SFN 2022 adjusts 2019 GDP by the share of biodiversity expenditure reported to CBD in 2015	2018 (based on China's GDP)	2019 (based on China's GDP)
	US National Accounts	The database reports government spending across budget functions	2020	2021
	SubsidyExplore.org. compiles data from three sources and adjusts figures to 2018 USD: Sumaila et al., 2019 estimates global fisheries subsidies OECD fisheries support estimates (FSE) database (2019) Schuhbauer et al (2017) estimate global small-scale fisheries subsidies	Estimate of government subsidies that support: Fisheries management: Programs aimed at improving methods for fish catching and processing, improving fishery resources through scientific or technical developments. R&D in fisheries: Including monitoring, control, surveillance programs, stock assessment and resource surveys, fishery habitat and stock enhancement programs.	N/A	2018
	Waldron et al. (2020)	Management expenditure in terrestrial and marine protected areas[2]	N/A	2020

[2] Includes private flows but it's not possible to disaggregate between public and private

Official Development Assistance	OECD Creditor Reporting System	Bilateral and multilateral aid in support of environment sustainability and aid to biodiversity, climate change mitigation, climate change adaptation and desertification from the DAC Creditor Reporting System database.	2018	2019
		Bilateral and multilateral aid in support of ocean conservation activities as well as support for ocean-based industries that integrates sustainability concerns	N/A	2019

The study uses the same methodological framework from SFN 2021 to identify NbS-relevant sectors and extract the share of public financial flows that is directed towards NbS. SFN 2021 acknowledged that there was no global database that tracks public NbS expenditure. Therefore, it employed multipliers (scaling factors) from existing literature and combined this with sectoral guidance from the OECD, to scale down the volume of public financial flows in each COFOG and ODA sector on the basis of the share of activities within that sector, which can more confidently be defined as NbS (See

Table 3 and Table 4 for a summary of the scaling factors used for COFOG and ODA sectors respectively). The same approach is applied in SFN 2022 to the latest data available.

Table 3: Methodological framework for COFOG sectors

COFOG second-level function	Scaling factor
0402: Agriculture, forestry, fishing and hunting	0.1
0502: Waste water management	0.1
0503: Pollution abatement	0.2
0504: Protection of biodiversity and landscape	0.9
0506: Environmental protection n.e.c.	0.2

Source: Based on expert assessment

Table 4: Methodological framework for Official Development Assistance sectors

Sector	Scaling Factors
14010: Water sector policy and administrative management	0.4
14015: Water resources conservation (including data collection)	0.7
14040: River basins development	1
31110: Agricultural policy and administrative management	0.1
31120: Agricultural development	0.1
31130: Agricultural land resources	0.9
31140: Agricultural water resources	0.1
31210: Forestry policy and administrative management	0.9
31220: Forestry development	1
32162: Forest industries	0.6
41010: Environmental policy and administrative management	0.5
41020: Biosphere protection	0.6
41030: Biodiversity	1
41040: Site preservation	0.1
41081: Environmental education/training	0.4
41082: Environmental research	0.4

Source: Based on expert assessment

In the same way as SFN 2021, uncertainty levels of public financial flows were assigned based on the relevance and granularity of each flow. For example, financial data coming from the OECD Creditor Reporting System indicates, for each activity, whether it targets the environment and the Rio conventions.[3] In this case, reliability is high. In contrast, financial flow data for domestic expenditure in the agricultural sector is more uncertain, as it may capture both NbS and non-NbS activities. Therefore, SFN 2022 uses the same framework developed for SFN 2021 to classify the level of uncertainty for each sector, see Table 5. It then applies this uncertainty level to the estimates to create upper and lower bound estimates that reflect the degree of uncertainty. The upper bounds represent a more comprehensive list of NbS activities, and the lower bounds represent a narrower scope of NbS. The final estimates are the midpoint between the upper and lower bounds.

[3] These are the Rio Markers, a scoring system of three values, in which aid activities are "marked" as targeting environment as the "principal objective" or a "significant objective", or as not targeting the objective.

Table 5: Methodological framework used to assess uncertainty

Range	High uncertainty	Low uncertainty		
Relevance	Low	Medium	High	
Estimate of share of NbS	1-33per cent	34-66per cent	67-100per cent	
Level	First-level data	Second-level data	Third-level data	
Source type	Fund / flow level	Expenditure level	Earmarked Programme level	Asset level / project level
Example	Agriculture	Agricultural land resources Agricultural water resources	Regenerative agriculture; Soil preservation; Shade agriculture Water conservation measure and agricultural wastewater reuse and repurposing	

Step 3: Collect data to estimate annual private financial flows in NbS

Data on private financial flows was collected across the same categories and data sources identified in SFN 2021, and if available, new data has been included to capture a more diverse account of global private financial flows in NbS, see Table 6.

- **Carbon Markets**: private financial flows were obtained using 2021 data published by Ecosystems Marketplace (2022), which tracks offset transactions from voluntary carbon markets across different projects, such as Forestry, Renewable energy and Waste Disposal. The lower bound estimate is calculated for voluntary carbon market transactions of forestry, land use and agriculture projects, while the upper bound includes all other types of projects.

- **Sustainable supply chains:** SFN 2021 obtained from the Paulson Institute (2020) report financial flows in biodiversity conservation from sustainable supply chains. The report included investments from certified forestry products, palm oil, seafood, and agricultural commodities. Due to a lack of recent data, these estimates have not been updated, however this edition includes financial flows from three additional certified commodities, namely: Rainforest alliance cocoa, Rainforest alliance coffee, and Roundtable on Responsible (RTRS) soy. Following the same approach as Paulson Institute (2020), financial flows are estimated to be 1 per cent (lower bound) and 1.5 per cent (upper bound) of the total market size of the certified commodity. The size of Rainforest Alliance cocoa market in 2019 is calculated based on Rainforest Alliance Certified products (2013) and Allied Market Research (2021). The size of Rainforest Alliance coffee market in 2020 is calculated based on Rainforest Alliance Certified products (2013) and Research and Markets (2021). The size of RTRS soy market in 2019 is based on Solidaridad Network (2020) and Research and Markets (2021).

- **Biodiversity offsets:** this category refers to financial flows in programmes intended to compensate for unavoidable impacts of development projects after prevention and mitigation measures have already taken place. Due to a lack of recent data, this year's edition relies on the same data source used in SFN 2021: the Bennett, Gallant and Ten Kate (2017) estimate, based on a survey of 99 regulatory biodiversity offsetting programmes in 33 countries for 2016.

- **Impact investing:** this category includes debt and equity investments intended to generate positive, measurable ESG impact alongside a financial return. We follow the same approach as Paulson Institute (2020) to derive a lower bound and upper bound of current financial flows.

  For the lower bound we extrapolate the share of private investment from the State of Private Investment in conservation survey (2004-2016) up to 2020 and apply the ratio of private investors in the survey (56 per cent) to obtain financial flows from private equity and debt.

  The upper bound is based on the Assets Under Management (AUM) for sectors related to biodiversity conservation, reported in the Global Impact Investing Network Annual Impact Investor Survey (2020). The survey reports the amount of capital invested in each year from 2015 to 2019 and the total AUM for that year. Therefore, a percentage of AUM that is invested per year is calculated and equal to 16.18 per cent. This share is applied to the total AUM from the survey and to the total AUM of additional impact asset funds obtained from 2020 IA50 and the Impactyield data platforms, which collect data on impact investment focused on Marine resources and conservation management, Natural resources and Conservation, and Sustainable Agriculture. Further screening was conducted across the funds website to ensure that only funds supporting NbS activities were included in the analysis.

- **Philanthropy:** financial flows from philanthropic foundations are obtained from the OECD (2020) Comprehensive Overview of Global Biodiversity Finance report, which estimates contributions from 14 foundations that support biodiversity-related activities in 2018 based on the Creditor Reporting Systems. The OECD calculates a lower bound based on flows that have marked biodiversity as a 'principal objective' and an upper bound based on flows that have biodiversity marked as a 'principal' or 'significant' contribution. In addition, the OECD also tracks philanthropic contributions towards the ocean economy in 2020, which is used to calculate flows in marine NbS.[4] These estimates are further supplemented by contributions from additional foundations not covered by the OECD CRA, including flows from the Bezos Earth Fund in 2020, and grants from 46 foundations in 2020 tracked by Fundingtheocean.org and OurShared Seas 2021 report (2020).

- **Conservation NGOs:** expenditure reported by the largest NGOs conservation in 2020 is estimated based on the annual financial report of Conservation International and Affiliates, RSBP, The Nature Conservancy, WCS and WWF. The upper bound estimate aggregates total expenditure and the lower bound subtracts reported revenue from public funding and philanthropies to avoid double counting.

[4] Since contributions towards the ocean economy include flows towards all ocean-based industries and some of this may not be NbS relevant (e.g., renewable marine energy), the team estimates the average annual share of sustainable ocean economy ODA relative to ocean economy ODA between 2010 and 2019, which is equal to 34per cent, and scales down the size of philanthropic contributions by this share to derive an upper bound of philanthropic funds in marine NbS. The lower bound scales down ocean economy flows by 10 per cent

- **Payments for ecosystem services (PES):** defined as voluntary financial flows between service users and service providers conditional on agreed rules of resource management for generating offsite services (Wunder, 2015). Data is obtained from the OECD: Tracking Economic instruments and Finance for Biodiversity (2021) study which captures PES finance based on a questionnaire conducted in late 2020 that identified 153 PES programmes in 37 countries. Moreover, to estimate the share of private payments, we calculate the market value share of PES mechanisms that are user-financed, and compliance-finance based on Salzman et al. (2018) and downscale the figure from OECD (2021) by 22 per cent to 44 per cent to derive a lower and upper bound estimate respectively.

- **Private finance mobilized by official development finance interventions:** financial flows mobilised by activities of Development Assistance Committee (DAC) countries' development finance institutions and other agencies as well as private finance leveraged by the Global Environment Facility and the Green Climate Fund were not updated in this report due to lack of recent data available. Hence, SFN 2022 reports last year's estimate based on the OECD Creditor Reporting system in 2018, annual average private finance leveraged by GCF between 2015 to 2020 and average annual private finance leveraged by GEF between 2015 to 2017. In addition, private finance mobilized for development of the ocean economy from the OECD (2020) was downscaled to derive marine NbS finance.[5]

[5] Since private finance mobilized for the ocean economy include flows towards all ocean-based industries and some of them may not be NbS relevant (e.g., renewable marine energy), the team estimates the average share of sustainable ocean economy ODA relative to ocean economy ODA between 2010 and 2019, equal to 34per cent, and scales down the size of private finance by this share to derive an upper bound of private finance in marine NbS. The lower bound scales down ocean economy flows more conservatively, by 10per cent.

Table 6: Data sources on private sector finance in NbS

Private financial flow	**Source**	**Description**	**Year in SFN 2021**	**Year in SFN 2022**
Carbon markets	Ecosystems Market Place (2021)	Transactions from voluntary carbon markets and investments in REDD+ programmes	2019	2020
Sustainable supply chains	a) Certified forestry products: (i) OECD Report (2020): A comprehensive overview of global biodiversity finance (ii) Breukink, G., Levin, J. Mo K. (2015). b) Certified Palm oil: 2019 Market Study Report on Global Sustainable Palm Oil market c) Certified agricultural goods: UNDP-BIOFIN (2020) d) Certified seafood: (i) FAO (2018) Report and (ii) Behan de Jong (2019) e) RTRS certified soy: Solidaridad Network (2020) and Research and Markets (2021). f) Certified coffee: Rainforest Alliance Certified products (2013) and Allied Market Research (2021). g) Certified cocoa: Rainforest Alliance Certified products	Investments into biodiversity conservation from sustainable-certified commodity markets The estimates follow the approach outlined in Paulson (2020) where 1per cent-1.5per cent of the certified commodity market is assumed to be invested in biodiversity-related activities based on findings from the forestry sector	a) 2015 b) 2019 c) 2019 d) 2018 e) Not reported f) Not reported g) Not reported	a) 2015 b) 2019 c) 2019 d) 2018 e) 2019 f) 2020 g) 2019

	(2013) and Research and Markets (2021)			
Biodiversity offsets	Bennett, Gallant and Ten Kate (2017) – survey of 99 regulatory biodiversity offsetting programmes in 33 countries for 2016	Investment in programmes intended to compensate for unavoidable impacts of development projects	2016	2016
Impact investing	State for Private Investment in Conservation (SOPIC) report (2016) GIIN survey (2020) Impact yield (2020) IA50 Impactyield.org	Private or public equity and debt investments intended to generate positive, measurable ESG impact alongside a financial return. The upper bound estimate assumes 16per cent of AUM is annual invested in NbS	2019	2020
Conservation NGOs	Annual report of: Conservation International and affiliates RSBP The Nature Conservancy WCS WWF	Expenditure reported by the largest conservation NGOs	2020	2021
Payments for Ecosystem Services	OECD survey of 153 PES programmes in 37 countries and the global status and trends of Payments for Ecosystem Services (Salzman et al. 2018) SFN 2021 was based on Bennett and Ruef (2016) and included PE for water quality trading and offsets and watershed services.	Voluntary financial flows between service users and service providers conditional on agreed rules of resource management for generating offsite services (Wunder, 2015)	2015	2020
Philanthropy	OECD, CRS (2018) used as a proxy for 2020 because no more recent data on	Financial flows reported by philanthropic foundations	2017	2020

	philanthropic contributions targeting biodiversity was available Bezos Earth fund (2020) Sustainable Ocean Economy (2020) Funding theocean.org (2020) OurSharedSeas (2020)			
Private finance leveraged by multilateral organisations	OECD CRS (2018) GEF (GEF secretariat, 2015-2017) GCF (GCF, 2015-2020) OECD Sustainable Ocean Economy (2020) -not included in SFN 2021	Private finance leveraged by activities of development finance institutions, development banks, other agencies working on development along with two multilateral climate and biodiversity funds The OCD CRS and OECD Sustainable Ocean Economy collect private flows mobilized through a variety of blended finance mechanisms using instrument-specific methodologies, covering all leveraging mechanisms used by DFIs and MDBs (guarantees, syndicated loans, project finance schemes, shares in collective investment vehicles, direct investment in companies, credit lines and simple co-financing.	2017/2018	2017/2018 and 2020 for marine

Step 4: Filter and harmonize data to avoid double counting

The data are triangulated between sources and the definitions are assessed to exclude repeated financial flows. Previous works points of the risk of double counting, which arises when the same transaction is included multiple times. With the emergence of new financial instruments, the boundaries between private- and public-sector flows into NbS are increasingly blurred. The combining of data sets can lead to double counting where categories overlap.

Subject to availability and granularity of data, financial flows in NbS have been divided explicitly for terrestrial and marine interventions to allow a comparison between them. For each finance category where marine finance data was explicitly reported, the team was able to present estimates separately for each type. On the other hand, for finance categories where explicit data on marine NbS finance was missing, the estimated figure is assumed to cover implicitly for both types. For example, carbon markets, data does not report explicitly marine NbS transactions. Therefore, to distinguish more accurately the proportion of marine investments against terrestrial NbS finance, data tracking tools could include more detailed information on the types of projects where NbS finance is being allocated.

All financial flows were adjusted to 2022 prices, including last year's estimates to allow comparison over time. The IMF GDP deflator dataset was used to derive inflation estimates by dividing USD GDP deflator in 2022 by USD GDP deflator in the data year. It then multiplies the data by this estimate to derive the value in 2022 prices.

Step 5: Gather nature harming public financial flows from published studies and public data sets

The report draws evidence from published studies and data sets that compile information on nature harming financial flows from the public sector. The studies apply their own bottom-up methodologies to identify public financial flows that might be harmful to nature across three sectors:

Agriculture: Estimates on nature harming financial flows in this sector were obtained from:

1. **A multi-billion-dollar opportunity – Repurposing agricultural support to transform food systems (FAO, UNDP, and UNEP, 2021).** The authors use the Ag-Incentives Consortium database to estimate price incentives and fiscal subsidies to individual agricultural producers across eighty-eight countries.[6] Price incentives refer to border measures (e.g., import tariffs) or market price regulations (e.g., domestic price fixation), that generate a gap between the domestic producer price and the border price of a specific agricultural commodity. Moreover, fiscal subsidies are monetary transfers made by the government in the context of policy measures, projects, and programmes to specific private actors of the agriculture sectors.

   The published paper emphasizes that price incentives and fiscal subsidies are forms of government support that may have significant negative implications on food systems. They highlight that 87 per cent of these forms of support incentivize production practices and behaviors that might be harmful to the health, sustainability, equity, and efficiency of foods systems. For instance, coupled subsidies, which link a financial transfer with a specific commodity can lead to negative environmental outcomes by incentivizing highly intensive practices. Thus, the upper bound of potential nature harming financial flows in agriculture in our report is based on the 87per cent of annual average of total price incentive and fiscal subsidy support between 2013 and 2018.

2. **Agricultural Policy Monitoring and Evaluation 2022: Reforming Agricultural Policies for Climate Change Mitigation (OECD, 2022**). The OECD report estimates agricultural support between 2019 and 2021 for 54 countries based on the OECD Agriculture Statistics database.[7] The authors consider market price support, which creates a gap between domestic producer

[6] The Ag-Incentives Consortium database aggregates estimates of agricultural support for the period 2005-2018. The database builds in the indicators generated by the International Organisations Consortium for Measuring the Policy Environment for Agriculture following a consistent and consolidated methodology for policy measurement originally developed by the OECD, and subsequently extended with other partners

[7] The database measures and monitors support to agriculture, defined as the annual monetary value of gross transfers to agriculture from consumers and taxpayers arising from governments policies that support agriculture. The support is expressed in monetary terms, including Total support Estimate (TSE) transfers represent the total support granted to the agricultural sector, and consist of producer support (PSE), consumer support (CSE) and general services support (GSSE). PSE transfers to agricultural producers are measured at the farm gate level and comprise market price support, budgetary payments and the cost of revenue foregone.

prices and reference prices of a specific agricultural commodity measures at the farm-gate level and payments based on commodity output or on variable input use, without imposing environmental constraints on farming practices, to be potentially the most environmentally harmful support. Hence, to estimate a lower bound estimate of potential nature harming financial flows, we aggregate support based on commodity output and input use in 2021.

Energy: Potential nature harming flows in the energy sector are based on fossil fuel support from:

1. **The International Energy Agency (IEA), 2021.** The IEA database provides estimates of subsidies to fossil fuels, including electricity, oil coal and gas, which are consumed directly by end-users or consumed as inputs to electricity generation across 42 countries.[8] As fossil fuel production contributes to climate change and the IPBES (2019) report identified climate change as the third largest direct driver of global biodiversity loss, we use the IEA estimate for 2020 as a lower bound estimate of potential nature harming financial flows in the energy sector.

2. **OECD-IEA combined estimates (2021).** The OECD and IEA collaborate to produce a joint estimate of fossil fuel support across five energy products: coal, electricity, natural gas, petroleum, and oil price per barrel. The database covers 51 economies based on the IEA data and the OECD G20 Inventory database.[9] Our report uses the total fossil fuel support in 2020 to calculate an upper bound for potential nature harming financial flows in the energy sector.

Fishing: potential harmful financial flows in the fishing sector are based on two published papers:

1. Sumaila et al (2019) and Skerritt J.D and Sumaila (2021). The authors identified and compiled published information on financial transfers provided to the fishing sector by governments and estimated the likely magnitudes of fisheries subsidies in countries for which this information was not available. The 2019 publication estimates subsidy values in 2018 data for 152 maritime countries while the 2021 publication uses the same data set but excludes nine countries for which data was too limited. Both papers categorize subsidies as 'beneficial', 'ambiguous' or 'capacity enhancing' based on many factors, including the policy objective of the subsidy. The capacity-enhancing subsidies were those that lead to disinvestments in natural capital assets. More specifically, according to the authors these subsidies allow for fishing capacity to develop beyond the point that would be sustainable in the long term by artificially increasing profits.[10] In our report, lower and upper bound estimates of capacity-enhancing subsidies are derived from the 2021 and 2019 publications respectively to estimate potential nature harming financial flows in the fishing sector. For both figures, we exclude fuel subsidies as it is assumed these are already accounted for in the energy sector estimates.

[8] The estimation of subsidies is based on the price-gap approach, which compares average end-user prices paid by consumers with reference prices that correspond to the full cost of supply. The price gap is the amount by which an end-use price falls short of the reference price and its existence indicates the presence of a subsidy.

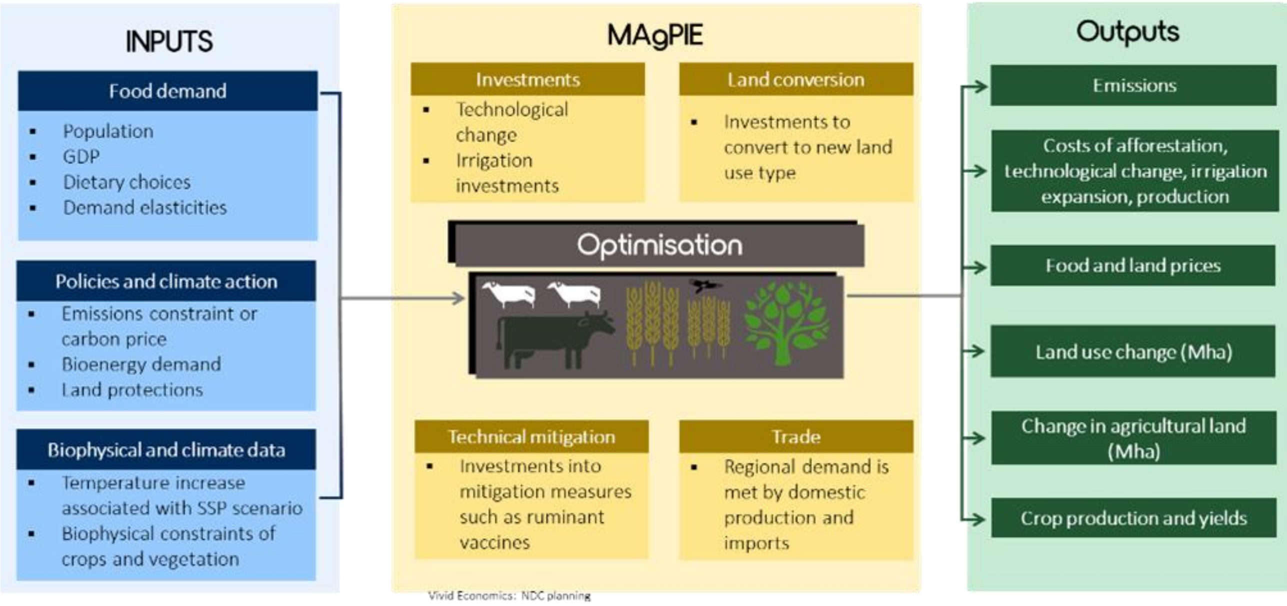
[9] The OECD Inventory of Support Measures for Fossil Fuels documents and estimates government measures that encourage fossil-fuel production or consumption relative to renewable alternatives.

[10] There are seven sub-categories of capacity enhancing subsidies: fuel subsidies and tax exemptions, boat construction, renewal, and modernization, fishing port construction and renovation, price and marketing support (processing and storage infrastructure, fishery development projects and support services, foreign access agreements and non-fuel tax exemptions

A3. Future NbS investment needs

To determine future investment needs, we primarily rely on modelled estimates from MAgPIE (Model of Agricultural Production and its Impact on the Environment), a global land use allocation model designed to explore land competition dynamics in the context of carbon policy. [11] The model takes a set of policy input assumptions and estimates the least cost way in which the land use sector can meet demand for agricultural products while respecting planetary boundaries (e.g., food and water security) and ensuring human wellbeing. Key outputs from the model include cost of action and land use change (Exhibit 2 describes the basic structure of the model).

Exhibit 2. MAgPIE: structure of the optimisation process.



In this work, we compare a policy scenario against a baseline scenario: the policy scenario focuses on the additional costs needed to achieve international climate (below 2°C scenario), biodiversity and land degradation neutrality targets. The scenario includes a baseline scenario where no climate or land policy takes place. The difference in costs between the policy scenario and the baseline scenario represents the additional investment needed to achieve respective climate, biodiversity and land targets, such that for each time period, t:

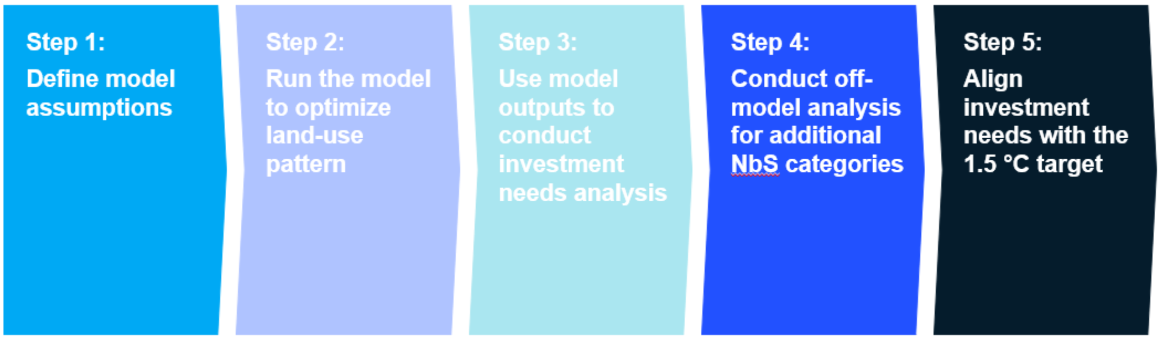
$$Investment\ Needs_t = Costs_{t,\ Policy\ Scenario} - Costs_{t,\ Baseline\ Scenario}$$

In the following sections, we lay out the methodology behind our modelling exercise, see Exhibit 3. In the first step, we define model assumptions for the policy and baseline scenario and provide an overview of the differences across them. Then, we discuss model interactions and how key assumptions are going to affect results. Next, we describe how the modelled outputs fit into our analysis of future investment needs. In step 4, we conduct off-model analysis to estimate investment

[11] Vivid Economics is currently using MAgPIE v4.1. The latest version, MAgPIE 4.3, models peatland restoration (see Humpenöder et al., 2020).

needed for additional NbS categories. Finally, we review the literature to estimate investment need aligned with the 1.5 °C target.

Exhibit 3: Methodology to estimate future NbS investment need



Step 1: Define model assumptions

Our modelling exercise starts with the development of two scenarios, each characterised by a set of assumptions. To study the additional costs needed to achieve international targets, we compare the 'Immediate Action' scenario – corresponding to a scenario in which global warming is kept below 2°C, and a corresponding baseline Scenario. [12] Table 7Table 9 lists selected assumptions, some of which remain unvaried across the two scenarios:

- **Population and GDP**: growth projections align with SSP2 of the Shared Socioeconomic Pathways (O'Neill *et al.*, 2014; Riahi *et al.*, 2017). This assumption implies a moderate increase in GDP, from about USD130,000 billion in 2020 up to over USD 300,000 billion in 2050. Global population growth is moderate and levels off in the second half of the century, after reaching ~9.2 billion people in 2050.
- **Trade:** trade liberalisation will increase across the board, with crop products achieving higher levels of liberalisation than livestock products.
- **Cost of investments:** investment in technological change is aligned with historical trends.
- **Protected areas.** Both scenarios include strict nature reserves, wilderness area and natural parks (IUCN I and II categories).

The difference between the policy scenarios and the baseline scenario is based on key policy assumptions, shown in Table 10 below.

[12] The 'Immediate Action' scenario and the baseline scenario were developed by Vivid Economic for the UK Treasury under the Dasgupta Review.

Table 7. Underlying assumptions for each scenario

Variable	Description	Source	2°C Scenario	Baseline scenario
1.GHG price trajectory	Defines global price trajectories for CO_2, N_2O, CH_4.	IIASA Database and PIK integrated assessment modelling exercise	SSP2 RCP2.6 consistent trajectory with carbon prices phasing-in globally in 2020 (higher for immediate action)	No carbon price
2.Reduction factor for CO_2 price	Lowers economic incentive for CO_2 emissions reduction from avoided deforestation and afforestation compared to carbon price level	-	0.5	-
3.Bioenergy trajectory	Defines demand for second generation bioenergy crops (only used for fuel production, not for food)	IIASA Database and PIK integrated assessment modelling exercise	Bioenergy production in the land use system allows the energy sector to reduce its emissions using BECCS.[13] SSP2 RCP2.6 consistent trajectory.	SSP2 NPi consistent trajectory
4.Population	Sets trajectories based on SSPs (Shared Socioeconomic Pathways)	SSP database	SSP2 – 'Middle of the road' consistent pathways	
5.GDP	Sets trajectories based on SSPs (Shared Socioeconomic Pathways)	SSP database	SSP2 – 'Middle of the road' consistent pathways	
6.Protected areas	WDPA categories plus all proposed areas and key biodiversity hotspots	(Leclère *et al.*, 2018)*	Protected areas expand to include ~21-24per cent of global land area to cover all categories of protected areas under the World Database of Protected	351 Mha (no change from current levels).

[13] Bioenergy with Carbon Capture and Storage (BECCS)

			Areas (WDPA) as well as key biodiversity hotspots 2708 Mha in 2020	
7.Ruminant meat fadeout	Defines decline in proportion of calories from ruminant meat in total meat demand relative to baseline scenario where it is treated as constant	(Bodirsky *et al.*, no date)	25 per cent reduction in ruminant meat share of diet by 2050.	Ruminant meat share remains constant.
8.Trade liberalisation	Defines change in current trade patterns	(Schmitz *et al.*, 2012)	10 per cent trade liberalisation for secondary and livestock products in 2030, 2050, 2100 and 20 per cent for crops	
9.Future costs of Notes: investment	Selected options for the expected costs of future productivity improvement.	(Dietrich *et al.*, 2014)	Trajectories for future investment costs in line with historical trends	

Notes: The default protection in MAgPIE is defined by the WDPA protected areas. It includes IUCN WDPA categories I and II. The WDPA protection covers approximately 400 Mha of the terrestrial land surface. For a world with increased protection, this work follows a procedure similar to the Bending the Curve project, where a 'potential protected area layer' is created - i.e. areas of the world that should be a priority to protect. Two criteria served for selection - (i) expanding the WDPA protection from Cat I and II to cover all categories, and in addition to designated WDPA protected areas, proposed PAs are also included (areas which are not protected, but deemed by WDPA to be prioritised for protection in near or distant future, using a variety of local factors). (ii) Key biodiversity hotspots, similar layer as used in Bending the Curve. The created potential protected layer is named the 'WDPA+', which comes to around 2700 Mha, which is ~21-24per cent of the terrestrial land surface and 600per cent more than present WDPA protection.

The next section lays out how model assumptions influence system costs, focusing on the impact of climate and land policy action on transition costs.

Step 2: Run the model to optimize land-use pattern

In MAgPIE, land is a limited resource which needs to be allocated to either agricultural production (food, feed and other materials) or carbon sequestration. This allocation process aims to minimise the costs incurred by the land use system to meet a certain demand for agricultural products. Demand for agricultural products is a function of both population and income. The former relationship is straightforward – more food and fibre will be needed to feed and clothe a growing population. The latter refers to the fact that, as people become richer, their budget constraint loosens, allowing individuals to demand more than “strictly” needed. As both population and GDP are set to increase under SSP2, demand will grow accordingly, and the agricultural sector will have to produce more using the same amount of land. This will intensify competition among land uses, leading to investment in innovation, higher production efficiency and higher food prices.

The introduction of climate policies puts additional pressure on the land use sector, increasing the costs associated with meeting agricultural demand. First, expanding area protection to include biodiversity hotspots as well as setting aside land to meet NDC commitments reduces the hectares of land available for agricultural production. Additionally, the introduction of a price on greenhouse gases has two direct effects on the land use system: on the one hand, it increases production costs for emission-intensive activities, such as production of beef and animal feed; on the other hand, it increases the benefits associated with non-productive activities, such as regrowth of natural vegetation for carbon sequestration. To meet demand under increasingly stringent land constraints and with cleaner/ less-costly production systems, the land use system faces substantial transition costs both in the form of investments to increase efficiency as well as operational costs associated with more intensive production systems.

The next section provides more detail on types of cost considered in estimation of investment needs.

Step 3: Use model outputs to conduct investment needs analysis

As the model accounts for all costs in the land use sector, we differentiate between direct and indirect costs of climate action. The former category includes costs related to GHG emissions and mitigation actions. The latter category includes costs in the agricultural sector, either investments or recurring costs, which are likely to increase with policy ambition. In this case, the difference across scenarios is going to be driven by the additional pressure put on the land use system by climate action. As mentioned in Step 2, the reason for this is that, to reach climate, biodiversity and land targets, the land use sector allocates larger areas to forestry and regrowth of natural vegetation, reducing the amount of land available for agricultural production. To "feed" an increasingly populous and rich world, agricultural producers need to become more efficient by investing in innovation and increasing spending on the overall production process. For example, firms trying to increase their crop yields will have to invest some capital in acquiring innovative machinery or develop new production systems and to spend more money on skilled labour.

Table 8. Costs from MAgPIE

Category	List of costs	Description
Indirect costs	**1. Costs of input factors**	Costs of input factors for producing food and materials includes labour, energy, physical inputs, non-land capital cost
Indirect costs	**2. Investment in technical change and adoption**	Investment in technical change and adoption includes R&D, adoption and irrigation expansion
Indirect costs	**3. Costs of processing, transport and trade**	Costs of processing, transport and trade includes all downstream cost to consumer
Indirect costs	**4. Cost of land conversion**	Cost of land conversion from one land use to another, including land clearing, land preparation, for agriculture or restoration
Indirect cost	**5. Cost of forest management**	Cost associated with forest management

Direct costs	**6. Costs of climate policy**	Split into a. Emissions costs associated with a Paris-aligned carbon pricing trajectory b. Rewards for negative emissions

To estimate investment needs, we look at the difference in indirect costs of policy action. Focussing on this category of cost allows us to estimate the global spending needed to meet climate, biodiversity and land degradation targets. Total investment needs between 2022 and 2050 are calculated as the difference in cumulative discounted cashflows of indirect costs of climate, biodiversity and land degradation neutrality action between policy and baseline scenario:

$$Total\ investment\ needs_{2022-2050} = \sum_{t=2022}^{2050} \Delta\, Costs_t$$
$$= \sum_{t=2022}^{2050} Costs_{t,\ Policy\ Scenario} - Costs_{t,\ Baseline\ Scenario}$$

Step 4: Conduct off-model analysis for additional NbS categories

The following section provides an overview of the analysis of investment needs for NbS that are not covered in the model. We start with a discussion on the sources of data for the off-the-model analysis and conclude with an overview of the methodology and outputs.

The off-model analysis focuses on nine types of NbS asset: peatland restoration and avoided degradation, agroforestry (silvopasture and silvoarable), cover crops, grazing-optimal intensity, avoided grassland conversion, and avoided impact and restoration of mangrove forests, seagrass meadows and saltmarshes.

The proposed focus on these NbS types is due to their mitigation potential, data availability and compatibility with modelled results. Estimates collected from Griscom et al. (2020), Roe et al (2021) and McKinsey's Blue Carbon report (2022) ensure that solutions with high climate mitigation potential are included from the analysis. A second stage of the analysis includes data collection on both costs and potential future uptake for each solution.

Solutions that could not be integrated with the modelled results are excluded. Only those marine NbS with established 'blue carbon' potential are included, in other words, those that meet minimum standards of scientific understanding and implementation potential and that offer scientifically verifiable levels of carbon abatement.[14] This study therefore excludes emerging and nascent solutions – kelp forests, seaweed farming. It also excludes oyster and coral reefs.[15] It is hoped that future studies will incorporate these NbS.

[14] Blue Carbon: The Potential of Coastal and Oceanic Climate Action (McKinsey, 2022)

[15] Coral reef restoration is not included due to ambiguity around its carbon sink properties.

As MAgPIE focuses on forests and innovation in the agricultural sector, we integrate our modelled results with some off-the-model analysis to include investment needs associated with NbS not covered by the model. For this analysis we rely on available literature on capital costs and operating expenses associated with a subset of relevant NBSs not covered in the modelling exercise. See Table 9 for a description of the off-model methodology and assumptions used to calculate investment needs for each NbS and Table 10 for a list of data sources employed.

The objective of the off-model analysis is to estimate direct costs of future restoration and protection of agroforestry, cover crops, grazing optimal intensity, peatland, grassland and coastal wetlands. To this end, for each hectare of protection and restoration we calculate the associated cash flows as the sum of the capital investment and the cumulative operations expenditure between the initial investment period and 2050. For peatland, the timing of the investments follows the dynamics set out in Humpenöder et al., 2020; for coastal ecosystem protection and restoration we assume a linear increase in land protected/restored between 2022 and 2050.

Methodology for each NbS

Table 9. List of NbS and description of approach used

NbS	Approach
Avoided peatland impact and restoration of peatlands	As in SFN 2021, area of land use change is taken from Humpenoder (2020). For this report, an upper bound aligned with a more ambitious 1.5°C target is included using estimates of land available for rewetting that are not constrained by socioeconomic factors based on Griscom (2017) and Wilkinson (2020).
Agroforestry and optimal managed grazing	Based on land use patterns from Wilkinson, et al (2020), assuming linear growth from 2020 to 2050.
Cover crops	In the lower bound scenario, the report uses an average of Griscom, Roe and Wilkinson. This is extended to an upper bound by using Griscom's figure for technical potential. Costs are taken from McKinsey Nature Net Zero (2021).
Avoided grassland conversion	Based on historical rate of conversion of natural grasslands to cropland from 1980-1990. Costs are taken from Vivid Economics analysis.
Avoided mangrove impact and restoration of mangroves	Based primarily on Mckinsey's Blue Carbon report (2022), Worthington (2018) and Griscom (2020).
Avoided impact and restoration of seagrass, saltmarshes and mangroves	**Restoration** Following Macreadie (2021), the upper bound for land suitable for mangrove restoration is set at 0.812 Mha. This is less than ten percent of the total land available (9-11 Mha). Furthermore, Mckinsey (2022) estimates that the feasible land for restoration, given biophysical and socioeconomic constraints, is 0.6 Mha, and Roe (2021) estimates that only 0.2 Mha is 'practically' available at a cost-effect level. We set this as our lower bound. In contrast, global estimates of land available for seagrass meadow and salt-marsh restoration are unconstrained, due in part to a lower volume of research and incomplete global mapping. The upper bound in each case is set at 11.8 and 5.5 Mha, respectively. We set lower bounds at a similar ratio to that for mangroves in order to capture the uncertainty in feasibility once biophysical and socio-economic constraints are introduced, that is at 0.65 and 0.3 Mha respectively. Costs for marine restoration are taken from Bayraktarov (2016). **Avoided loss of seagrass and saltmarhes** Area of projected land use change is based on historical rates, following Griscom (2017). Costs are from Vivid Economics analysis.

Table 10. Table of sources for land use change and average cost

NbS type	Source	Land use change (2022-50)	Average cost (2022 US$):	
Agroforestry - Silvoarable (tree intercropping)	Wilkinson, et al (2020)	149-223 Mha	$1153	$173
Agroforestry - Silvoarable (multistrata agroforestry)		51-86 Mha	$1560	$133
Agroforestry - Silvopasture		184-259 Mha	$1378	$506
Agroforestry - Silvoarable	Griscom et al (2020)	608 Mha (max)	-	-
Agroforestry - Silvoarable & silvopasture	Roe et al (2021)	747 Mha	-	-
Cover crops	Wilkinson, et al (2020)	184-259 Mha	$414	$0
	Griscom, et al (2020)	352 Mha	-	-
	McKinsey (2021)	-	$0	$53
Optimal managed grazing	Wilkinson, et al (2020)	408-632 Mha	$75	$0
	Griscom, et al (2020)	884 Mha (max)	-	-
	Vivid analysis: Wilkinson, et al (2020), Laporte et al (2021)	-	$91	$13
Peatland restoration	Humpenöder (2021)	20 Mha	$9700	$280
	Wilkinson, et al (2020)	37-50 Mha	-	-
	Griscom et al (2020)	46 Mha (max)	-	-
	Roe et al (2021)	16-46 Mha	-	-
	Vivid analysis: Defra, Glenk (2018), Moxay and Moran (2014)	-	$10000-12500	$2-90
Avoided peatland degradation	Humpenöder (2021)	23-30 Mha	-	-

	Griscom, et al (2020)	23 Mha	-	-
	Roe, et al (2021)	5-10 Mha	-	-
	Vivid Economics: NOAA (2020), Defra	-	$490	$52
Avoided grassland conversion	Griscom, et al (2017)	51 Mha	-	-
	Vivid analysis: Climate Trust (2014), Baker et al (2020), ICF (2013)	-	$1551	$0.15
Mangrove restoration	Worthington (2018), Spalding (2018), Saintilan. et al (2020)	0.812 Mha	-	-
	Griscom, et al (2017)	11 Mha (max)	-	-
	Mckinsey (2022)	0.6 Mha	-	-
	Roe, et al (2021)	0.24 Mha	-	-
	Bayraktarov (2020)	-	$18,900 (TOTEX)	-
	Earth Security (2020)	-	$20,500 (TOTEX)	-
	Taillardat (2021)	-	$5,500 (TOTEX)	-
	Vivid analysis: Bayraktarov et al. (2015), McKinsey (2021), Kapos et al. (2019), Gilman et al. (2007), Defra	-	$280-12,400	$110-2300
Seagrass meadows restoration	Griscom, et al (2017)	17 Mha (max)	-	-
	Mckinsey (2022)	11.8 Mha	-	-
	Bayraktarov, et al (2020)	-	$130,000 (TOTEX)	-
	Vivid analysis: Megan et al. (2015), Fonseca et al. (2006),Fonseca et al. (1998), Tan et al. (2020)	-	$1,100	$2,000
Salt-marshes restoration	Griscom, et al (2017)	2 Mha	-	-
	Mckinsey (2022)	5.5 Mha	-	-

	Bayraktarov (2016)	-	$84,000	-
Avoided mangrove impact	Griscom, et al (2017)	3 Mha	-	-
	McKinsey (2022)	1.3 Mha	-	-
	Roe (2021)	0.48 Mha	-	-
	Vivid analysis: McKinsey (2021), Caldeira (2021), Aerts et al (2018)	-	$394	$104
Avoided seagrass meadows impact	McKinsey (2022	9.5 Mha	-	-
	Stower,s et al (2003)	-	$0.43-0.65	$37-57
Avoided saltmarshes impacts	Griscom, et al (2017)	24 Mha	-	-

Note: In deriving OPEX, when costs are negative, we assume them to be zero.

Step 5: Align investment needs with the 1.5°C UNFCCC target

To ensure that the NbS interventions included in this report were aligned with the UNFCCC goal of keeping global warming below 1.5 °C, a scenario was constructed from peer-reviewed sources cited in UNEP (2021), which explicitly calculate abatement estimates of NbS under a 1.5 °C target.[16]

A literature review was conducted to identify NbS categories with the potential to be scaled up in line with a 1.5 °C. Griscom, et al (2017), Roe, et al (2021), Wilkinson, et al (2020), and Giradin, et al (2021) provided comprehensive analysis of NbS potential that are aligned with the 1.5 °C target. McKinsey's *Nature and Net Zero* (2021) and *Blue Carbon* (2022) reports provided corroborative guidance, along with Vivid Economic's analysis for the Inevitable Policy Response and the Dasgupta 'Immediate Action' scenario. [17] [18] We analysed these references to identify the NbS categories with the potential to be scaled up in line with a 1.5°C target and compared this the distribution of NbS abatement potential in our 2°C scenario.

Investment needed under a 1.5°C target was estimated for four NbS categories. Our calculations are based on Wilkinson (2020), which estimated the abatement emissions potential under a 1.5 °C scenario for agroforestry (silvopasture), restoration of peatlands, optimal managed grazing, and cover crops.

[16] United Nations Environment Programme (2021), https://wedocs.unep.org/xmlui/bitstream/handle/20.500.11822/37318/NBSCCM.pdf

[17] https://www.unpri.org/inevitable-policy-response/what-is-the-inevitable-policy-response/4787.article

[18] https://www.vivideconomics.com/wp-content/uploads/2021/02/210211-The-Urgency-of-Biodiversity-Action.pdf

We collected data on available area for each of these four categories and combined it with capex and opex data to derive investment needed under a 1.5 °C scenario.

SFN 2022 recommends further research to be conducted on NbS pathways under a 1.5°C scenario. The literature review indicated that only a small sample of studies have identified and accurately estimated NbS abatement potential under a 1.5 °C scenario. In addition, these estimates tend to focus on a more limited scope of NbS.

A4. Physical benefits

Emissions

For forestry NbS, emissions benefits were taken from MAgPIE using the Dasgupta 'Immediate Action' scenario. For avoided deforestation, emissions were calculated relative to business-as-usual scenarios.

To estimate the emissions benefit associated with additional NbS, the team took peer-reviewed sequestration rates – weighted according to region, where available – and applied them to modelled land use change between 2022 and 2050, assuming linear growth in most cases.

In the scenario aligned with a 2°C target, total yearly emissions abated by 2050 are over 13 $GtCO_2e$. This is a little over the range of abatement potential from Griscom, Giradin and Roe (10-12 Gt), partly as a result of faster and greater reforestation. In the more ambitious scenario, explicitly aligned with a 1.5 °C target, total yearly emissions abated by 2050 rises to 15 $GtCO_2e$, midway between Giradin and Roe's estimates.

Table 11. Table of references for abatement potential

NbS type	Source	Abatement potential (tCO_2e/ha/year)	Abatement potential per year ($GtCO_2e$/year)	
			By 2030	By 2050
Agroforestry - Silvoarable (tree intercropping)	Wilkinson, et al (2020)	1.7	0.65	
Agroforestry - Silvoarable (multistrata agroforestry)		4.5		
Agroforestry - Silvopasture		2.7	1.1	
Agroforestry - Silvoarable	Griscom, et al (2017)	0.37		1.0
	McKinsey (2021)		0.3	
Agroforestry - Silvoarable & silvopasture	Giradin (2021)			1.9
	Roe et al (2021)			1.1 – 3.2
Cover crops	Wilkinson, et al (2020)	0.25-0.78		
Cover crops	Griscom, et al (2017)	0.32		0.41
	Giradin (2021)			0.37
	McKinsey (2021)		0.45	
Optimal managed grazing	Wilkinson, et al (2020)	0.6	0.7	

	Griscom, et al (2017)			0.3
	Giradin (2021)			0.22
Peatland restoration	Humpenöder (2021)		1.0	
	Wilkinson, et al (2020)			
	Giradin (2021)			0.39
	Griscom, et al (2017)			0.82
	Roe, et al (2021)			0.6
	McKinsey (2021)	-	1.0	
Avoided peatland impact	Humpenöder (2021)		0.9	
	Giradin (2021)			0.68
	Griscom, et al (2017)			0.75
	Roe, et al (2021)			0.2
	McKinsey (2021)		0.9	
Avoided grassland conversion	Griscom, et al (2017)			0.12
	Giradin (2021)			0.04
Mangrove restoration	Worthington (2018)			
	Griscom, et al (2017)			0.6
	Mckinsey (2022)	23.5		0.6
	Roe et al (2021)			0.006
	Ove Hoegh-Guldberg et al (2010)			0.16-0.25
Seagrass meadows restoration	Griscom, et al (2017)			0.21
	Mckinsey (2022)	12.5		0.21
	Ove Hoegh-Guldberg et al (2010)			0.03-0.05
Salt-marshes restoration	Griscom, et al (2017)			0.036
	Mckinsey (2022)			0.03-0.04

	Ove Hoegh-Guldberg, et al (2010)			0.01-0.03
Avoided mangrove impact	Griscom, et al (2017)			0.13
	McKinsey (2022)	42.9		0.13
	Roe (2021)			0.065
	Ove Hoegh-Guldberg, et al (2010)			0.02-0.04
Avoided seagrass meadows impact	Griscom, et al (2017)			0.13
	McKinsey (2022)	17.4		0.16
	Ove Hoegh-Guldberg, et al (2010)			0.19-0.65
Avoided salt-marshes impact	Griscom, et al (2017)	143		0.42
	McKinsey (2022)			0.04-0.06
	Ove Hoegh-Guldberg, et al (2010)			0.04-0.07

Biodiversity

The Biodiversity Intactness Index (BII) summarises the change in ecological communities in response to human pressures. The BII is an estimated percentage of the original number of species that remain and their abundance in any given area, despite human impacts. For this report, the BII is reported from MAgPIE under the Dasgupta 'Immediate Action' scenario, which prioritises biodiversity, compared to a BAU scenario.

Land restoration

The global restoration commitments, which cover around one billion hectares, were mapped to the SFN scenario outcomes, see 5. The commitments, include measures that countries plan to implement by 2030. These have been gathered in the Global Restoration Commitments (GRC) database developed by PBL for UNCCD's Global Land Outlook 2. **Error! Reference source not found.** shows that while there is not a one-to-one mapping against some restoration categories, overall, the SFN scenario outcomes align with the one billion hectares of land restoration commitments.

Table 12: Comparison of the global restoration commitments to SFN scenario outcomes		
Category	Global restoration commitment by 2030, Mha	SFN 2022 scenario outcomes by 2030, MhA
Restore/improve forest land	**279**	**431** of total managed forest land cover
Increase forest land	**94**	**137** Mha increase in forest land cover
Increase soil fertility and carbon stock	**167**	**375-533 Mha:** 98-128 Mha of cover crops land cover 67-103 Mha increase trees in agricultural land (Agroforestry) 17 Mha increase of avoided grassland conversion 136-211 Mha increase of optimal managed grazing 57-74 Mha increase of trees in pasturelands (Agroforestry)
Restore/improve cropland	**99**	
Restore/improve grassland and savanna	**84**	
Restore/improve multiple functions (productivity and carbon stock)	**40**	
Increase protected areas	**76**	**210-226 Mha**[19] 205 Mha increase in protected forests 0.4-1.7 Mha increase in mangrove protection 2.2-16.2 Mha increase in peatland protection 3.1 Mha increase in seagrass protection
Restore/ improve protected areas	**29**	
Restore/improve multiple land use	**24**	**15.6 – 34 Mha increase of other land uses:** 0.27 Mha increase of mangrove restoration 15 – 28 Mha increase of peatland restoration 0.2-3.9 Mha increase in seagrass restoration 0.1-1.8 Mha increase in saltmarsh restoration)
Other/general/unspecified	**21**	
Total	**913 Mha**	**>1000 Mha**

Source: Global restoration commitments from PBL, Goals and Commitments for the Restoration Decade (2020) and SFN 2022 scenario outcomes from MAgPIE scenario analysis from Vivid Economics and Natural History Museum (2020), 'The Urgency of Biodiversity Action', Project Drawdown, McKinsey Nature and Net Zero (2020), Humpenoder et al., (2020), McKinsey Blue Carbon (2022), Worthington et al. (2018) Notes: The total area to be restored through different measures is used as a proxy target to assess the finance gap to achieve land degradation neutrality.

19 In addition, an increase in marine and land protected areas to reach the CBD target of protecting 30per cent of the world by 2030, was estimated separately by Waldron et al., (2020)

A5. The finance gap in protected areas

The estimation of the finance gap to protect 30per cent of land and marine areas by 2030 was based on Waldron et al (2020). The authors collected current spending in protected areas from primary sources. Then, they used statistical analysis to estimate the shortfalls in spending of current protected areas. Moreover, to estimate how much additional spending would be needed to expand protected areas to 30per cent of land and sea, they developed spatial scenarios of how the 30x30 target could be implemented (See Table 16 for a description of each scenario). The outputs of this analysis were estimated global costs needed in 2030 in order to meet adequate fundings needs of current protected areas and to achieve the 30x30 target proposed under the Post-2020 Global Biodiversity Framework.

SFN used the estimates from Waldron et al (2020) to estimate the cumulative finance gap in protected areas to achieve 30x30 between 2022-2030. SFN 2022 took the average of the minimum, mean and maximum estimated costs across all scenarios to construct a lower bound, mid-point and upper bound estimate of cost needed by 2030. We assumed a linear growth up to 50per cent of total cost from 2022-28 and then 100per cent by 2030 to derive cumulative cost up to 2030. For cumulative cost up to 2050, we extrapolated the cost from 2030 to 2050, assuming constant real costs.

Table 16: Scenarios that achieve 30x30 target

Scenario	Terrestrial/ marine	Description
Save Species from Extinction	Terrestrial	Expand the existing PA system to the 30 per cent target of land that optimally reduce global species extinction
Harsh Political Reality	Terrestrial	Disqualify from protection area needed for agricultural production up to 2050, then choose the areas of non-disqualified land that optimally minimize global species extinctions (plus existing PAs)
Biodiversity-Production Compromise	Terrestrial	Add ~5 per cent more of the land surface to the existing PA network (up to 20per cent planetary land), choosing sites to optimally reduce global species extinctions. The remaining 10 per cent of new PAs are not allowed to go on potential agricultural land, but are placed in the next-best set of sites instead (using the same criteria)
Three Conditions	Terrestrial	Protect all global habitat that retains a state of minimal human intervention ('wilderness'), plus existing PAs
Top30	Marine	Expand the existing MPA system to the 30 per cent of ocean that optimally reduce global species extinctions
HPR marine	Marine	Marine reserves are not allowed in areas of ocean that are currently high-value fishing grounds. The existing MPA system is expanded to the next-best set of ocean sites to preserve marine biodiversity
50:50EEZ	Marine	Expand the existing MPA system to the 30 per cent of ocean that optimally reduce global species extinctions, but 50 per cent of the protected area immediately adjacent to coasts (where small scale fisheries tend to operate) permits sustainable fishing, while the other 50 per cent bans all economic activity

Source: Waldron et al. (2020), Protecting 30 per cent of the planet for nature: costs, benefits and economic implications

A6. Limitations

There are several limitations and notes regarding this report.

- **Geographic scope:** This report collects data from the whole world. Since not every country publishes detailed data on public finance of NbS, some public finance will have been omitted.
- **Double-counting of current financial flows:** There is a risk of double-counting, which arises because it is unclear in some cases whether projects are included in multiple categories within data sets. During the data analysis, the authors triangulated data between sources and definitions with the intent to reduce the amount of double counting, but some might remain.
- **Double counting of financial flows needed:** in relation to the establishment of protected areas (MPAs and TPAs) and NbS interventions that avoid destruction or degradation of ecosystems. The former measures costs required to manage an area of land, both terrestrial and marine, equivalent to 30 per cent of the earth's surface area, while the latter measures costs required to protect land at a rate proportionate to historical rates of loss. The types of costs measured are not equivalent and the areas of land are not comparable.
- **Uncertainty around annual impact investments:** Since private funds do not typically disclose their annual investment nor how much investment is allocated across projects in their portfolio**,** we applied the same assumptions from Paulson Institute (2020) to derive an approximate share of annual investments based on the funds reported Assets Under Management (AUM).
- **Uncertainty around potential of marine NbS restoration**: compared to terrestrial NbS, there is significant uncertainty around both land area and costs related to marine restoration. The range given for potential seagrass and salt-marsh restoration is so wide as to be of limited use. Furthermore, costs might be overestimated, based on developed country projects and limited by low economies of scale, or they might be underestimates, if they represent projects that are 'low-hanging fruits' – there is too little data to know.
- **The model does not capture effects of climate change**, climate change is one of the main drivers of biodiversity loss, the analysis does not model how an increase in wildfires, extreme flooding and droughts will have implications on investment needed in nature.
- **Investment at the 'asset level':** This report focuses on actual investment in assets rather than pledged or budgeted figures.
- **Data limitations and related issues:** The authors encountered lack of comparable data, aggregation and limited disclosure of proprietary information. These risk double-counting and partial quantification of costs, benefits, and impacts.

A7. References for data analysis

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