2023

State of Finance for Nature

The Big Nature Turnaround
Repurposing $7 trillion to combat nature loss

Technical Annex

UN environment programme · Global Canopy · ELD The Economics of Land Degradation

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A Technical Annex

| Photo by Dimitris Poursanidis on Grida

A1. Methodology and data

State of Finance for Nature (SFN) 2023 estimates :

- Public nature-negative finance flows
- Private nature-negative finance flows
- Public finance flows to nature-based solutions (NbS)
- Private finance flows to NbS
- Future investment needs to NbS

All estimates are adjusted to 2023 prices (International Monetary Fund [IMF] Gross domestic product [GDP] deflator), including SFN 2022 estimates to allow comparison.

A1.1. Public nature-negative finance flows

For public nature-negative flows, SFN 2023 uses publicly available data and reports on environmentally harmful subsidies in four sectors:

Agriculture

A multi-billion-dollar opportunity – Repurposing agricultural support to transform food systems (Food and Agriculture Organization [FAO], United Nations Development Programme [UNDP], and United Nations Environment Programme [UNEP] 2021).

The report emphasises that price incentives and fiscal subsidies are forms of government support that may have significant negative impacts on food systems. It finds that 87 per cent of this type of support incentivises production practices and behaviours that might be harmful to the health, sustainability, equity, and efficiency of foods systems. The upper bound of potential nature harming finance flows in agriculture is based on 87 per cent of annual average price incentive and fiscal subsidy support from 2013-2018.

Agricultural Policy Monitoring and Evaluation 2022: Reforming Agricultural Policies for Climate Change Mitigation (Organisation for Economic Co-operation and Development [OECD] 2022). This report estimates agricultural support between 2019 and 2021 for 54 countries based on the OECD Agriculture Statistics database.[26] SFN aggregates support based on commodity output and input use in 2021 as the lower bound estimate of potential nature harming finance flows.

[26] 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.

Fossil Fuels

The International Energy Agency (IEA; 2023) database provides estimates of subsidies to fossil fuels, including electricity, oil, coal and natural gas, which are consumed directly by end-users or consumed as inputs to electricity generation across 49 countries.[27] IEA's initial estimate for 2022 fossil fuel subsidies is used as the midpoint of public nature-negative finance flows. In SFN 2022, a combined OECD-IEA estimate was used as the upper bound, however, it is unavailable at the time of analysis. Therefore, no range is provided for fossil fuels in SFN 2023.

Fisheries

Sumaila *et al.* (2019) and Skerritt and Sumaila (2021) compiled information on government financial transfers to the fishing sector and estimate the likely magnitudes of fisheries subsidies in countries for which this information was not available. Sumaila *et al*. (2019) estimates subsidy values using 2018 data for 152 maritime countries. Skerritt and Sumaila (2021) use the same dataset but exclude nine countries with insufficient data. In SFN, lower and upper bound estimates of capacity-enhancing subsidies are derived from the 2021 and 2019 publications respectively. Fuel subsidies are excluded as they are included in energy sector estimates.

Forestry

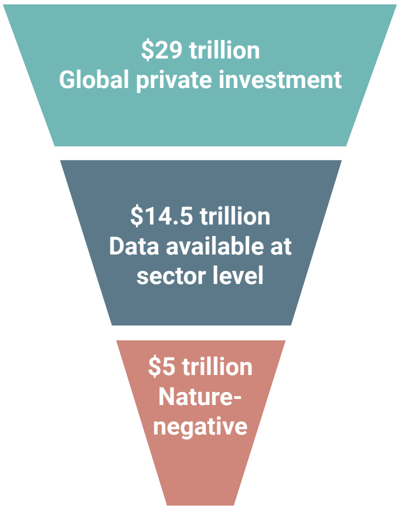
Koplow and Steenblik (2022) estimate environmentally harmful subsidies (EHS) in forestry based on the value of illegally harvested wood. Other types of subsidies were excluded due to lack of data. The paper uses data from the International Criminal Police Organization and the World Bank.

A1.2. Private nature-negative finance flows

SFN 2023 applies a bottom-up approach to estimate global nature-negative private finance flows across thirteen sectors defined by The Refinitiv Business Classification (TRBC). Estimation is based on the share of activities within each sector flagged as nature-negative and covers corporate loans, bonds and equities (including resale) with issue dates in 2022. The estimation only accounts for direct (Scope 1) impacts of economic activities to be consistent with the scope of NbS investments.[28] The following data and method was used to estimate nature-negative finance flows, summarised in Figure A1.1.

[27] 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.
[28] Nature-negative is not a negative equivalent of NbS. Nature-negative is here defined as any activities with a direct negative impact on either biodiversity, ecosystems or climate.

Figure A1.1. Hierarchy of data used to estimate nature-negative finance flows by sector and activity



Global private investments are estimated at approximately $29 trillion
IMF Investments and Capital Stocks Dataset 2021 (2019 data) tracks country level private investment in fixed capital assets.

The private investment database Refinitiv covers $14.5 trillion in private financial flows, about 50% of IMF private investments estimates.
Data collected on corportate loans, bonds, and equity tracks investments into publicly listed companies (2022).

Nature-negative private investments are estimated at approximately $5 trillion, about 30% of the volume of finance tracked at sector-level

Private investment data in SFN 2023 Coverage:
corporate loans, bonds and equities (including resale), with issue date in 2022
Limitations: Public and private companies are included but smaller size deals may not be captured, e.g, small farmer lending linked to deforestation may not be captured leading to an underestimate of ature-negative finance to agriculture

Step 1: Data collection

Nature-negative private finance was calculated using an activity-tagging approach, estimating nature-negative financial flows to a sector based on the number of activities within this sector flagged as nature-negative.

To start, the 2021 IMF Investments and Capital Stocks dataset 2021 (latest data 2019), which tracks country level private investment in fixed capital assets, provides an overview of total global annual private investments estimated at approximately $29 tn.

The private investment database (Refinitiv) provides data on corporate loans, bonds, and equities proceeds by sector and activity. The database covers US$14.5 trillion, providing valuable detail on roughly 50 per cent of IMF private investments.

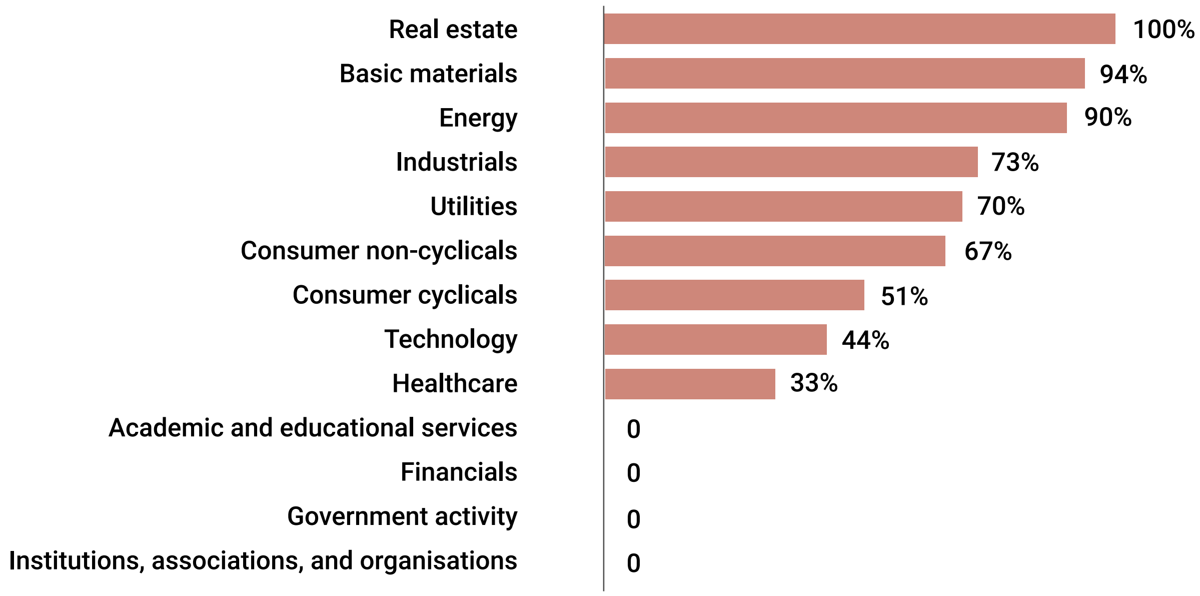
Two alternative approaches were used in step 2 to identify nature-negative finance flows at sector and activity level.

Step 2a: Using ENCORE

The tool 'Exploring Natural Capital Opportunities, Risks and Exposure' (ENCORE) was used to identify the share of production processes with high or very high impact on nature within each sub-industry.[29] This share was used as an initial scaling factor (Figure A1.2) to multiply with total finance flows to each sector to obtain an estimate of nature-negative finance flows by sector.

[29] Production processes are the level at which links with the environment are assessed in ENCORE. Production processes are different to activities in that one process can be applied to multiple industries while activities are industry-specific.

Figure A1.2. Share of production processes with high or very high impact on nature by sector



Step 2b: Activity-level tagging

In an alternative approach, all industry activities (636 activities) were reviewed and activities with a direct negative impact on nature were tagged as nature-negative based on literature and expert insights.

Step 3: Aggregation

Private nature-negative finance flows across sub-industries and activities tagged as nature-negative were aggregated.

The two approaches used in step 2 produced similar results. The main differences arise in specific industries. The activity level approach is better able to filter out activities with no direct impact on nature within certain industries that have a high impact on nature. This produced lower estimates of nature-negative finance flows for real estate (US$170 billion lower) and fishing and farming (40 per cent lower). Moreover, the limited number of processes identified for each subindustry in ENCORE results in the tagging of some large industries as 100 per cent nature-negative e.g. construction and engineering (an industry of the industrials sector). We will continue to explore how to improve the measurement of nature-negative impacts and finance flows in future editions.

A1.3. Public finance flow to nature-based solutions

The study estimates public finance flows to NbS using the latest data available on actual and expected disbursement. SFN 2023 aggregates public finance flows from domestic government expenditure and Official Development Assistance (ODA) data from sources listed in Table A1.1. If 2022 data is not available the most recent data is annualised and average annual disbursement is estimated. For all countries, data used is actual expenditure and excludes pledged or budgeted funding.

Domestic government expenditure

Public funding for NbS from governments and public financial institutions is estimated based on domestic expenditure across five government budget lines of the OECD's Classification of the Functions of Government (COFOG).

Domestic government expenditure was collated for over 60 countries and five sectors, which represent 76 per cent of global GDP. The OECD COFOG was used to gather second-level domestic expenditure of government functions in 2022.[30] IMF's Government Finance Statistics (GFS) was the primary data source for non-OECD government expenditure (IMF 2021; OECD 2023b). Data sources are listed in Table A1.1.

Official Development Assistance (ODA)

ODA data 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 Development Assistance Committee (DAC). The data is from 2021, available for 16 sectors and covers 138 recipient countries.

[30] The Classification of Functions of Government (COFOG) data sets provide first- and second-level data 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.

Table A1.1. Public NbS finance flows – description of data used

Public finance flow	Source	Description	Year in SFN 2021	Year in SFN 2022	Year in SFN 2023	Sector	Sub-sector
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 for which the funds are used.	2018	2019	2021	04: Economic Affairs 05: Environmental Protection	0402: Agriculture, forestry, fishing and hunting 0502: Waste water management 0503: Pollution abatement 0504: Protection of biodiversity and landscape 0506: Environnemental protection not elsewhere classified
	IMF Classification of COFOG		2016	2017	2021		
	China's National Accounts	The statistical yearbooks report annual government spending across 3 budget functions. This is mapped to COFOG categories.	N/A	N/A	2022		
	US National Accounts	Database of government spending across budget functions	2020	2021	2022	Agriculture Natural Resources and Environment	Agriculture Water resources Pollution control and abatement Conservation, land management and other natural resource spending Recreation resources
	FAO/UNDP/UNEP	Estimates of agricultural subsidies i.e. price incentives, output/input subsidies and subsidies on factors of production	N/A	N/A	2021		
	Agricultural Policy Monitoring and Evaluation	Estimates of agricultural support across sectors and countries	N/A	N/A	2021		
	Fossil Fuel Subsidies, OECD and IEA	Database provides data on fossil fuel support to end-user by country and by fuel	N/A	N/A	2021		
	SubsidyExplore.org (Environmental Markets Lab 2018) compiles data from three sources Sumaila *et al*. (2019) estimates global fisheries subsidies OECD Fisheries Support Estimate (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. Research and development in fisheries: Including monitoring, control, surveillance programs, stock assessment and resource surveys, fishery habitat and stock enhancement programs.	N/A	N/A	2018		
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 CRS database.	N/A	2019	2023	140: Water Supply and Sanitation 311: Agriculture 312: Forestry 401: General Environmental Protection	14010: Water sector policy and administrative management 14015: Water resources conservation (including data collection) 14040: River basins development 31110: Agricultural policy and administrative management 31120: Agricultural development 31130: Agricultural land resources 31140: Agricultural water resources 31192: Plant and post-harvest protection and pest control 31210: Forestry policy and administrative management 31220: Forestry development 31261: Fuelwood/charcoal 31281: Forestry education/training 31282: Forestry services 32162: Forest industries 31291: Forestry services

As there is no global database that tracks public NbS expenditure, the analysis uses scaling factors with sectoral guidance from the OECD. Scaling factors represent the share of activities within a COFOG and ODA sector which can confidently be identified as NbS. Scaling factors for COFOG and ODA sub-sectors are summarised in Table A1.2 and A1.3.

Table A1.2. Scaling factors used to adjust domestic sectoral expenditure to NbS

COFOG sub-sector	Scaling factor	Source
0402: Sustainable agriculture, forestry and fishing	0.1	The Nature Conservancy 2020
0502: Waste water management	0.1	UN Water 2015
0503: Pollution abatement	0.2	The Nature Conservancy 2020
0504: Protection of biodiversity and landscape	0.9	UNDP 2016
0506: Environmental policy and other	0.2	The Nature Conservancy 2020

Table A1.3. Scaling factors to identify NbS in ODA budgets

ODA sub-sector	Scaling factor	Source
31110: Agricultural policy and administrative management 31120: Agricultural development 31130: Agricultural land resources 31140: Agricultural water resources 31210: Forestry policy and administrative management 31220: Forestry development 32162: Forest industries	0.3	FAO 2018a The Nature Conservancy 2023 Expert consultation
14010: Water sector policy and administrative management 14015: Water resources conservation (including data collection) 14040: River basins development	0.2	FAO 2018b UN Water 2015
41020: Biosphere protection 41030: Biodiversity 41040: Site preservation	0.6	The Biodiversity Finance Initiative (BIOFIN) 2016
41010: Environmental policy and administrative management 41081: Environmental education/training 41082: Environmental research	0.6	FAO 2020

A1.4. Private finance flow to nature-based solutions

Sources of data on private finance flows are listed below. New data has been included when available to broaden the scope (see Table A1.4).

- Carbon markets: private finance flows via carbon markets use 2021 data from Ecosystems Marketplace (2022), which tracks carbon offset transactions in voluntary carbon markets across different projects, such as forestry, renewable energy and waste disposal. A lower bound estimate is calculated for voluntary carbon market transactions of forestry, land use and agriculture projects, while an upper bound includes value of forestry, land use, agriculture and waste disposal projects.

- Sustainable supply chains: SFN 2023 makes the assumption that 1-1.5% of the certified commodity market is assumed to be invested in biodiversity-related NbS (Deutz *et al*. 2020) based on findings from the forestry sector. Included in the estimation are seven types of certified product supply chains: forestry products, palm oil, organic agricultural goods, seafood, soy, coffee and cocoa. Estimates of certified forestry products, palm oil, and seafood were extrapolated from data used in SFN 2022 as updated data was not available. Estimation of soy, coffee and cocoa was based on updated sources (annual reports 2022 from Rainforest Alliance and RTRS, market statistics on global production volumes). A new approach was used to estimate finance flows to certified organic agricultural goods, which replaced BIOFIN (2020) estimates (used for SFN 2021 and 2022) with organic market size (Statista 2022) to avoid double counting.

- Biodiversity offsets : this category refers to finance flows to programmes intended to compensate for unavoidable impacts of development projects after prevention and mitigation measures have taken place. This analysis projects 2016 values from Bennett *et al*. (2017) using two different compound annual growth rates (CAGR). A lower bound applies six per cent annual growth, starting at US$2.6 billion in 2016. An upper bound applies 13 per cent annual growth (based on Facts and Factors' market research on the global mitigation market) starting at US$7.3 billion (Bennett *et al*. 2017; Facts and Factors 2022).

- Biodiversity Credits: this category refers to investment in programmes intended to increase biodiversity levels (net gain). Biodiversity credits were not included in previous editions. Only a few credit schemes are in place in 2022. A Terrasos estimate is used as a lower bound. An upper bound is based on the higher BloombergNEF estimate (Carbon Pulse 2023).

- Impact investing: this category includes private or public equity and debt investments intended to generate positive, measurable ESG impact alongside a financial return. Sources include State for Private Investment in Conservation (SOPIC) report (2016 extrapolated to 2022), Global Impact Investing Network (GIIN) survey (2020), Impact yield (2023), Funds for Nature (2023), Capital for Climate (2023). A lower estimate is from SFN 2022 but extrapolated to 2023. The upper bound uses the amount invested from the GIIN survey and the upper limit of percentage of the Assets Under Management (AUM) reported for 92 funds in funds for nature, capital for climate and impact yield.

- Philanthropy: Data is sourced from OECD CRS up to 2021 (includes Bezos Earth Fund) (OECD 2023a). Upper limit: Disbursements tagged to biodiversity plus biosphere protection. Lower limit: Disbursements tagged to biodiversity only.

- Conservation non-governmental organisations (NGOs): Data is sourced from annual expenditure reported by the largest conservation NGOs, including Conservation International and affiliates, Royal Society for the Protection of Birds (RSPB), The Nature Conservancy, Wildlife Conservation Society (WCS), and World Wildlife Fund (WWF). Any funding received from public institutions and philanthropy is excluded to avoid double counting.

- Payments for ecosystem services (PES): voluntary finance flows between ecosystem service users and providers conditional on agreed rules of resource management for generating ecosystem services (Wunder 2015). Data is obtained from the OECD: Tracking Economic Instruments and Finance for Biodiversity study which captures PES based on a survey conducted in late 2020 including 153 PES programmes in 37 countries (OECD 2021). To estimate the share of private payments, we calculated the market value share of PES mechanisms that are user-financed and compliance-financed based on data from 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 mobilised by official development finance interventions: Data is sourced from OECD, including CRS private finance mobilization from all donors (including multilateral agencies such as Global Environment Facility [GEF], Green Climate Fund [GCF] and the World Bank) tagged to General Environmental Protection sector. Upper limit: total mobilised to General Environmental Protection. Lower limit: only climate finance mobilised to General Environmental Protection.[31]

- Farmer's investments into conservation agriculture: this element is new. Farmer's investments into conservation agriculture are estimated bottom-up with a three-step methodology: Step 1. Calculate growth in hectares under conservation agriculture per year, Step 2. Multiply with upper and lower bound average capex per hectare for conservation agriculture, Step 3. Multiply calculated total investment from step 2 with the share of total agricultural investment from farmer's retained profits. The share used is 37 per cent, taken from Planet Tracker analysis (Kassam *et al*. 2019).

[31] Since private finance mobilised 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), this analysis estimates the average share of sustainable ocean economy ODA relative to ocean economy ODA between 2010 and 2019, equal to 34%, 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 10%.

Table A1.4. Private NbS finance flows data description

Private finance flow	Source	Description	Year in SFN 2021	Year in SFN 2022	Year in SFN 2023
Carbon markets	Ecosystems Market Place 2022	Transactions from voluntary carbon markets and investments in Reducing Emissions from Deforestation and forest Degradation (REDD+) programmes	2019	2020	2021
Sustainable supply chains	Certified forestry products: (i) OECD (2020a): A comprehensive overview of global biodiversity finance (ii) Breukink *et al*. 2015 Certified Palm oil: 2019 Global Market Report: Palm Oil (Voora *et al*. 2019) Certified agricultural goods: BIOFIN 2020 Certified seafood: (i) FAO 2018b and (ii) De Jong 2019 RTRS certified soy: Solidaridad Network 2020. Certified coffee: Rainforest Alliance 2022b. Certified cocoa: Rainforest Alliance 2022a.	Investments into biodiversity conservation from sustainable-certified commodity markets The estimates follow the approach outlined in Deutz *et al*. (2020) where 1-1.5% 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	a) 2015 b) 2019 c) 2019 d) 2018 e) 2021 f) 2021 g) 2021
Biodiversity offsets	Bennett *et al*. 2017 – survey of 99 regulatory biodiversity offsetting programmes in 33 countries. Facts and Factors 2022 - Global mitigation banking market is likely to grow at a CAGR value of 13.10% by 2028.	Investment in programmes intended to compensate for unavoidable impacts of development projects	2016	2016	2016, projected to 2022
Biodiversity credits	Bloomberg NEF 2023 World Economic Forum (WEF) 2022	Investment in programmes intended to increase biodiversity levels (net gain)	N/A	N/A	2022
Impact investing	State of Private Investment in Conservation (SOPIC) 2016 GIIN survey 2020 Impact yield 2020 ImpactAssets 50 (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 16% of AUM is annual invested in NbS	2019	2020	2022
Conservation NGOs	Annual reports of: Conservation International RSBP The Nature Conservancy WCS WWF	Expenditure reported by the largest conservation NGOs	2020	2021	2022
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) Bennett and Ruef (2016) include PES for water quality trading and offsets and watershed services.	Voluntary finance flows between service users and service providers conditional on agreed rules of resource management for generating offsite services (Wunder 2015)	2015	2018	2018
Philanthropy	OECD CRS 2021 Bezos Earth fund 2020 OECD 2020b Fundingtheocean.org 2020 Our Shared Seas 2021	Finance flows reported by philanthropic foundations	2017	2020	2021
Private finance leveraged by multilateral organisations	OECD 2018 GEF 2017 GCF 2020 OECD 2020b	Private finance leveraged by development finance institutions, development banks, other development agencies and two multilateral climate and biodiversity funds. The OECD 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 multilateral development banks (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	2021
Farmer's investments into conservation agriculture	Kassam *et al*. 2019 Elwin *et al*. 2023	Farmers' management decisions, such as to invest into conservation agriculture, have positive impacts on nature.	N/A	N/A	2019

The key assumptions made to estimate private finance flows to NbS are summarised in Table A1.5.

Table A1.5. Private NbS finance flows assumptions

Description	Assumption	Source
Private financial flows		
Impact investments: average capital invested in relation to the AUM	16.8%	Deutz *et al.* (2020) report
Impact investments: share of annual investment actually spent on biodiversity conservation (for those funds indicated in the Paulson Institute report)	5%	Deutz *et al.* (2020) report
Amount re-invested into biodiversity from sustainable supply chains (lower bound)	1.0%	Deutz *et al.* (2020) report
Amount re-invested into biodiversity from sustainable supply chains (upper bound)	1.5%	Deutz *et al.* (2020) report
Upper bound share of sustainable ocean economy flows relative to ocean economy flows for private finance	34%	Share of sustainable ocean economy flows relative to ocean economy flows for ODA
Lower bound share of sustainable ocean economy flows relative to ocean economy flows for private finance	10%	Expert consultation
Impact investments: share of annual investment of marine funds actually spent on biodiversity conservation	6%	In line with GIIN data

A1.5. Future nature-based solutions investment needs

To estimate future investment needs, SFN 2023 relies on modelling using Model of Agricultural Production and its Impact on the Environment (MAgPIE), a global land use allocation model designed to explore land competition dynamics in the context of carbon policy as well as off-model analysis.[32]

[32] MAgPIE v4.1 was used to model majority of the future NbS financial flows for Rio-aligned scenario. However, the latest version, MAgPIE v4.3, was used to model peatland restoration (Humpenöder *et al.* 2020). v4.5 was used to model FPS scenario.

Step 1: Define model assumptions

Two scenarios with different assumptions were developed.

Policy scenario assumptions

Assumptions were defined for policy scenarios, including a carbon price trajectory aligned with a 1.5°C climate outcome, and land policy that meets post-2020 global biodiversity framework targets. Detailed modelling assumptions and sources are listed in Table A1.6 and A1.7.

Table A1.6. **Rio-aligned and Forecast Policy Trajectory scenario descriptions**

	Rio-aligned	**Forecast Policy Trajectory**
Narrative	Key Rio Conventions targets are met, limiting climate change to 1.5°C, halting biodiversity loss and achieving land degradation neutrality.	Key Rio Convention targets are not fully achieved. Policy action is based on national and international commitments, market trends and probability of policy implementation.
Source	Scenario created by SFN 2022 using the MAgPIE land use model and additional analysis drawing on academic literature on NbS technical potential.	UN PRI Inevitable Policy Response – Forecast Policy Scenario + Nature. This scenario was also developed using MAgPIE combined with additional analysis.
Key assumptions / outcomes	• All countries meet GBF protected areas 30x30 target • 2nd generation bioenergy demand increases to 18 EJ/year by 2050. • 13% of global land area under restoration by 2050	• Countries fall short of GBF protected area target - only 20% of land is protected by 2030. • 2nd generation bioenergy demand increases to 90 EJ/year by 2050. • 6% of global land area under restoration by 2050

Table A1.7. Scenario modelling assumptions

Variable	Description	Source (Rio-aligned)	Rio-aligned Scenario	FPS+nature scenario[1]	Baseline scenario
1. Greenhouse gas (GHG) price trajectory	Defines global price trajectories for CO_2, N_2O, CH_4.	International Institute for Applied Systems Analysis (IIASA) Database and Postdam Institute for Climate Impact Research (PIK) integrated assessment modelling exercise	Shared Socioeconomic Pathways (SSP) 2 Representative Concentration Pathway (RCP) 2.6 consistent trajectory with carbon prices phasing-in globally in 2020	Implicit carbon prices proxy for a range of policies/regulations targeting a reduction in land use emissions, average at $54/t$CO_2$ in 2030 and $105/t$CO_2$ in 2050	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	2nd generation bioenergy demand increases to 18 EJ/year by 2050. SSP2 RCP2.6 consistent trajectory.	Bioenergy production aligned with national renewable energy regulations and strategies and Net Zero targets, 17EJ in 2030, 90EJ in 2050 (all 2nd generation bioenergy by 2050)	SSP2 National Policies Implemented (NPi) consistent trajectory
4.Population	Sets trajectories based on SSPs	SSP database	SSP2 – 'Middle of the road' consistent pathways	SSP2 – 'Middle of the road' consistent pathways	SSP2 – 'Middle of the road' consistent pathways
5.GDP	Sets trajectories based on SSPs	SSP database	SSP2 – 'Middle of the road' consistent pathways	SSP2 – 'Middle of the road' consistent pathways	SSP2 – 'Middle of the road' consistent pathways
6.Protected areas	Defines trajectory of area under protection as per WDPA categories plus all proposed areas and key biodiversity hotspots	UNCBD - Global Biodiversity Framework (GBF) target	All countries meet GBF protected areas 30x30 target	Protected areas expand to 20% of global terrestrial land by 2030 and 24% by 2050	no change from current levels
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.* n.d. Whitton *et al.* 2021	25% reduction in ruminant meat share of diet by 2050.	Per capita global ruminant meat consumption falls by 20% by 2050 Ruminant meat production stabilises at 37 megatons of dry matter per year in 2050 (decrease by 4% compared to 2020)	Ruminant meat share remains constant.

Note: 1. This list is not exhaustive and derived from the FPS+nature scenario overview (UN Principles for Responsible Investment [PRI] 2023b). The FPS+nature scenario results from the combination of a set of levers which includes FPS energy-related policy levers, land related policy levers and includes additional assumptions on nature markets: (i) increasing biodiversity credit prices, (ii) soil nitrogen uptake efficiency increases to 65 per cent in 2050, (iii) food waste falls globally by 23 per cent between 2020 and 2050 (UNPRI 2023a).

Scope of nature-based solutions

16 NbS were selected based on their mitigation potential and data availability and quality (Figure A1.3). The different types of NbS included are described in Table A1.8. Investment needs for these NbS is estimated from the present to 2050 through land use modelling and additional off-model analysis based on academic literature.

Figure A1.3. NbS included in investment needs analysis

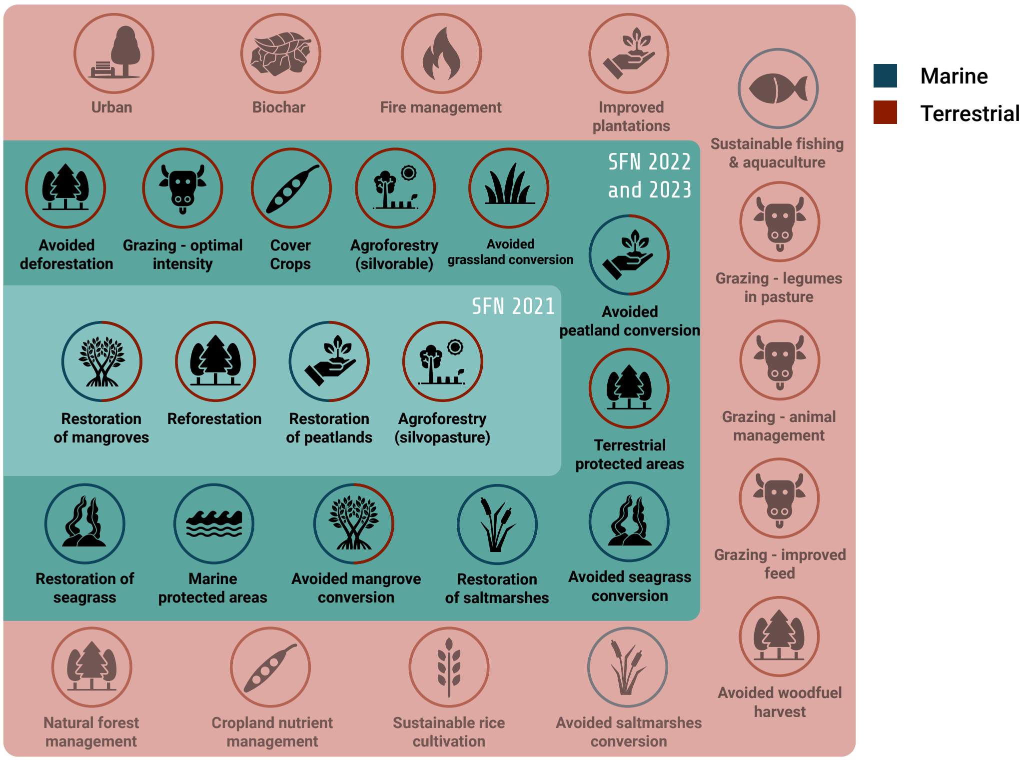


Table A1.8. NbS types and definitions

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 included silvoarable agroforestry, which is the planting of trees in croplands. Following Wilkinson *et al*. (2020), two silvoarable types are considered: tree intercropping and multistrata agroforestry. SFN2023 continues the 2022 categorisation.
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 by Tyukavina *et al*. (2012).
Avoided grassland conversion	Avoided conversion of temperate grasslands, tropical savannas and shrublands; the focus is placed on the conversion of grasslands to croplands.
Avoided mangrove conversion	Avoided conversion, destruction or degradation of global mangrove forests.
Avoided seagrass conversion	Avoided conversion, destruction or degradation of global seagrass.
Avoided peatland conversion	Avoided conversion, destruction or degradation of global peatlands.
Protected area	Area closures that can help reduce conversion and degradation of marine and terrestrial ecosystems, including deforestation and forest degradation.

Regional analysis

SFN 2023 and MAgPIE's modelling results are presented by region based on aggregation countries and areas based on the following list.

Oceania: Australia; Heard Island and McDonald Islands; New Zealand;

North America: Canada; Saint Pierre and Miquelon; United States of America;

Latin America: Aruba; Anguilla; Argentina; Antarctica; Antigua and Barbuda; Bonaire, Sint Eustatius and Saba; Bahamas ; Saint Barthélemy; Belize; Bermuda; Bolivia; Brazil; Barbados; Bouvet Island; Chile; Colombia; Costa Rica; Cuba; Curaçao; Cayman Islands; Dominica; Dominican Republic; Ecuador; Falkland Islands; Guadeloupe; Grenada; Guatemala; French Guiana; Guyana; Honduras; Haiti; Jamaica; Saint Kitts and Nevis; Saint Lucia; Saint Martin (French part); Mexico; Montserrat; Martinique; Nicaragua; Panama; Peru; Puerto Rico; Paraguay; South Georgia and the South Sandwich Islands; El Salvador; Suriname; Sint Maarten (Dutch part); Turks and Caicos Islands; Trinidad and Tobago; Uruguay; Saint Vincent and the Grenadines; Venezuela (Bolivarian Republic of); Virgin Islands (British); Virgin Islands (U.S.);

Europe: Åland Islands; Albania; Andorra; Austria; Belgium; Bulgaria; Bosnia and Herzegovina; Switzerland; Cyprus; Czechia; Germany; Denmark; Spain; Estonia; Finland; France; Faroe Islands; United Kingdom of Great Britain and Northern Ireland; Guernsey; Gibraltar; Greece; Greenland; Croatia; Hungary; Isle of Man; Ireland; Iceland; Italy; Jersey; Liechtenstein; Lithuania; Luxembourg; Latvia; Monaco; North Macedonia; Malta; Montenegro; Netherlands; Norway; Poland; Portugal; Romania; Svalbard and Jan Mayen; San Marino; Serbia; Slovakia; Slovenia; Sweden; Turkey; Holy See;

Africa: Angola; Burundi; Benin; Burkina Faso; Botswana; Central African Republic; Côte d'Ivoire; Cameroon; Democratic Republic of the Congo; Congo; Comoros; Cabo Verde; Djibouti; Eritrea; Ethiopia; Gabon; Ghana; Guinea; Gambia; Guinea-Bissau; Equatorial Guinea; Kenya; Liberia; Lesotho; Madagascar; Mali; Mozambique; Mauritania; Mauritius; Malawi; Mayotte; Namibia; Niger; Nigeria; Réunion; Rwanda; Senegal; Saint Helena, Ascension and Tristan da Cunha; Sierra Leone; Somalia; South Sudan; Sao Tome and Principe; Eswatini; Seychelles; Chad; Togo; Tanzania, the United Republic of; Uganda; South Africa; Zambia; Zimbabwe;

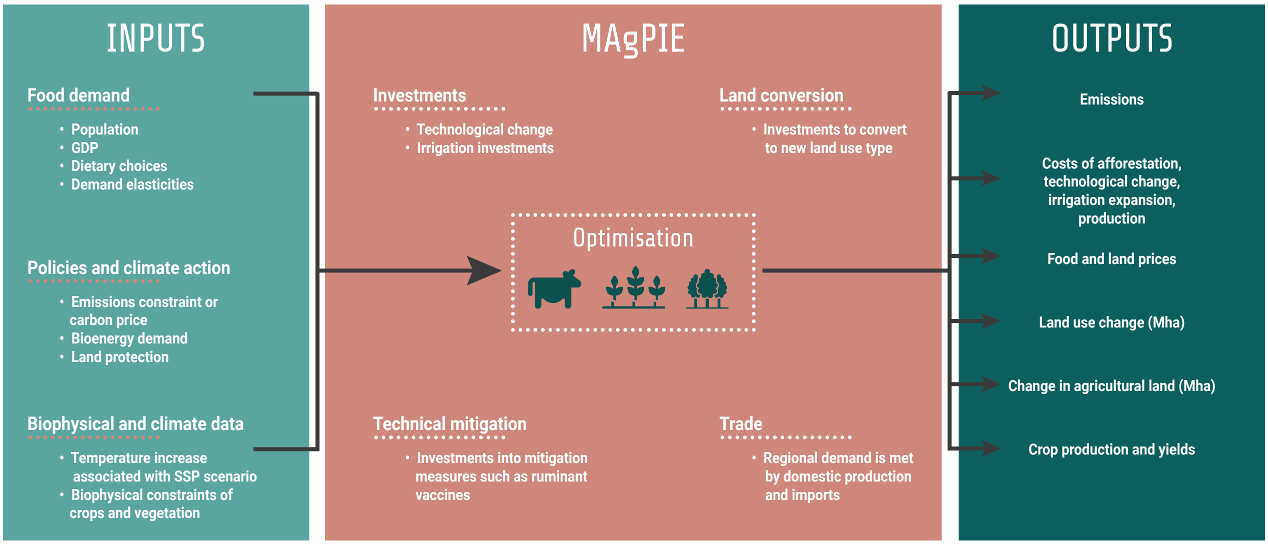
Asia: Afghanistan; American Samoa; French Southern Territories; Bangladesh; Brunei Darussalam; Bhutan; Cocos (Keeling) Islands; China; Cook Islands; Christmas Island; Fiji; Micronesia (Federated States of); Guam; Hong Kong; Indonesia; India; British Indian Ocean Territory; Japan; Cambodia; Kiribati; Republic of Korea; Lao People's Democratic Republic; Sri Lanka; Macao; Maldives; Marshall Islands; Myanmar; Northern Mariana Islands; Malaysia; New Caledonia; Norfolk Island; Niue; Nepal; Nauru; Pakistan; Pitcairn; Philippines; Palau; Papua New Guinea; Democratic People's Republic of Korea; French Polynesia; Singapore; Solomon Islands; Thailand; Tokelau; Timor-Leste; Tonga; Tuvalu; Taiwan; United States Minor Outlying Islands; Viet Nam; Vanuatu; Wallis and Futuna; Samoa;

Middle East and Reforming Economies: United Arab Emirates; Armenia; Azerbaijan; Bahrain; Belarus; Algeria; Egypt; Western Sahara, Georgia; Iran (Islamic Republic of); Iraq; Israel; Jordan; Kazakhstan; Kyrgyzstan; Kuwait; Lebanon; Libya; Morocco; Republic of Moldova; Mongolia; Oman; Palestine, State of; Qatar; Russian Federation; Saudi Arabia; Sudan; Syrian Arab Republic; Tajikistan; Turkmenistan; Tunisia; Ukraine; Uzbekistan; Yemen.

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

MAgPIE 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

Figure A1.4. MAgPIE: structure of the optimisation process



MAgPIE's modelling outputs were adjusted to 2023 USD prices and aggregated with off-model analysis to estimate annual investment needed between 2023 and 2050.

The Rio-aligned scenario is compared with a business as usual (BAU) scenario which assumes no increase in finance flows to NbS over time. The difference in costs between the modelled scenario and the BAU scenario represents the additional investment needed to achieve climate, biodiversity and land targets, such that for each time period, t:

$$\text{Investment Needs}_t = \text{Costs}_{t,\ \text{Rio-aligned or forecasted policy Scenario}} - \text{Costs}_{t,\ \text{BAU Scenario}}$$

In MAgPIE, land is a limited resource which is allocated to either agricultural production (food, feed and other materials) or carbon sequestration. This allocation process minimises costs incurred by the land use system to meet 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 reflects 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, demand will grow, 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 protected areas to include biodiversity hotspots as well as setting aside land to meet Nationally Determined Contributions (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 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.

Step 3: Use model outputs to conduct investment needs analysis

The model accounts for all costs in the land use sector. The analysis differentiates between direct and indirect costs of climate action. Direct costs include costs related to GHG emissions and mitigation actions. Indirect costs include investment and recurring costs in the agricultural sector, which are likely to increase with policy ambition. The difference across scenarios is driven by the additional pressure on land use systems by climate action. To reach climate, biodiversity and land degradation 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 the production process. For example, to increase their crop yields firms will have to invest capital to acquire innovative machinery or develop new production systems and spend more on skilled labour.

Table A1.9. Costs estimated in MAgPIE

Category	List of costs	Description
Indirect costs	1. 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	Includes Research and Development, adoption and irrigation expansion
Indirect costs	3. Costs of processing, transport and trade	Includes all downstream costs to consumer
Indirect costs	4. Cost of land conversion	Including land clearing and 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, the analysis focuses on differences in indirect costs of policy action. Focussing on this category of cost allows estimation of investment in NbS needed to meet climate, biodiversity and land degradation targets.

Total investment needs between 2023 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:

$$\text{Total investment needs}_{2023-2050} = \sum_{t=2023}^{2050} \Delta\,\text{Costs}_t = \sum_{t=2023}^{2050} \text{Costs}_{t,\ \text{Rio/Policy-Aligned Scenario}} - \text{Costs}_{t,\ \text{BAU Scenario}}$$

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

This section provides an overview of the analysis of investment needs for NbS that are not covered in the model. As MAgPIE focuses on forests and innovation in the agricultural sector, modelled results are integrated with off-model analysis to complement the estimation of future NbS finance flow needs:

- Identify feasible area for mangrove, seagrass, saltmarsh, grassland, wetland and peatland restoration and protection.
- Estimate direct costs of sustainable land management of agroforestry, cover crops, grazing optimal intensity.
- Gather annual capital investment and operating costs to deploy NbS across regions.
- Combine cost in 2023 prices and feasible area data (constrained by relevant MAgPIE variables where possible) to calculate the sum of capital investment and the cumulative operations expenditure between the initial investment period and 2050.

The 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 (2022) ensure that solutions with high climate mitigation potential are included. 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 modelled results are excluded. Only those marine NbS with established 'blue carbon' revenue generating potential and scientifically verifiable levels of carbon abatement are included.[33] This analysis excludes emerging and nascent solutions, e.g. kelp forests and seaweed farming. It also excludes oyster and coral reefs.[34]

See Table A1.10 for a description of the off-model methodology and assumptions used to calculate investment needs for each NbS and Table A1.11 for a list of data sources employed.

[33] Blue Carbon: The Potential of Coastal and Oceanic Climate Action (Mckinsey 2022)
[34] Coral reef restoration is not included due to ambiguity around its carbon sink properties.

Table A1.10. **Investment needs analysis and approach outside MAgPIE**

NbS	Approach
Avoided peatland conversion and restoration of peatlands	Area of land use change is taken from Humpenöder *et al*. (2020). An upper bound aligned with the 1.5°C target uses estimates of land available for rewetting that are not constrained by socioeconomic factors based on Griscom *et al*. (2017) and Wilkinson *et al*. (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 estimates from Griscom *et al*. (2017), Roe *et al*. (2021) and Wilkinson *et al*. (2020). This is extended to an upper bound by using Griscom's figure for technical potential. Costs are taken from World Economic Forum's Nature Net Zero (WEF 2021).
Avoided grassland conversion	Based on the historical rate of conversion of natural grasslands to cropland from 1980 to 1990. Costs are taken from Vivid Economics analysis.
Avoided mangrove conversion and restoration of mangroves	Based primarily on Mckinsey (2022), Worthington and Spalding (2018) and Griscom *et al*. (2020).
Avoided conversion and restoration of seagrass and saltmarsh	**Restoration** Following Macreadie *et al*. (2021), the upper bound for land suitable for mangrove restoration is set at 0.812Mha. This is less than ten percent of the total land available (9-11Mha). Mckinsey (2022) estimates that the feasible land for restoration, given biophysical and socioeconomic constraints, is 0.6Mha. Roe *et al*. (2021) estimates that only 0.2Mha is 'practically' available at a cost-effective level. This is set as the 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 5.5Mha, respectively. We set lower bounds at a similar ratio to that for mangroves to capture the uncertainty in feasibility once biophysical and socio-economic constraints are introduced, that is at 0.65 and 0.3Mha respectively. Costs for marine restoration are taken from Bayraktarov *et al*. (2016). **Avoided conversion of seagrass and saltmarshes** Area of projected land use change is based on historical rates, following Griscom *et al*. (2017). Costs are from Vivid Economics analysis.

Table A1.11. Off modelling analysis data sources

NbS type	Source
Agroforestry - Silvoarable (tree intercropping)	Wilkinson *et al.* 2020
Agroforestry - Silvoarable (multistrata agroforestry)	
Agroforestry - Silvopasture	
Agroforestry - Silvoarable	Griscom *et al.* 2020
Agroforestry - Silvoarable and silvopasture	Roe *et al.* 2021
Cover crops	Wilkinson *et al.* 2020 Griscom *et al.* 2020 WEF 2021
Optimal managed grazing	Wilkinson *et al.* 2020 Griscom *et al.* 2020 Wilkinson *et al.* 2020 Laporte *et al.* 2021
Peatland restoration	Humpenöder *et al.* 2021 Wilkinson *et al.* 2020 Griscom *et al.* 2020 Roe *et al.* 2021 Defra, Glenk 2018, Moxey and Moran 2014
Avoided peatland degradation	Humpenöder *et al.* 2021 Griscom *et al.* 2020 Roe *et al.* 2021 NOAA 2020, DEFRA Financial Intervention Model
Avoided grassland conversion	Griscom *et al.* 2017 Climate Trust 2014, Baker *et al.* 2020, ICF International 2013
Mangrove restoration	Worthington and Spalding 2018 Saintilan *et al.* 2020 Griscom *et al.* 2017 Mckinsey 2022 Roe *et al.* 2021 Bayraktarov 2020 Earth Security 2020 Taillardat 2021 Bayraktarov *et al.* 2015, WEF 2021, Kapos *et al.* 2019, Gilman *et al.* 2007
Seagrass meadows restoration	Griscom *et al.* 2017 Mckinsey 2022 Bayraktarov *et al.* 2020 Bayraktarov *et al.* 2015, Fonseca and Koehl 2006, Fonseca *et al.* 1998, Tan *et al.* 2020
Saltmarsh restoration	Griscom *et al.* 2017 Mckinsey 2022 Bayraktarov 2016
Avoided mangrove conversion	Griscom *et al.* 2017 McKinsey 2022 Roe *et al.* 2021 WEF 2021, Caldeira 2012, Aerts *et al.* 2018
Avoided seagrass meadows conversion	McKinsey 2022 Stowers *et al.* 2003
Avoided saltmarsh conversion	Griscom *et al.* 2017

A2. Physical benefits

Investing in NbS is estimated to have significant benefits through GHG removals and the protection of biodiversity.

A2.1. Greenhouse gases removals

For forestry NbS, emissions benefits were taken from MAgPIE using the Dasgupta 'Immediate Action' scenario (Dasgupta 2021). To estimate the emissions benefit associated with additional investment in NbS, this analysis uses peer-reviewed sequestration rates – weighted according to region – and applies them to modelled land use change between 2023 and 2050, assuming linear growth in most cases. GHG removals from protected areas are not included as there are possibilities of overlap with capture from other NbS (especially protection and restoration NbS), and there is also high uncertainty due to the variable ecosystems covered by protected areas. For avoided deforestation, emissions were calculated relative to business-as-usual scenarios.

Table A2.1. GHG abatement potential by NbS

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
	WEF 2021		0.3	
Agroforestry - Silvoarable and silvopasture	Girardin *et al*. 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
	Girardin *et al*. 2021			0.37
	WEF 2021		0.45	
Optimal managed grazing	Wilkinson *et al*. 2020	0.6	0.7	
	Griscom *et al*. 2017			0.3
	Girardin *et al*. 2021			0.22
Peatland restoration	Humpenöder *et al*. 2021		1.0	
	Wilkinson *et al*. 2020			
	Girardin *et al*. 2021			0.39
	Griscom *et al*. 2017			0.82
	Roe *et al*. 2021			0.6
	WEF 2021		1.0	
Avoided peatland conversion	Humpenöder *et al*. 2021		0.9	
	Girardin *et al*. 2021			0.68
	Griscom *et al*. 2017			0.75
	Roe *et al*. 2021			0.2
	WEF 2021		0.9	
Avoided grassland conversion	Griscom *et al*. 2017			0.12
	Girardin *et al*. 2021			0.04
Mangrove restoration	Worthington *et al*. 2018			
	Griscom *et al*. 2017			0.6
	Mckinsey 2022	23.5		0.6
	Roe *et al*. 2021			0.006
	Hoegh-Guldberg and Bruno 2010			0.16-0.25
Seagrass meadows restoration	Griscom *et al*. 2017			0.21
	Mckinsey 2022	12.5		0.21
	Hoegh-Guldberg and Bruno 2010			0.03-0.05
Salt-marshes restoration	Griscom *et al*. 2017			0.036
	Mckinsey 2022			0.03-0.04
	Hoegh-Guldberg and Bruno 2010			0.01-0.03

Avoided mangrove conversion	Griscom *et al*. 2017			0.13
	McKinsey 2022	42.9		0.13
	Roe *et al*. 2021			0.065
	Hoegh-Guldberg and Bruno 2010			0.02-0.04
Avoided seagrass meadows conversion	Griscom *et al*. 2017			0.13
	McKinsey 2022	17.4		0.16
	Hoegh-Guldberg and Bruno 2010			0.19-0.65
Avoided saltmarshes conversion	Griscom *et al*. 2017	143		0.42
	McKinsey 2022			0.04-0.06
	Hoegh-Guldberg and Bruno 2010			0.04-0.07

A2.2. 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 (Dasgupta 2021).

References for Technical Annex

Aerts, J.C.J.H. (2018). A review of cost estimates for flood adaptation. *Water* 10(11), 1646. https://www.mdpi.com/2073-4441/10/11/1646.

Baker, J.S., Proville, J., Latane, A., Cajka, J., Aramayo-Lipa, L. and Parkhurst, R. (2020). Additionality and avoiding grassland conversion in the Prairie pothole region of the United States. *Rangeland Ecology & Management* 73(2), 201-215.

Bayraktarov, E., Saunders, M.I., Abdullah, S., Mills, M., Beher, J., Possingham, H.P. *et al*. (2015). The cost and feasibility of marine coastal restoration. *Ecological Society of America* 26(4), 1055-1074.

Bennett, G., Gallant, M. and Ten Kate, K. (2017). *State of Biodiversity Mitigation 2017: Markets and Compensation for Global Infrastructure Development*. http://www.forest-trends.org/wpcontent/uploads/2018/01/doc_5707.pdf.

Bezos Earth Fund (2023). Conserving and restoring nature. https://www.bezosearthfund.org/our-programs/conserving-restoring-nature. Accessed 15 June 2023.

BloombergNEF (2023). $1 trillion to protect biodiversity is cheaper than the cost of inaction, 5 April. https://about.bnef.com/blog/1-trillion-to-protect-biodiversity-is-cheaper-than-the-cost-of-inaction/. Accessed on 30 October 2023.

Bodirsky, B.L., Dietrich, J.P., Martinelli, E., Stenstad, A., Pradhan, P., Rolinski, S. *et al*. (no date). *From Starved to Stuffed: Long-Term Dynamics of Diets and Anthropometrics*.

Caldeira, K. (2012). Avoiding mangrove destruction by avoiding Carbon Dioxide emissions. *Biological Sciences* 109(36), 14287-14288.

Capital for Climate (2023). Nature-based solutions investment. Exemplar funds and vehicles. https://nbs.capitalforclimate.com/fundsandvehicles. Accessed 13 June 2023.

Carbon Pulse (2023). Forecasters see rapidly growing biodiversity market as nature crisis forces response, 10 January. https://carbon-pulse.com/186974. Accessed 01 June 2023.

Climate Policy Initiative (2021). *Global Landscape of Climate Finance 2021*. https://www.climatepolicyinitiative.org/wp-content/uploads/2021/10/Full-report-Global-Landscape-of-Climate-Finance-2021.pdf.

Conservation International and Affiliates (2022). *Conservation International and Affiliates Annual report*. https://www.conservation.org/about/annual-report. Accessed 01 June 2023.

Dasgupta, P. (2021). *The Economics of Biodiversity: The Dasgupta Review*. London.

De Jong, B. (2019). *World Seafood Map 2019: Value Growth in the Global Seafood Trade Continues*. April. https://research.rabobank.com/far/en/documents/175201_1966414_rabobank_value-growth-global-seafood-trade_beyhan_may2019.pdf.

Deutz, A., Heal, G. M., Niu, R., Swanson, E., Townshend, T., Zhu, L. *et al*. (2020). *Financing Nature: Closing the global biodiversity financing gap*. The Paulson Institute, The Nature Conservancy, and the Cornell Atkinson Centre for Sustainability. https://www.paulsoninstitute.org/wp-content/uploads/2020/10/ FINANCING-NATURE_Full-Report_Final-with-endorsements_101420.pdf. doi: 10.3389/fcosc.2020.615419.

Earth Security (2020). *Financing the Earth's Assets: The Case for Mangroves*. 7 December. https://www.earthsecurity.org/reports/financing-the-earths-assets-the-case-for-mangroves.

Ecosystem Marketplace (2022). *State of the Voluntary Carbon Markets 2021*. https://www.ecosystemmarketplace.com/publications/state-of-the-voluntary-carbon-markets-2022.

Elwin P., Amadi E., Mitchell E. and Hunter P. (2023). *Financial Markets Roadmap for Transforming the Global Food System, Planet Track*er. March 2023. https://planet-tracker.org/wp-content/uploads/2023/03/Financial-Markets-Roadmap-for-transforming-the-Global-Food-System.pdf.

Environmental Markets Lab (2018). Subsidy Explorer. http://www.subsidyexplorer.org/. Accessed 01 June 2023.

Facts and Factors (2022). Global mitigation banking market is likely to grow at a CAGR value of 13.10% by 2028, 9 August. https://www.fnfresearch.com/news/global-mitigation-banking-market. Accessed 21 September 2023.

Fonseca, M.S. and Koehl, M.A.R. (2006). Flow in seagrass canopies: The influence of patch width. *Estuarine, Coastal and Shelf Science* 67 (1-2), 1-9. https://www.sciencedirect.com/science/article/pii/S0272771405003252.

Fonseca, M.S., Kenworthy, W.J. and Thayer, G.W. (1998). *Guidelines for the Conservation and Restoration of Seagrasses in the United States and Adjacent Waters*. United States of America, National Oceanic and Atmospheric Administration.

Food and Agriculture Organisation (2018a). *The State of the World's Forest 2018- Forest pathways to sustainable development*. Rome. https://www.fao.org/3/i9535en/i9535en.pdf.

Food and Agriculture Organisation (2018b). *The State of World Fisheries and Aquaculture 2018 - Meeting the Sustainable Development Goals*. Rome. http://www.fao.org/documents/card/en/ c/I9540EN/.

Food and Agriculture Organisation (2020). FRA 2020 remote sensing survey. https://www.fao.org/forest-resources-assessment/remote-sensing/fra-2020-remote-sensing-survey/en/. Accessed 19 September 2023.

Food and Agriculture Organisation (2021). *Nature-Based Solutions in Agriculture Sustainable Management and Conservation of Land, Water, and Biodiversity*. Rome. https://www.fao.org/3/cb3140en/cb3140en.pdf.

Funding the Ocean (2020). Funding the ocean. https://fundingtheocean.org/. Accessed 01 June 2023.

Garardin, C.A.J., Jekins, S., Seddon, N., Allen, M., Lewis, S.L., Wheeler, C.E. *et al*. (2021). Nature-based solutions can help cool the planet — if we act now. *Nature* 593, 191-194.

Gilman, E., Ellison, J., Sauni, I. and Tuaumu, S. (2007). Trends in surface elevations of American Samoa mangroves. *Wetlands Ecology and Management,* 15, 391-404.

Glenk, K. and Martin-Ortega, J. (2012). The economics of peatland restoration. *Journal of Environmental Economics and Policy* 7(4), 345-362. https://www.tandfonline.com/doi/full/10.1080/21606544.2018.1434562.

Global Impact Investing Network (2020). *Annual Impact Investor Survey 2020*. https://thegiin.org/assets/GIIN%20Annual%20Impact%20Investor%20Survey%202020.pdf.

Griscom, B.W., Adams, J., Ellis, P.W., Houghton, R.A., Lomax, G., Miteva, D.A. *et al*. (2017). Natural climate solutions. *Proceedings of the National Academy of Sciences* 114, 11645-11650. https://www.pnas.org/doi/abs/10.1073/pnas.1710465114.

Hamrick, K. (2017). *State of Private Investment in Conservation 2016: A Landscape Assessment of an Emerging Market*. Ecosystems Marketplace, A Forest Trends Initiative. https://www. forest-trends.org/publications/state-of-private-investment-in-conservation-2016/.

Henderson, B.B., Gerber, P.J., Hilinski, T.E., Falcucci, A., Ojima, D.S., Salvatore, M. *et al*. (2015). Greenhouse Gas mitigation potential of the world's grazing lands: Modeling soil carbon and nitrogen fluxes of mitigation practices. *Agriculture, Ecosystems & Environment* 207, 91-100. 1 September. https://www.sciencedirect.com/science/article/abs/pii/S0167880915001139.

Hoegh-Guldberg, O. and Bruno J.F. (2010). The impact of climate change on the world's marine ecosystems. *Science* 328(5985), 1523-1528. https://www.science.org/doi/abs/10.1126/science.1189930.

Humpenöder, F., Karstens, K., Lotze-Campen, H., Leifeld, J., Menichetti, L., Barthelmes, A. *et al*. (2020). Peatland protection and restoration are key for climate change mitigation. *Environmental Research Letters* 15, 10. https://iopscience.iop.org/article/10.1088/1748-9326/abae2a/pdf.

ICF International (2013). *Greenhouse Gas Mitigation Options and Costs for Agricultural Land and Animal Production within the United States*. https://www.usda.gov/sites/default/files/documents/GHG_Mitigation_Options.pdf.

Impact Assets (2023). IA50 Database. https://impactassets.org/ia-50/. Accessed 13 June 2023.

Impact Yield (2023). Impact Investing Database. https://impactyield.com/impact-investing-search. Accessed 13 June 2023.

International Energy Agency (2023). Fossil Fuel Consumption Subsidies. https://www.iea.org/reports/fossil-fuels-consumption-subsidies-2022. Accessed 22 June 2023.

International Monetary Fund (2021). Government Finance Statistics. Functional Expenditures (COFOG). https://data.imf.org/regular.aspx?key=61037799. Accessed 25 May 2023.

Kapos, V., Wicander, S., Salvaterra, T., Dawkins, K. and Hicks, C. (2019). *The Role of the Natural Environment in Adaptation: Background Paper for the Global Commission on Adaptation*. https://gca.org/wp-content/uploads/2020/12/RoleofNaturalEnvironmentinAdaptation_V2.pdf?_gl=1*1lhxkl6*_ga*MjA3NzQyNjY2OC4xNjk4NzY0OTA3*_up*MQ.

Kassam, A., Friedrich T. and Derpsch, R. (2019). Global spread of Conservation Agriculture. *International Journal of Environmental Studies* 76(1), 29-51. https://www.tandfonline.com/doi/epdf/10.1080/00207233.2018.1494927?needAccess=true.

Koplow, D. and Steenblik, R. (2022). *Protecting Nature by Reforming Environmentally Harmful Subsidies: The Role of Business*. https://www.earthtrack.net/document/protecting-nature-reforming-environmentally-harmful-subsidies-role-business.

Laporte, T., Jutel, V. and Leenknegt, V. (2021). La mise en défens ou comment gérer les pressions de pâturage. https://cen-nouvelle-aquitaine.org/wp-content/uploads/2021/06/FicheTechnique_CATZH64_N%c2%b05_generalites_V4.pdf. Accessed on 31 October 2023.

Macreadie, P.I., Costa, M.D.P., Atwood, T.B., Friess, D.A., Kelleway, J.J., Kennedy, H. *et al*. (2021). Blue carbon as a natural climate solution. *Nature Reviews Earth & Environment* 2, 826-839.

Mckinsey (2022). *Blue Carbon: The Potential of Coastal and Oceanic Climate Action*. https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/blue%20carbon%20the%20potential%20of%20coastal%20and%20oceanic%20climate%20action/blue-carbon-the-potential-of-coastal-and-oceanic-climate-action-vf.pdf?shouldIndex=false.

Moxey, A. and Moran, D. (2014). UK peatland restoration: Some economic arithmetic. *Science of the Total Environment* 484, 114-120. https://www.sciencedirect.com/science/article/pii/S0048969714003635.

Naphade, A. (2020). Sustainable palm oil market analysis with key players, applications, trends and forecasts to 2026. http://news.marketsizeforecasters.com/sustainable-palm-oil-market-analysis-with-key-players-applications-trends-and-forecasts-to-2026. Accessed 22 June 2023.

Organisation for Economic Co-operation and Development (2019). Fisheries Support Estimates Database. https://impactyield.com/impact-investing-search. Accessed 13 June 2023.

Organisation for Economic Co-operation and Development (2020a). *A Comprehensive Overview of Global Biodiversity Finance*. https://www.oecd.org/environment/resources/biodiversity/report-a-comprehensive-overview-of-global-biodiversity-finance.pdf.

Organisation for Economic Cooperation and Development (2020b). *Reframing Financing and Investment for a Sustainable Ocean Economy*. https://www.oecd-ilibrary.org/environment/reframing-financing-and-investment-for-a-sustainable-ocean-economy_c59ce972-en.

Organisation for Economic Co-operation and Development (2021). *Tracking Economic Instruments and Finance for Biodiversity 2021*. https://www.oecd.org/environment/resources/biodiversity/tracking-economic-instruments-and-finance-for-biodiversity-2021.pdf.

Organisation for Economic Co-operation and Development (2022). *Agricultural Policy Monitoring and Evaluation 2022: Reforming Agricultural Policies for Climate Change Mitigation*. https://www.oecd.org/publications/agricultural-policy-monitoring-and-evaluation-22217371.htm.

Organisation for Economic Co-operation and Development (2023a). Creditor Reporting System (CRS). Official Development Assistance. https://stats.oecd.org/index.aspx?DataSetCode=CRS1. Accessed 25 May 2023.

Organisation for Economic Co-operation and Development (2023b). Government Expenditure by Function (COFOG). https://stats.oecd.org/Index.aspx?DataSetCode=SNA_TABLE11. Accessed 25 May 2023.

Our Shared Seas (2021). *A Decade of Ocean funding: Landscape Trends 2010-2020*. https://oursharedseas.com/funding/.

Partnership for Forests (2023). Funds for Nature Investor Database. https://partnershipsforforests.com/fundsfornature/. Accessed 25 May 2023.

Rainforest Alliance (2022a). *Cocoa Certification Data Report 2021*. https://www.rainforest-alliance.org/wp-content/uploads/2022/05/Cocoa-Certification-Data-Report-2021.pdf.

Rainforest Alliance (2022b). *Coffee Certification Data Report 2021*. https://www.rainforest-alliance.org/wp-content/uploads/2022/05/Coffee-Certification-Data-Report-2021.pdf.

Roe, S., Streck, C., Beach, R., Busch, J., Chapman, M., Daioglou, V. *et al*. (2021). Land-based measures to mitigate climate change: Potential and feasibility by country. *Global Change Biology* 27, 6025–6058. https://doi.org/10.1111/gcb.15873.

Roundtable for Responsible Soy (2022). *Management Report 2021*. https://issuu.com/rtrs/docs/rtrs_management_report_2021.

Royal Society for the Protection of Birds (2023). *Annual Report 2022-2023: Together, We're Creating a World where Wildlife and People can Thrive*.

Saintilan, N., Khan, N.S., Ashe, E., Kelleway, J.J., Rogers, K., Woodroffe, C.D. *et al*. (2020). Thresholds of mangrove survival under rapid sea level rise. Science 364(6495), 1118-1121. https://www.science.org/doi/full/10.1126/science.aba2656.

Salzman, J., Bennett, G., Carroll, N., Goldstein, A. and Jenkins, M. (2018). The global status and trends of Payments for Ecosystem Services. *Nature Sustainability* 1, 136-144.

Schuhbauer, A., Chuenpagdee, R., Cheung, W.W.L., Greer, K. and Sumaila, U.R. (2017). How subsidies affect the economic viability of small-scale fisheries. *Marine Policy* 82, 114-121.

Skerritt, D. and Sumaila, R. (2021). Broadening the global debate on harmful fisheries subsidies through the use of subsidy intensity metrics. *Marine Policy* 128, 104507. 10.1016/j.marpol.2021.104507.

Solidaridad Network (2019). *Responsible Soy – 10 Years on*. https://www.solidaridadnetwork.org/news/responsible-soy-10-years-on.

Statista (2022). Global organic food market value in 2021 and 2026. https://www.statista.com/statistics/869052/global-organic-food-and-beverage-market-value/. Accessed 01 July 2023.

Stowers, J.F., Fehrmann, E. and Squires, A. (2003). *Seagrass Scarring in Tampa Bay: Impact Analysis*. https://studylib.net/doc/13358208/seagrass-restoration--success--failure--and-the-costs-of-.

Sumaila, R., Skerritt, D., Schuhbauer, A., Ebrahim, N., Li, Y., Kim, H.S. *et al*. (2019). Updated estimates and analysis of global fisheries subsidies. *Marine Policy* 109. https://www.sciencedirect.com/science/article/pii/S0308597X19303677.

Taillardat, P., Fong, L., Sasmito, S.D., Ren, J., Tarigan, S., Lupascu, M. *et al.* (2021). *From Peatlands to the Coast: Organic Carbon Cycling and Associated Greenhouse Gas Emissions across the Aquatic Continuum in Southeast Asia.*

The Biodiversity Finance Initiative (2016). *BIOFIN Workbook – Mobilizing Resources for Biodiversity and Sustainable Development*. https://www.biofin.org/sites/default/files/content/publications/undp-biofin-web_0.pdf.

The Biodiversity Finance Initiative (2020). *Moving Mountains - Unlocking Private Capital for Biodiversity and Ecosystems.* https://www.biofin.org/sites/default/files/content/publications/BIOFIN%20-%20Moving%20Mountains%20-%20Unlocking%20private%20capital%20for%20biodiversity%20and%20ecosystems%20%28Web%20Version%29.pdf.

The Climate Trust (2014). *Evaluation of Avoided Grassland Conversion and Cropland Conversion to Grassland as Potential Carbon Offset Project Types*. https://climatetrust.org/wp-content/uploads/2014/07/Evaluation-of-Avoided-Grassland-Conversion-and-Cropland-Conversion-to-Grassland-as-Potential-Carbon-Offset-Project-Types-.pdf.

The Nature Conservancy (2023). *2022 Annual Report, Progress for the planet*. https://www.nature.org/content/dam/tnc/nature/en/documents/TNC_AR_2022.pdf.

Tyukavina, A., Potapov, P. and Hansen, M.C. (2012). *Assessment of Recently Unchanged Forested Areas in the United States Using Landsat-WELD and LIDAR Data*.

United Nations Environment Programme (2021). *Nature-Based Solutions for Climate Change Mitigation.* 4 November. https://www.unep.org/resources/report/nature-based-solutions-climate-change-mitigation.

United Nations Environment Programme, United Nations Development Porgramme and Food and Agriculture Organisation (2021). *A Multi-Billion-Dollar Opportunity: Repurposing Agricultural Support to Transform Food Systems*. https://www.unep.org/resources/repurposing-agricultural-support-transform-food-systems.

United Nations Principles for Responsible Investment (2023a). IPR Forecast Policy Scenario + nature. https://www.unpri.org/inevitable-policy-response/ipr-forecast-policy-scenario--nature/10966.article. Accessed 31 October 2023.

United Nations Principles for Responsible Investment (2023b). IPR: Forecast Policy Scenario + nature (FPS + nature) - Preparing financial markets for climate- & nature-related policy & regulatory risks. https://www.unpri.org/download?ac=17705. Accessed 31 October 2023.

United Nations Water (2015). *A 10 Year Story – The Water for Life Decade 2005-2015 and Beyond.* https://www.un.org/waterforlifedecade/pdf/WaterforLifeENG.pdf.

United States of America, National Oceanic and Atmospheric Administration (2020). *Nature-Based Solutions: Installation and maintenance Costs*. https://coast.noaa.gov/data/digitalcoast/pdf/nature-based-solutions-installation-maintenance.pdf.

Voora, V., Larrea, C., Bermudez, S. and Balino, S. (2019). *Global Market Report: Palm Oil*. https://www.iisd.org/system/files/publications/ssi-global-market-report-palm-oil.pdf.

Whitton, C., Bogueva, D., Marinova, D. and Phillips, C.C. (2021). Are we approaching peak meat consumption? Analysis of meat consumption from 2000 to 2019 in 35 countries and its relationship to Gross Domestic Product. *Animals* 11(12), 3466.

Wildlife Conservation Society (2023). *2022 Impact Report*. https://cdn.wcs.org/2022/10/03/79thlo8qoi_WCS_Impact_Report_2022_fnl_linked_WEB.pdf?_gl=1*1o3wycp*_ga*MTY1NzQ3MTgzNS4xNjg0NzY5Njkz*_ga_BTX9HXMYSX*MTY4NDc2OTY5My4xLjAuMTY4NDc2OTY5My42MC4wLjA.

Wilkinson, K. (ed.) (2020). *The Drawdown Review. Climate Solutions for a New Decade*. Project Drawdown. https://drawdown.org/drawdownframework/drawdown-review-2020.

World Economic Forum (2021). *Nature and Net Zero*. https://www3.weforum.org/docs/WEF_Consultation_Nature_and_Net_Zero_2021.pdf.

World Economic Forum (2022). *Biodiversity Credits: Unlocking Financial Markets for Nature-Positive Outcomes.* https://www3.weforum.org/docs/WEF_Biodiversity_Credit_Market_2022.pdf.

World Wildlife Fund (2015). *Profitability and Sustainability in Responsible Forestry. Economic Impacts of FSC Certification on Forest Operators*. https://d2ouvy59p0dg6k.cloudfront.net/downloads/profitability_and_sustainability_in_responsible_forestry_main_report_final.pdf.

World Wildlife Fund (2022). *Annual Report and Financial Statements 2021-22*. https://www.wwf.org.uk/sites/default/files/2022-12/WWF-UK-Annual-Report-and Financial-Statements-2021-22.pdf.

Worthington, T. and Spalding, M. (2018). *Mangrove Restoration Potential: A Global Map Highlighting a Critical Opportunity*. https://api.repository.cam.ac.uk/server/api/core/bitstreams/a48758ae-9956-4c5f-96ba-d20d5c1e183e/content.

Wunder, S. (2015). Revisiting the concept of payments for environmental services. *Ecological Economics* 117, 234-243. https://www.sciencedirect.com/science/article/pii/S0921800914002961.