ANNEX I AND II

# MAKING THE CASE FOR CLIMATE AND NATURE RESILIENCE INVESTMENTS: THE NEED TO REVISE GROWTH AND DEBT SUSTAINABILITY FRAMEWORKS

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# ANNEX I: LIMITATIONS OF ANALYSIS

## Complexity of climate and nature risk and adaptation modelling

- Climate and nature risk modelling involves significant uncertainties, especially for projections extending beyond 2030. This uncertainty stems from the complex interplay of various factors, including economic growth, technological advancements, and policy decisions, which are challenging to predict accurately over extended periods. Consequently, existing literature presents a wide range of cost estimates for future climate impacts and adaptation needs.[1]

## Sources and methodological divergence.

- Investment estimates are derived from the following primary sources (IMF, 2024; UNEP, 2023; Waldron et al. (2022a); Waldron et al. (2022b) and UNEP (2022)), each applying different methodologies across sectors.
- Sector-specific approaches also vary within a single source. For example, IMF (2024) estimates health adaptation costs as additional spending required by benchmarking countries against 'high-performing peers,' while education costs are calculated as the total expense of retrofitting infrastructure. These differences may limit the comparability of estimates across sectors.
- Comparability of results is further limited as certain estimates focus solely on retrofitting new infrastructure (e.g., UNEP, 2023 for energy and transport), while others, such as IMF (2024) for education, include retrofitting both new and existing infrastructure. Details on methodologies, assumptions, and specific limitations are provided in the Appendix.

## Simplified assumptions

- Modeling climate and nature risks, as well as adaptation interventions and macro-fiscal impacts, can rely on making simplified assumptions. For example, agricultural adaptation costs in this assessment (UNEP, 2023) assume a direct causal relationship between increased research and development spending and productivity, based on generalized assumptions about technology adoption and crop yields. While these assumptions offer a directionally accurate foundation for estimating the costs of resilience interventions, they are intended to guide strategic planning rather than provide precise figures. This reinforces the need for recalculating estimates at the country level using more detailed, project-specific data to ensure accuracy and relevance.

## Limited assessment of broader societal consequences of climate and nature risks and adaptation

- This report does not fully address the broader societal impacts of climate and nature risks or adaptation strategies, such as involuntary migration and social inequality, due to their complexity. However, the link between climate adaptation, social inequality, migration and other societal considerations is increasingly recognized, underscoring the importance of incorporating these considerations into comprehensive resilience plans.[2]
- Many adaptation policies would benefit from a greater emphasis on social equity, as climate change tends to impact the most vulnerable populations the hardest, deepening existing economic inequalities and driving more people into poverty. Research indicates that climate-related effects could push between 68 and 135 million people into poverty by 2030. To tackle these challenges, adaptation strategies must focus on protecting at-risk communities and implementing equitable measures that enhance resilience for those most affected by climate change[3,4]

[1]Global Change Research Program, Climate models, scenarios and projections, 2017.
[2]UNFCCC, Strengthening Capacities to Mainstream Human Mobility into National Adaptation Plans, 2024.
[3]IMF, Linking Climate and Inequality, 2021.
[4]World Bank, Global Action Urgently Needed to Halt Historic Threats to Poverty Reduction, 2020.

# ANNEX II: METHODOLOGY

## 1. HAZARDS

We developed an integrated climate and nature hazard framework, as climate and nature hazards are interrelated and mutually reinforcing (see Section 1). In the framework, we define a hazard as: the potential occurrence of a climate or nature related physical event or trend that may result in loss of life, injury, or other health impacts, as well as damage to property, infrastructure, livelihoods, essential services, ecosystems, and environmental resources. [5]

First, we reviewed existing frameworks to compile a **comprehensive list of climate and nature hazards**, streamlined to remove duplicates:

- Climate hazards – 2023 National Adaptation Plans Progress Publication (UNFCCC),[6] Climate Risk Landscape Report 2024 (UNEP),[7] Climate Change 2022: Impacts, Adaptation and Vulnerability (IPCC) and the European Environment Agency (2024) analysis of climate hazards.[8]
- Nature hazards – We define nature hazards as nature loss and degradation resulting in the loss of ecosystem services, in line with existing literature. We sourced ecosystem services from: Global Assessment Report on Biodiversity and Ecosystem Services 2019 (IPBES),[9] and Nature-related Financial Risks Framework (NGFS).[10]

Second. we **classified each hazard as a climate-hazard and/or a nature-hazard**, depending on their connection to climate change and/or nature loss. According to IPBES (2019),[11] nature loss is driven by five key factors: climate change, invasive species, land and sea use change, pollution, and resource exploitation.

- Climate hazard only – A hazard primarily driven by climate change.
- Nature hazard only – A hazard primarily driven by nature loss due to invasive species, land and sea use change, pollution, and resource exploitation (i.e. four of the five nature loss drivers, excluding climate change).
- Climate and nature hazard – A hazard driven by both climate change and nature loss due to at least one of the other four nature loss drivers (i.e. invasive species, land and sea use change, pollution, and resource exploitation).

**Table 1: Assumptions and definitions for climate and nature hazard framework**

| HAZARD | ASSUMPTION | DEFINITION | CLIMATE AND NATURE TAGGING |
|---|---|---|---|
| **Soil erosion and soil health decline** | Merged UNEP (2024)'s[12] 'soil erosion' with 'decline of soil quality' from IPBES (2019).[7] Assumed other | Accelerated removal of topsoil from the land surface through water, wind and tillage (FAO, | Directly caused by land use change and climate change[14] |

[5] Definition adapted from IPCC (2022) to include the impact of nature loss. IPCC (2022)
[6] UNFCCC (2023)
[7] UNEP (2024)
[8] European Environment Agency (2024)
[9] IPBES (2019)
[10] NGFS (2023)
[11] IPBES (2019)
[12] UNEP FI (2024)
[14] Eekhout & de Vente (2022)

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| | soil-related ecosystem service losses, e.g. formation and protection of soils', 'soil and sediment retention services' from IPBES (2019) [7] fall here. | 2020)[13] and reduced ability of the soil to sustain the productivity, diversity and environmental services of terrestrial ecosystems. | |
| **Pollution** | Created "pollution" to cover soil-related ecosystem service losses not covered by 'soil erosion and soil health decline', e.g. 'decontamination of soils', IPBES (2019). [7] | Contamination of the land surface and soil through the accumulation of solid waste, chemicals, heavy metals or other pollutants | Directly caused by land use change and climate change[15] |
| **Provisions decline (terrestrial)** | Created loss of provisioning ecosystem services based on 'provisioning services' as ecosystem category from IPBES (2019)[7], NGFS (2024)[8,] ENCORE (2024)[16] as 'provisions decline (terrestrial)'. | Decline of terrestrial provisioning ecosystem services, which include any type of material or energy outputs from an ecosystem | Key causes of decline of provisioning services include ecosystem modifications from human activities like agricultural expansion and urbanization (land use change)[17] |
| **Loss of pollination services** | Based on IPBES (2019)[7]: "pollination services" as ecosystem service | Pollination is the process in which pollen is taken from one plant or part of a plant to another so that new plant seeds can be produced | Key causes of wild pollinator loss include changes in land use, use of harmful pesticides and advancing climate change[18] |
| **Land use change** | Based on "land and forest degradation: from UNFCCC (2023)[19]" | Land use change refers to the "modification or management of natural environments into human dominated environments, such as settlements, semi-natural and agricultural areas" | Directly caused by both climate change and other drivers of nature loss (directly linked to land use change, one of the four direct drivers of nature loss besides climate change)[20] |
| **Residual loss of terrestrial, habitat and species** | Based on NGFS (2024)[21]'s ecosystem service: "habitat species and biodiversity intactness" as well as other ecosystem services highlighted by IBES (2019)[15], such as "habitat creation and maintenance". Separated into 'terrestrial' and 'marine' in the framework. | Residual loss of terrestrial and marine biological diversity, which is the variety of living things that inhabit the planet (incl. genetic, species and ecosystem levels) (UNDRR, 2024)[22] in a particular area, not covered by one of the other hazards. | Directly caused by both climate change and other drivers of nature loss. The main driver of biodiversity loss is land use change. In addition, climate change has altered marine, terrestrial and freshwater ecosystems around the world.[23] |
| **Sea use change** | Based on "land and forest degradation: from UNFCCC (2023)[24]", then extended this hazard to the ocean realm | Land use change refers to the "modification or management of natural environments into human dominated environments, such as settlements, semi-natural and | Directly caused by both climate change and other drivers of nature loss (directly linked to land use change, one of the four direct drivers of nature loss besides climate change)[26] |

[13] FAO (2020)
[15] Eekhout & de Vente (2022)
[16] ENCORE (2024)
[17] IPBES (2019); Kling et al. (2024)
[18] IPBES (2019); Brunet & Fragoso (2024)
[19] UNFCCC (2023)
[20] IPBES (2019); European Environment Agency (2025); U.S. Global Change Research Program (2018)
[21] NGFS (2024)
[22] UNDRR (2024)
[23] IPBES (2019); UN (2025)
[24] UNFCCC (2023)
[26] IPBES (2019); European Environment Agency (2025); U.S. Global Change Research Program (2018)

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| | | agricultural areas", whilst sea use change refers to "measures and activities altering the use of marine areas"[25] | |
| **Coastal erosion** | Taken from UNEP FI (2024)[27] | Physical reduction of land mass at the coast that results from the interfacing of marine, fluvial and landsliding[28] | Directly caused by both climate change and other drivers of nature loss (such as human activities like sand mining, development of coastal infrastructure)[29] |
| **Sea level rise** | Taken from UNEP FI (2024)[22] | Change to the height of sea level, both globally and locally at seasonal, annual, or longer time scales[30] | The primary cause of sea level rise is climate change[31] |
| **Decline of provisioning services (marine ecosystems)** | Created loss of provisioning ecosystem services based on 'provisioning services' as ecosystem category from IPBES (2019)[7], NGFS (2024)[8,] ENCORE (2024)[32] as 'provisions decline (marine)' | Decline of terrestrial provisioning ecosystem services, which include any type of material or energy outputs from an ecosystem | Key causes of decline of provisioning services include ecosystem modifications from human activities like agricultural expansion and urbanization (land use change)[33] |
| **Ocean acidification** | Taken from UNEP FI (2024)[34] | Reduction in the pH of the ocean over an extended period of time, caused primarily by uptake of CO2 from the atmosphere (National Ocean Service, 2024)[35] | Primary cause of ocean acidification is human-caused CO2[36] |
| **Residual loss of marine biodiversity, habitat and species** | Based on NGFS (2024)[37]'s ecosystem service: "habitat species and biodiversity intactness" as well as other ecosystem services highlighted by IBES (2019)[15], such as "habitat creation and maintenance". Separated into 'terrestrial' and 'marine' in the framework. | Residual loss of terrestrial and marine biological diversity, which is the variety of living things that inhabit the planet (incl. genetic, species and ecosystem levels) (UNDRR, 2024)[38] in a particular area, not covered by one of the other hazards. | Directly caused by both climate change and other drivers of nature loss. The main driver of biodiversity loss is land use change. In addition, climate change has altered marine, terrestrial and freshwater ecosystems around the world.[39] |
| **Reduced flood mitigation** | Based on ENCORE (2024) and TNFD (2023): "flood mitigation"[40] | Decline of flood mitigation ecosystem services, which refers to the natural capacity of ecosystems to decrease both severity and frequency of floods, for example through | Key ecosystems that can mitigate floodings include wetlands and forests and grasslands. For both, climate change and land use change are causing declining flood mitigating services[42] |

[25] IPBES (2024); CBD (2024)
[27] UNEP FI (2024)
[28] UNDRR (2024)
[29] NSW Government (2025); GCA (2022)
[30] UNDRR (2024)
[31] WEF (2024)
[32] ENCORE (2024)
[33] IPBES (2019); Kling et al. (2024)
[34] UNEP FI (2024)
[35] National Ocean Service (2024)
[36] UNH (2023)
[37] NGFS (2024)
[38] UNDRR (2024)
[39] IPBES (2019); UN (2025)
[40] ENCORE (2024)
[42] WWT (2024); Climate Council (2024)

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| | | regulating water flow and absorbing excess rainfall[41] | |
| **Water stress** | Taken from UNEP FI (2024)[27] | Demand for water exceeding the available amount during a certain period or when poor quality restricts its use (EEA, 2024)[43] | Directly caused by both climate change (temperature increase) and other drivers of nature loss (land use change through population and agricultural expansion) |
| **Water pollution and saline intrusion** | Taken from UNEP FI (2024)[27]: "saline intrusion" and "water pollution" as physical nature-related threat from WWF (2022)[44] | Presence in water of harmful and objectionable material in sufficient concentrations to make it unfit for use, including salt water (from the sea) flowing inland in freshwater aquifers (EEA, 2024)[33] | Directly caused by both climate change (temperature increases) and other drivers of nature loss (pollution)[45] |
| **Reduced regulation of water quantity and quality** | Based on IPBES (2019) ecosystem services: "regulation of freshwater quantity, location and timing" and "regulation freshwater and coastal water quality"[46] | Decline of water flow regulation and water purification ecosystem services[47] | Climate change and other drivers of nature loss (e.g. land use change, pollution) directly cause decline of water regulating services of ecosystems[48] |
| **Temperature increase and variability** | Merged UNEP FI (2024)'s 'changing temperature (air) / (freshwater) / (marine water) and 'temperature variability' into one hazard called: 'temperature increase and variability'[49] | Rise in average global temperatures due to climate change (Fiveable, 2024) and variations in mean state and other climate statistics (standard deviations) of temperature (FAO, 2024)[50] | Directly linked to changing climate[51] |
| **Changing wind patterns** | Taken from UNEP FI (2024)[42] | Changing consistent and predictable patterns of movement of air across Earth's surface (UGC Berkely, 2024)[52] | Directly linked to changing climate[44] |
| **Heat stress** | Taken from UNEP FI (2024)[42] | Perceived discomfort and physiological strain associated with exposure to a hot environment (Wills, 2014)[53] | Directly linked to changing climate and changes in land cover and management[54] |
| **Changing precipitation (patterns and types)** | Merged UNEP (2024)'s[42]: 'changing precipitation patterns and types (rain, hail, snow/ice)' and 'precipitation and/or hydrological variability' under a new category called "changing precipitation (patterns and types)" | Changes in distribution, frequency and intensity of rainfall and other forms of moisture in a given area over time (Five able, 2024)[55] | Directly linked to changing climate and land use change[56] |

[41] Vari et al. (2022)
[43] European Environment Agency (2024)
[44] WWF (2022)
[45] UN (2025); IPBES (2019)
[46] IPBES (2019)
[47] TNFD (2023)
[48] UNFCCC (2018); IPBES (2019)
[49] UNEP FI (2024)
[50] Fiveable (2024); FAO (2024)
[51] IPCC (2022); UNEP FI (2024)
[52] UGC Berkeley (2024)
[53] Wills (2014)
[54] IPCC (2022); Orlov et al. (2023)
[55] Fiveable (2024)
[56] IPCC (2022); Baudena et al. (2021)

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| **Air pollution** | Based on WWF (2022)'s "air pollution" as top-cited nature-related threat[57] | Contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere[58] | Directly caused by both climate change and other drivers of nature loss (direct pollution)[59] |
| **Disrupted regulation of climate, weather and air quality** | Merged "climate and weather regulation", "air quality regulation" and "climate regulation" from IPBES (2019)[60] | Decline of climate and weather regulating ecosystem services, which is the ecosystem service that regulates processes related to atmospheric chemical composition, the greenhouse effect, the ozone layer, precipitation, air quality and moderation of temperature and weather patterns[61] | Climate change and other drivers, such as land use change, are key causes of decline of peatlands, wetlands, soil, forests, oceans, which help regulate climate, weather and air quality[62] |
| **Reduced storm mitigation** | Based on ENCORE (2024) and TNFD (2023)[63] | Decline of storm mitigating ecosystem services, including mitigating the impacts of wind, sand and other storms on local communities through natural ecosystems[64] | Climate change and other drivers of nature loss (e.g. land use change, pollution) directly cause reduced storm mitigation from ecosystems like mangroves, coral reefs, salt marshes, seagrass beds[65] |
| **Residual acute and sudden onset terrestrial nature hazards'** | Based on WWF (2022); IPBES (2019); NGFS (2024) 'acute nature loss' categories[66] | Residual, short-term, specific events that change the state of terrestrial nature causing ecosystem services decline, not covered by the other hazards[67] | Acute terrestrial nature loss causing loss of ecosystem services, such as acute chemical accidents on land (pollution) or rapid, intensive clearing of forest (deforestation)[68] |
| **Mass movements** | Merged UNEP FI (2024)'s 'avalanche', 'subsidence' and 'landslide', under the term "mass movements"[69] | Category of hazards characterized by the horizontal or lateral movement of large quantities of physical matter[70] | Directly linked to climate change and land use change[71] |
| **Snow glacier and icesheet thawing** | Created new category called "snow glacier and icesheet thawing" that covers 'permafrost thawing' and 'glacial lake outburst' and 'solifuction'[59] | The removal of surface waste of snow or ice due to melting, evaporation, wind action, or other causes[72] | Directly linked to climate change[59] |
| **Wildfires** | Taken from UNEP FI (2024)[59] | Uncontrolled fire in wildland vegetation, often in rural areas[73] | Directly caused by both climate change (temperature increase) and other drivers of nature loss (land use change)[74] |

[57] WWF (2019)
[58] WHO (2024)
[59] EPA (2025); IPBES (2019)
[60] IPBES (2019)
[61] TNFD (2023); Zari (2017)
[62] IPBES (2019); European Commission (2016)
[63] ENCORE (2024); TNFD (2023)
[64] Encore (2024)
[65] IPBES (2019); IUCN (2024)
[66] NGFS (2024); IPBES (2019)
[67] Global Association of Risk Professionals (2024)
[68] IPBES (2019); NGFS (2024)
[69] UNEP FI (2024)
[70] Haddow et al. (2020)
[71] UNEP FI (2024); Dandrigde et al. (2022)
[72] Dartmouth (2024)
[73] National Geographic (2024)
[74] UNEP FI (2024); Kumar et al. (2022)

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| **Droughts** | Taken from UNFCCC (2023) as hazard addressed by countries' National Adaptation Plans, as well as European Environment Agency (2024).[75] | Deficiency of precipitation over an extended period of time, resulting in a water shortage[76] | Directly caused by both climate change (temperature increase) and other drivers of nature loss (land use change)[77] |
| **Residual acute marine nature degradation** | Based on WWF (2022); IPBES (2019); NGFS (2024) 'acute nature loss' categories[78] | Residual, short-term, specific events that change the state of marine nature causing ecosystem services decline, not covered by the other hazards[79] | Acute marine nature loss causing loss of ecosystem services, such as acute chemical accidents in the sea (pollution) |
| **Floods** | Merged UNEP (2024)'s 'flood (coastal) and 'flood groundwater' under "floods"[80] | Overflow of water that submerges land that is usually dry[81] | Directly caused by both climate change and other drivers of nature loss[82] |
| **Heatwave** | Taken from UNEP FI (2024)[68] | Period where local excess heat accumulates over a sequence of unusually hot days and nights[83] | The primary cause of increasing heatwaves is climate change. Urbanization and land use change also contributes to increasing heatwaves[84] |
| **Cold wave (frost)** | Taken from UNEP FI (2024)[68] | Period of marked and unusual cold weather characterized by a sharp and significant drop in air temperatures near the surface[85] | Directly caused by both climate change and other drivers of nature loss (changes in land use)[86] |
| **Storms** | Merged UNEP (2024)'s: 'cyclone, hurricanes, typhoons', 'storms (blizzards)', 'storms (dust)' and 'tornado' all under "storms"[68] | Disturbed state of Earth's atmosphere, which can manifest itself in temperature, humidity, pressure, wind velocity, cloud cover, lightning, and precipitation[87] | The primary cause of increasing extreme weather and storms is climate change, but this is reinforced by other drivers like land use change (deforestation)[88] |
| **Heavy precipitation (rain, hail, snow ice)** | Taken from UNEP FI (2024)[68] and UNFCCC (2023) 'heavy rainfall'[89] | Instances during which the amount of rain or snow experienced in a location substantially exceeds what is normal[90] | Directly caused by both climate change and other drivers of nature loss (changes in land use)[91] |

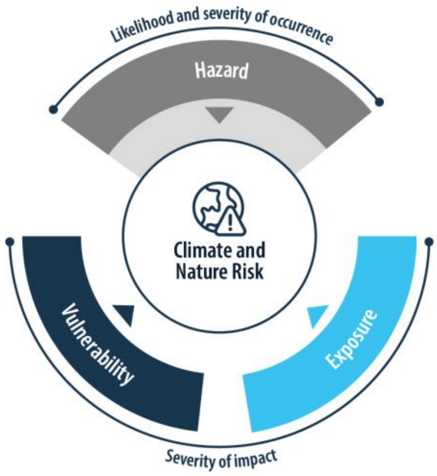
[75] UNFCCC (2023); European Environment Agency (2024)
[76] National Integrated Drought Information System (2024)
[77] UNEP FI (2024); NASA (2025)
[78] NGFS (2024); IPBES (2019)
[79] Global Association of Risk Professionals (2024)
[80] UNEP FI (2024)
[81] WHO (2024)
[82] UNEP FI (2024); UK Centre for Ecology & Hydrology (2022)
[83] WMO (2024)
[84] EPA (2025); Copernicus (2025)
[85] UNDRR (2024)
[86] UNEP FI (2024); Gogoi et al. (2019)
[87] Glossary of Meteorology (2024)
[88] UNEP FI (2024); Taylor et al. (2021)
[89] UNFCCC (2023)
[90] EPA (2024)
[91] UNEP FI (2024); Smith et al. (2023)

# 2. RISKS

We qualitatively outline how the climate and nature hazards we identify in Section 1 translate to physical climate and nature risks, without quantifying their potential scale or impact.[92]

We define **risk** as: the potential for adverse consequences from climate and nature hazards to affect human or ecological systems, recognizing the diversity of values and objectives associated with such systems.[93] According to the Intergovernmental Panel on Climate Change (IPCC), risk is determined by the interaction of three key factors: hazard, vulnerability and exposure.[94]

**Figure B: Risk as a Function of Hazard, Exposure and Vulnerability**




**Hazard**
The potential occurrence of climate or nature related physical events that may cause damage and loss.

**Exposure**
The presence of assets, services, resources and infrastructure that could be adversely affected by the hazard, e.g. people, ecosystems, infrastructure.

**Vulnerability**
The propensity or predisposition to be adversely affected by the hazard incl. sensitivity to harm and capacity to cope and adapt e.g. income level, floor height of buildings in a flood zone.

The risk posed by climate and nature hazards can vary depending on the human or ecological system being affected. We have chosen to examine the effect of climate and nature hazards on the following economic sectors: (i) agriculture and food security; (ii) health; (iii) water and sanitation; (iv) terrestrial biodiversity and ecosystems; (v) coastal systems and low-lying areas; (vi) infrastructure and built environment; (vii) fisheries, aquaculture and marine ecosystems; (viii) education; (ix) adaptation for business and industry; (x) cross-sectoral enablers.

For each sector, we identified:

- The key hazards which affect the sector
- The key risks the hazards pose to the sector

**Table 2: Key sector-specific hazards and risks**

| SECTOR | HAZARD | RISK | ASSUMPTIONS FOR SECTOR HAZARDS AND RISKS |
|---|---|---|---|
| **Agriculture and food security** | Temperature increase and variability, changing precipitation (patterns and types), heavy precipitation (rain, hail, snow-ice), | Changes in temperature, rainfall, soil erosion and soil health decline damage agricultural productivity and total food production | Based on EPA (2024)[95], UNEP (2023)[96]<br>Based on FAO (2024)[97] |

[92] We do not consider transition risks.
[93] Amended from IPCC (2022)
[94] IPCC (2022)
[95] EPA (2024)
[96] UNEP (2023)
[97] FAO (2024)

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| | droughts, soil erosion and soil health decline | Increases in temperature, less rainfall and droughts will contribute to higher water demand for crop production and natural vegetation | |
| **Health** | Temperature increase and variability, changing precipitation (patterns and types), heat waves, droughts, wildfires, storms (incl. tornados, cyclones, hurricanes, typhoons, air pollution) | Temperature increase and changing precipitation and air pollution contribute to increased malaria, dengue, diarrhea, heat-related mortality, asthma and cardiovascular diseases<br>Heatwaves, wildfires, droughts and storms pose direct health risks for people. | Based on UNEP (2023),[81] IMF (2024)[98] and Planetary Health Alliance (2024)[99] |
| | Floods, storms (incl. tornados, cyclones, hurricanes, typhoons) | Coastal floods and extreme weather contribute to damaged health infrastructure such as hospitals and drug stores | Based on UNEP (2023)[81] |
| | Cross-cutting | Cross-cutting | N/A |
| **Water & sanitation** | Floods, storms (incl. tornados, cyclones, hurricanes, typhoons) | Increased floods and wind damage can compromise WASH facilities, such as water sources and sanitation facilities | Based on IMF (2024)[100] |
| | Droughts, water stress, changing precipitation (patterns and types), sea level rise | Changing precipitation (patterns and types) and droughts contribute to changing water cycles and cause growing water stress. Sea level rise extends salinization of groundwater, reducing water availability | Based on UNICEF (2024) and IMF (2024)[101] |
| | Cross-cutting | Cross-cutting | N/A |
| | Temperature increase and variability, floods, droughts | Higher temperatures, floods and droughts exacerbate many forms of water pollution, affecting water quality | Based on UNICEF (2024)[102] |
| **Terrestrial biodiversity & ecosystems** | Land use change, decline of provisioning services from terrestrial ecosystems, loss of pollination services, residual loss of terrestrial biodiversity, habitat and species | Terrestrial biodiversity loss presents risks to people and global economic prosperity directly (e.g. loss of production and revenue in agriculture, forestry, fisheries) and indirectly (e.g. decline in overall productivity, ill health, increased climate change) | Based on Waldron et al. (2020)[103] |
| **Coastal systems & low-lying areas** | Sea level rise, floods, coastal erosion | Increasing coastal floods directly affect people (loss of lives, displacement) and assets (coastal infrastructure, settlements) | Based on Lincke & Hinkel (2018)[104] |

[98] IMF (2024)
[99] Planetary Health Alliance (2024)
[100] IMF (2024)
[101] IMF (2024); UNICEF (2024)
[102] UNICEF (2024)
[103] Waldron et al. (2020)
[104] Lincke & Hinkel (2018)

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| | Floods | Increasing river floods directly affect people (loss of lives) and assets (damage to infrastructure, food production) | Based on PLB (2018)[105] |
| **Infrastructure and built environment** | Sea level rise, changing precipitation (patterns and types), storms (incl. tornados, cyclones, hurricanes, typhoons), heat waves | Sea level rise, changes in precipitation, extreme weather, and heat pose risks to the transportation system (e.g. affecting highways, railways, bridges). Similarly, the energy system is affected by heat waves, severe droughts, sea level rise and storms (e.g. supply of oils, energy infrastructure) | Based on various sources, including US EPA (2024) and IEA (2024)[106] |
| **Fisheries, aquaculture and marine ecosystems** | Sea level rise, sea use change, ocean acidification, storms (incl. tornados, cyclones, hurricanes, typhoons), decline of provisioning services from marine ecosystems, residual loss of marine biodiversity, habitat and species | Sea level rise and storms are causing damage to critical fish habitat, and increasing ocean temperatures and acidification lead to loss of marine habitats and species<br>Marine biodiversity loss presents risks to people and global economic prosperity directly (e.g. loss of production and revenue in fisheries) and indirectly (e.g. increased climate change) | Based on FAO (2024)[107]<br>Based on MSC (2024)[108] |
| **Education** | Storms (incl. tornados, cyclones, hurricanes, typhoons) | Extreme weather damages education infrastructure, causes loss of education material and injury/mortality of students and teachers | Based on IMF (2024)[109] |
| **Adaptation for business & industry** | Land use change, sea use change, storms (incl. tornados, cyclones, hurricanes, typhoons), temperature increase and variability, heat waves | Higher temperatures and heat waves can change and reduce demand for tourism. Severe storms and extreme weather can disrupt transport, power and water supplies needed for tourism. Terrestrial and marine biodiversity loss can reduce ecotourism | Based on UNEP (2023) and WEF (2023)[110] |
| | Cross-cutting | Climate change and nature loss will cause risks in all business and industry dependent on subsector and location. Also, climate change and nature loss will cause shifts in demand for goods, services and trade | Based on UNEP (2023) and WEF (2023)[111] |

[105] PLB (2018)
[106] EPA (2024); IEA (2024)
[107] FAO (2024)
[108] MSC (2024)
[109] IMF (2024)
[110] UNEP (2023); WEF (2023)
[111] UNEP (2023); WEF (2023)

# 3. TYPE OF INTERVENTION

We identified four key types of interventions that can reduce climate and nature risks. Each intervention type includes several subcategories:

- **Infrastructure**
  Infrastructure investments specifically designed to safeguard infrastructure development from climate change and nature loss related risks.[112] These include grey, green, and hybrid (grey-green) infrastructure. Green infrastructure integrates ecosystems as a strategic alternative to traditional man-made solutions.[113]

  - **Retrofitting existing infrastructure.** This involves upgrading existing infrastructure – such as hospitals, schools, and roads – with additional measures to withstand climate and nature-related hazards (e.g. storms), which are becoming increasingly frequent and severe.
  - **Risk-proofing new infrastructure.** This means designing and constructing new infrastructure to withstand future risks. For example, ensuring new roads and bridges are built to endure projected climate hazards.
  - **Building protective infrastructure.** This includes building infrastructure specifically designed to safeguard communities and other critical infrastructure from climate and nature risks. Examples include constructing dikes and seawalls or restoring natural barriers like mangroves and wetlands to protect coastal and flood-prone critical infrastructure such as energy facilities and healthcare facilities.

- **Targeted Interventions**

  - **Direct, sector-specific action.** These are targeted interventions designed to address specific climate and nature risks within sectors. They are typically operating expenditures (OPEX) rather than capital expenditures (CAPEX). Examples include disease control programs or vaccine distribution.
  - **Ecosystem-based adaptation.** This approach refers to the use of ecosystem management activities to increase resilience and reduce vulnerability to climate change and nature loss. An example is agroforestry, which integrates trees and vegetation into farming systems to enhance soil health and protect crops from climate extremes.

- **Enablers**
  Enabling investments facilitate the effective implementation of resilience strategies by supporting and amplifying other resilience interventions. Three key categories of enablers were considered for this consultation paper:

  - **Governance and capacity-building.** Examples of this include building and strengthening (cross-sectoral) institutional frameworks, such as policies, regulations and governance structures.
  - **Decision-support tools and analytics.** Examples include data infrastructure, such as climate databases and early warning systems, which supports decision-making by providing reliable information for risk assessment, planning, and adaptive responses.

[112] We distinguish between intervention types which drive broader development and intervention types which /build resilience. See 4. Interventions.
[113] AIIB (2023)

- **Forward-planning & risk-spreading.** Examples include disaster risk management, integrating risk assessment, governance and financial mechanisms to proactively reduce vulnerabilities and increase resilience.

- **Insurance**
    - **Insurance solutions for residual risk.** Resilience investments cannot fully offset the impacts of climate and nature risks. Insurance plays a crucial role in managing these residual risks.
    - **Insurance as an enabler.** Insurance enables investments in climate and nature resilience by reducing financial risk for major investments like seawalls or bridges.

# 4. INTERVENTIONS

We identified interventions that can address the critical risks in each sector by reviewing the literature. By linking interventions to specific climate and nature risks, we identify interventions for resilience as distinct from interventions for development. The interventions we identify are ones required to ensure countries can meet development goals in a world of rising climate and nature risks. For example, "Resilient transport and energy infrastructure" refers to the additional reinforcements needed to ensure transport and energy infrastructure can withstand projected climate and nature hazards – it does not include the baseline infrastructure needed for development.[114]

**Table 3: Typology of resilience interventions**

| SECTOR | RISKS | INTERVENTION | ASSUMPTIONS AND SOURCE |
|---|---|---|---|
| **Agriculture and food security** | Changes in temperature, rainfall and soil erosion damage agricultural productivity and total food production | Resilient infrastructure along the value chain | Taken directly from UNEP (2023)[115] |
| | | Resilient agricultural production | Taken directly from UNEP (2023)[99] |
| | Increases in temperature, less rainfall and droughts will contribute to higher water demand for crop production and natural vegetation | Resilient water management and irrigation | Taken directly from UNEP (2023)[99] |
| | Cross-cutting | Agriculture adaptation R&D | Taken from ASAP project[116], covering: 'temperature regulation technology for livestock, remote sensing-based drought monitoring tool, crop data and analytics platform, climate monitoring and forecasting |
| | | Climate monitoring and forecasting for agrifood | Covering IPCC (2022)[117] interventions: agroforestry, improved cropland management, efficient livestock systems, and UNFCCC (2023)[118] intervention: develop climate-resilient agriculture for food, nutrition and livelihood security |
| **Health** | Temperature increase and changing precipitation contributing to increased malaria, dengue, diarrhea and heat-related mortality. | Disease detection, surveillance and control systems | Merged intervention from UNEP (2023) and IMF (2024)[119]and CPI (2024) |
| | | Vaccines, medical products and technology for climate-sensitive diseases | Based on CPI (2024); UNEP (2023); McKinsey (2024)[120] |

[114] The level of future infrastructure is determined by reference to development goals e.g. relevant Sustainable Development Goals.
[115] UNEP (2023)
[116] ASAP (2020)
[117] IPCC (2022); UNFCCC (2023)
[118] UNFCCC (2023)
[119] UNEP (2023); IMF (2024); CPI (2024)
[120] CPI (2024) Taxonomy; UNEP (2023); McKinsey (2024). Health-related climate adaptation: how to innovate and scale global action for local needs

| | | | |
|---|---|---|---|
| | Heatwaves, wildfires, droughts and storms pose direct health risks for people. | Heat mitigation and heat-alert schemes | Based on UNEP (2023) |
| | Increased temperature is associated with more non-communicable diseases such as asthma, whilst air pollution drives cardiovascular diseases and associated mortality. Increased exposure to extreme weather such as storms increases risk of mental disorders. | Health sector responses to respiratory health issues | Based on Planetary Health Alliance literature on air pollution and respiratory health[121] |
| | | Health sector response to malnutrition and exposure to hazards | Based on World Bank (2024) and WEF (2024)[122] |
| | | Targeted measures to improve mental and psychosocial health | Based on CPI (2024) and BCG analysis[123] |
| | Cross-cutting | Emergency health services | Based on UNEP (2023) and IMF (2024)[103] |
| | | Climate and nature-health information, surveillance and early warning systems | Based on McKinsey (2024)[124] |
| | | Health workforce training | Combined CPI (2024) and UNEP (2023)[125] |
| | Coastal floods and extreme weather contribute to damaged health infrastructure such as hospitals | Resilient health infrastructure (incl. building, equipment, IT) | Based on UNEP (2023) and IMF (2024)[103] |
| | | Resilient healthcare supply chains | Based on McKinsey (2024) [126] |
| **Water and sanitation** | Increased floods and wind damage can compromise water and sanitation infrastructure | Resilient, upgraded and accessible water supply and sanitation infrastructure | Based on UNEP (2023) and Rozenberg & Fay (2019)[127] |
| | Changing precipitation (patterns and types) and droughts contribute to changing water cycles and cause growing water stress. Sea level rise extends salinization of groundwater, reducing water availability | Alternative sources of water supply | Authors' intervention based on several interventions highlighted in EU Sustainable Taxonomy[128] and Tailwind.[129] |
| | Cross-cutting | Water use efficiency and integrated management of water resources | Taken from IPCC (2022)[130], definition adapted from interventions from IPCC (2022), ASAP (2020), TNA (2023)[131] |

[121] Climate and health alliance (2025). Clean air, healthy lives
[122] World Bank (2024). The cost of inaction: quantifying the impact of climate change on health in low- and middle-income countries; WEF (2024). Quantifying the impact of climate change on human health
[123] CPI (2024)
[124] McKinsey (2024)
[125] CPI (2024) and IMF (2024)
[126] McKinsey (2024)
[127] UNEP (2023); Rozenberg & Fay (2019)
[128] EU Taxonomy (2020)
[129] Tailwind (2024)
[130] IPCC (2022)
[131] TNA (2023)

| | | | |
|---|---|---|---|
| | Higher temperatures, floods and droughts exacerbate many forms of water pollution, affecting water quality | High-quality and safe water | Based on IPCC (2022)[132], definition taken from TNA Adaptation Taxonomy[109] |
| **Terrestrial biodiversity & ecosystems** | Terrestrial biodiversity loss presents risks to people and global economic prosperity directly (e.g. loss of production and revenue in agriculture, forestry, fisheries) and indirectly (e.g. decline in overall productivity, ill health, increased climate change) | Expansion and adaptation of terrestrial protected areas | Based on UNEP (2023) and Waldron et al. (2020)[133] |
| | | Ecosystem-based adaptation outside protected areas | Adapted from several sources, e.g. IPCC (2022) "forest-based adaptation"; list of terrestrial biodiversity ecosystems from IUCN (2020), ICF Biodiversity Finance (2023)[134] |
| **Coastal systems & low-lying areas** | Increasing coastal floods directly affect people (loss of life, displacement) and assets (coastal infrastructure, settlements) | Coastal protection and hardening | Taken from UNEP (2023), Hinkel et al. (2013), Lincke et al. (2018)[135] |
| | | Integrated coastal zone management | Taken from IPCC (2022)[110], definition from European Environment Agency (2024)[136] |
| | | Restoration and creation of coastal habitats | Author's definition based on interventions from a range of sources, including EU Sustainable Taxonomy (2020)[137], ASAP (2020)[138], TNA Adaptation Taxonomy (2023)[109] |
| | Increasing river floods directly affect people (loss of lives) and assets (damage to infrastructure, food production) | River flood protection | Taken from UNEP (2023)[111], Lincke et al. (2018) |
| **Infrastructure and built environment** | Sea level rise, changes in precipitation, extreme weather, and heat pose risks to the transportation system (e.g. affecting highways, railways, bridges). Similarly, the energy system is affected by heat waves, severe droughts, sea level rise and storms (e.g. supply of oils, energy infrastructure) | Resilient energy and transport subsectors | Taken from UNEP (2023), World Bank (Hallegatte et al., 2019; Rozenberg & Fay, 2019)[139] |
| | Sea level rise, floods, storms and other hazards directly threaten urban infrastructure | Urban green and blue infrastructure | Intervention taken from IPCC (2022)[140]: "urban and infrastructure systems: green infrastructure and ecosystem services" and "urban and |

132 IPCC (2022)
133 UNEP (2023); Waldron et al. (2020)
134 IPCC (2022); ICF (2023); IUCN (2020)
135 UNEP (2023); Lincke & Hinkel (2018);
136 European Environment Agency (2024)
137 EU Taxonomy (2020)
138 ASAP (2020)
139 UNEP (2023); Rozenberg & Fay (2019)
140 IPCC (2022)

| | | | |
|---|---|---|---|
| | | | infrastructure systems: sustainable urban water management", merged based on recent concept of Pinto et al. (2023) Oxford Open: "urban green and blue infrastructure"[141] |
| | Sea level rise, floods, storms and other hazards directly threaten built infrastructure | Resilient built environment | Based on UNEP's (2023)[142] qualitative review of adaptation costs for "heat-related impacts for built environment and energy demand for cooling as well as impacts on labor productivity" |
| **Fisheries, aquaculture and marine ecosystems** | Sea level rise and storms are causing damage to critical fish habitat, and increasing ocean temperatures and acidification lead to loss of marine habitats and species. | Sustainable and adaptive fisheries and aquaculture production | Based on UNEP (2023)[119] adaptation intervention for fisheries, aquaculture and marine ecosystems and IFC Biodiversity Finance (2023)[143] 'sustainable aquaculture production', sustainable fisheries and fishery practices' and 'regenerative aquaculture' |
| | Marine biodiversity loss presents risks to people and global economic prosperity directly (e.g. loss of production and revenue in fisheries) and indirectly (e.g. increased climate change) | Expansion and adaptation of marine protected areas | Based on UNEP (2023)[119]'s adaptation intervention for fisheries, aquaculture and marine ecosystems |
| | | Ecosystem-based adaptation outside protected areas | Based on ICF (2023)'s "conservation/restoration of marine areas"[144] |
| **Education** | Extreme weather damages education infrastructure, causes loss of education material and injury/mortality of students and teachers | Resilient education sector | Based on IMF (2024) education adaptation intervention[145] |
| **Adaptation for business & industry** | Higher temperatures and heat waves can change and reduce demand for tourism. Severe storms and extreme weather can disrupt transport, power and water supplies needed for tourism. Terrestrial and marine biodiversity loss can reduce ecotourism. | Resilient tourism industry | Based on UNEP (2023)'s[146] qualitative review of adaptation costs for tourism and ICF (2023)[122] highlighting of ecotourism as adaptation strategy |
| | Climate change and nature loss will cause risks in all business and industry dependent on subsector and location. Also, climate change and nature loss will | Resilient other industries & commerce | Based on UNEP (2023)[124] qualitative review of adaptation costs for business and industry, including supply chains" (removed tourism from this subcategory and created a |

[141] Pinto et al. (2023)
[142] UNEP (2023)
[143] ICF (2023)
[144] ICF (2023)
[145] IMF (2024)
[146] UNEP (2023)

| | | | |
|---|---|---|---|
| | cause shifts in demand for goods, services and trade | | separate subcategory for tourism above) |
| **Cross-sectoral enablers** | Cross-cutting | Governance and capacity building | Based on UNEP (2023)[124] "capacity-building and governance" category and IPCC (2022)[147], enabling interventions: "institutional frameworks", "cross-sectoral integration of adaptation" |
| | | Decision-support tools and analytics | Based on enabler from IPCC (2022)[148]: "decision-support tools and decision-analytic methods" , incorporating several interventions from other sources, including: "early warning systems" (UNEP, 2023)[124], "online data integration system for monitoring, dissemination of information and awareness-raising in relation to impacts of climate change" (UNFCCC, 2023)[149], and "enhancing climate change literacy on impacts and solutions" from IPCC (2022)[150] |
| | | Forward planning, risk-management and risk-spreading | Based on "forward-looking adaptive planning and iterative risk management" from IPCC (2022), including also "disaster risk management", "social safety nets" and "risk spreading and sharing" from IPCC (2022), as well as "ensure protection against climate variability and natural disasters: from UNFCCC (2023) and "adaptive social protection" from UNEP (2023)[151] |

[147] IPCC (2022)
[148] IPCC (2022)
[149] UNFCCC (2023)
[150] IPCC (2022)
[151] IPCC (2022); UNFCCC (2023); UNEP (2023)

# 5. INVESTMENT NEEDS

## Sources

We estimated the investment needs for each sector's resilience interventions at a regional and global level. We compiled the costs of as many interventions as possible, based on up-to-date, available data. Three main sources were used:

- UNEP (2023).[152] This report introduces a new methodology to estimate the adaptation needs of developing countries for the current decade, updating its previous 2016 cost estimates. UNEP (2023) estimates adaptation needs per sector for six geographies: Sub-Saharan Africa, South Asia, Middle East and North Africa, Latin America and the Caribbean, Europe and Central Asia, and East Asia and the Pacific. In addition, the results are published for four country income groups in US$2022 prices: low-income countries (LICs), lower middle-income countries (LMIC), upper middle-income countries (UMICs), high income countries (HICs). To do so, UNEP (2023) collaborated with several research teams to create updated, annual adaptation investment need estimates for the following sectors: coastal zones, river floods, energy and transport infrastructure, agriculture, fisheries, aquaculture and marine ecosystems, health, disaster risk reduction and social protection, and terrestrial biodiversity and ecosystem services. While its primary focus is climate adaptation, nature is considered only a smaller component within the analysis.
- IMF (2024).[153] This report evaluates the additional funding required to achieve strong performance in selected Sustainable Development Goals (SDGs), while accounting for the impacts of climate risks. It builds on previous work by Gaspar et al. (2019)[154] and Carapella et al. (2023)[155], which estimate the cost of achieving SDGs in five sectors (health, education, water and sanitation, electricity, road infrastructure), to calculate the additional cost of achieving these SDGs in context of climate risks. For example, the additional cost to build transport infrastructure to withstand increased frequency and severity of climate hazards.
- Waldron et al. (2022a); Waldron et al. (2022b); UNEP (2022)[156] present estimates on current and required spending for achieving 30x30 (a worldwide initiative for governments to designate 30% of Earth's land and ocean area as protected areas by 2030) through terrestrial and marine protected areas. These reports assess the additional investment required to expand and maintain these areas throughout the decade. The results are shown as additional finance needed to achieve 30x30 by country income group. These estimates are more comprehensive than those used in UNEP (2023), as they account for the total investment required for protected areas, rather than only a portion attributed to climate change.

While these estimates represent some of the most up-to-date assessment of resilience intervention costs, there are limitations around their comparability, due to different timeframes and methodologies:

- UNEP (2023) assumes each sector and region will experience a certain level of climate and nature risks this decade. It then estimates the costs of interventions that will reduce those risks in a central scenario, including all interventions with a BCR >1.
- IMF (2024) assesses the costs of 'climate-proofing' high SDG performance. It estimates countries' additional adaptation investment needs, on top of a baseline of high SDG spending, in line with peer countries (based on income and region) that have achieved strong SDG outcomes.

[152] UNEP (2023)
[153] IMF (2024)
[154] Fiscal Policy and Development: Human, Social, and Physical Investments for the SDGs
[155] IMF (2023)
[156] Waldron et al. (2022a). The costs of global protected-area expansion; Waldron et al. (2022b). Costs and economic impacts of expanding marine protected area systems to 30%; UNEP (2022). State of Nature Finance.

- Waldron et al. (2022a); Waldron et al. (2022b) and UNEP (2022) assess the additional cost of achieving 30x30 (relative to current spending), including optimal management of protected areas and the cost of acquiring new protected areas.

We have drawn on the following sources to compile estimates for each sector:

- UNEP (2023): agriculture and food security; coastal systems and river flood protection; infrastructure and built environment; health; fisheries and marine; disaster risk reduction and social protection; and, terrestrial biodiversity.
- IMF (2024): water and sanitation
- Waldron et al. (2022a), Waldron et al. (2022b) and UNEP (2022): terrestrial biodiversity and ecosystems; fisheries, aquaculture and marine ecosystems. These sources have been used to estimate the additional, full finance to achieve 30x30 in developing countries, defined as non-Annex I countries that are not 'high income countries (HICs)'. Given that the UNEP (2023) report already incorporated 15% of additional finance needed for 30x30, 85% of the total estimates for additional finance needed for terrestrial and marine protected areas have been added to the 'terrestrial biodiversity' and 'fisheries and marine' estimates from UNEP (2023).
- IMF (2023); World Bank (2025); IMF (2024):[157] education.
- We also include estimates for 'cross-sectoral enablers' by applying a 12.5% markup to all sector investment estimates other than disaster risk reduction and social protection. The 12.5% markup is based on UNEP (2023), which suggests a 10-15% range. We consider disaster risk reduction and social protection as falling within this 10-15% range, and so do not apply the markup to this sector.
- This markup is not applied to disaster risk reduction and social protection, as these are already considered cross-sectoral enablers.

Both UNEP (2023) and IMF (2024) provide estimates for health and infrastructure and built environment. We use UNEP (2023) for infrastructure and built environment, as the IMF (2024) estimates include mitigation costs, and we use UNEP (2023) for health but note these estimates include some, health-related water and sanitation estimates.[158]

IMF (2024) is the only source that includes estimates for the water and sanitation sector. The estimates focus exclusively on water and sanitation infrastructure for municipalities, and include the cost of making water and sanitation infrastructure resilient as well as expanding municipal water infrastructure supply to mitigate climate-related water stress. The IMF (2024) estimates cover EMDEs almost exclusively. As described in more detail below, we present all results in World Bank country income groups. To split the IMF (2024) estimates between World Bank income groups, we used 'projected population by 2030' as a proxy for estimating how water and sanitation investment needs should be distributed across low income, lower middle income and upper middle income countries.

IMF (2024) is also the only source for education estimates. However, we do not use these estimates as investment needs appear high relative to other sectors and relative to general increased investments in education needed to achieve SDG4. Instead, we base our education numbers on a new analysis that primarily uses three sources: IMF (2023); World Bank (2025); IMF (2024).[159] These sources provide insights into: (i) current education investment per country as a % of GDP; (ii) current capital expenditure as a % of public education investment; (iii) future education investment needed for high SDG4 performance; (iv) the costs of climate-proofing education infrastructure.

[157] Carapella et al. (2023). How to assess spending needs of the sustainable development goals: the third edition of the IMF SDG costing tool; Aggarwal et al. (2024). Accounting for climate risks in costing the SDGs; World Bank (2025). Government expenditure on education
[158] However, these only capture a marginal investment needed (US$0.9 to 2.3 billion per year) for climate-proofing future water and sanitation systems. In addition, the total health estimate from UNEP (2023) (including the small part on water and sanitation) is still below estimates from the IMF (2024) on climate-proofing health systems.

[159] Carapella et al. (2023). How to assess spending needs of the sustainable development goals: the third edition of the IMF SDG costing tool; Aggarwal et al. (2024). Accounting for climate risks in costing the SDGs; World Bank (2025). Government expenditure on education

Our education estimates are based on a central scenario that takes the average of two approaches: (i) climate-proofing current education infrastructure investment, derived by taking current education infrastructure spend as a % of GDP (from World Bank (2025)), and multiplying this by projected GDP per country in 2030; and (ii) climate-proofing current and future additional education infrastructure needed to achieve high SDG4 performance, derived by taking current infrastructure spend as a percentage of GDP and future education infrastructure investment spend for high SDG4 performance as a % of GDP (from Carapella (2023)), and multiplying this by projected GDP per country in 2030.

## Country income groups and emission scenarios

### Country income groups

This paper integrates estimates from three sources to provide country income group and global estimates of resilience investment needs. While all three sources offer regional and country income group estimates, their classifications vary. For consistency, this analysis adopts the World Bank country income groups (low income countries, lower middle income countries, upper middle income countries, high income countries). It maps country classifications from the IMF (2024), that separates between low-income developing countries (LIDCs), emerging market and developing economies (EMEs) and advanced economies (AEs), to the World Bank country income groups to the corresponding World Bank country income groups.

### Emission scenarios

*The level of investment needed for resilience depends on a country's climate and nature risk exposure, which in turn is shaped by global emissions pathways. Higher-emission scenarios lead to more severe climate and nature hazards and risks and greater resilience investments to build resilience. In lower-emission scenarios, risks are comparatively lower, reducing the need for resilience investments. Similarly, socioeconomic factors—such as population growth, income distribution, technological progress, and consumption patterns—shape climate resilience and land use, impacting resilience investment needs.*[160]

*For this paper, multiple emission scenarios were considered, each incorporating implicit assumptions about nature loss. These scenarios, based on IPCC (2022) data, provide a framework for assessing future climate risks.*[161] *Representative Concentration Pathways (RCPs) outline potential greenhouse gas (GHG) trajectories, modeling different emission levels and their climate impacts. Alongside these, Shared Socioeconomic Pathways (SSPs) offer narratives on how global socioeconomic conditions may evolve, influencing both climate change adaptation and mitigation.*

| EMISSION SCENARIO | SURFACE TEMPERATURE INCREASE IN 2050 (Relative to the period 1850-1900) | SURFACE TEMPERATURE INCREASE IN 2100 (Relative to the period 1850-1900) |
|---|---|---|
| **RCP1.9 - SSP1** | 1.5 | 1.4 |
| **RCP2.6 - SSP1** | 1.75 | 1.7 |
| **RCP4.5 - SSP2** | 1.8 | 2.7 |
| **RCP7.0 - SSP3** | 2.1 | 3.9 |
| **RCP8.5 - SSP5** | 2.3 | 4.6 |

160 IPCC (2019)
161 IPCC (2022)

Similar to UNEP (2023), the central estimates for our paper have been based on RCP4.5 – SSP2 or equivalent scenarios for resilience investment needs by 2030. This scenario represents a moderate emission scenario with medium level adaptation required.[162]

## Full costing methodology

The cost methodology draws on and synthesizes cost estimates from UNEP (2023), IMF (2024) and Waldron et al. (2022) These cost methodologies follow an intervention-based approach, for the most part estimating costs at the country level and scaling them up to country income group, regional and global levels. These estimates are normative, reflecting the aspirational investment needed to build resilience under a central scenario. The costs are usually based on a set of input variables (e.g. kilometers of expanded rural roads) multiplied by unit costs (e.g. unit cost of rural road per kilometer), controlled for other factors like GDP and demographics. The full costing methodology is summarized in the table below, all methodologies are further specified in the underlying sources.

**Table 4: Costing methodology for resilience interventions**

| SECTOR | INTERVENTIONS | COSTING METHODOLOGY | COSTED INTERVENTION |
|---|---|---|---|
| **Agriculture and food security** | Resilient infrastructure along the value chain | UNEP (2023)[24], | Expanded rural infrastructure to improve market efficiency to combat climate change impact on hunger |
| | Resilient water management and irrigation | | Expansion of irrigated area coupled with increased water use efficiency and improved soil water-holding capacity |
| | Agriculture adaptation research & development (R&D) | | Increased R&D investment across the portfolio, including adoption of new technologies |
| | Climate monitoring and forecasting for agrifood production | Not costed | N/A |
| | Resilient agricultural production | Not costed | N/A |
| **Health** | Disease detection, surveillance and control systems | UNEP (2023) | More robust surveillance e and detection networks to address climate risks |
| | Vaccines, medical products and technology for climate-sensitive diseases | UNEP (2023) | Reduce or prevent health outcomes from malaria, dengue, diarrhea |
| | Heat mitigation and heat-alert schemes | UNEP (2023) | Reduce or prevent heat-related mortality |
| | Targeted measures to improve mental and psychosocial health | Not costed | N/A |
| | Health sector responses to respiratory health issues | Not costed | N/A |
| | Health sector response to malnutrition and exposure to hazards | Not costed | N/A |

[162] Coast Adapt (2024)

| | | | |
|---|---|---|---|
| | Emergency health services | Not costed | N/A |
| | Climate and nature-health information, surveillance and early warning systems | Not costed | N/A |
| | Health workforce training | Not costed | N/A |
| | Resilient healthcare infrastructure (incl. building, equipment, IT) | UNEP (2023) | Based on markup from Rozenberg & Fay (2019) for capital health expenditure |
| | Resilient healthcare supply chains | Not costed | N/A |
| **Water & sanitation** | Resilient, upgraded and accessible water supply and sanitation infrastructure | IMF (2024)[30] | Construction of new WASH infrastructure to combat water stress and climate-proofing WASH infrastructure |
| | Alternative sources of water supply | | Increasing water supply through recycling, rainwater harvesting or desalination |
| | Water use efficiency and integrated management of water resources | Not costed | N/A |
| | High-quality and safe water | Not costed | N/A |
| **Terrestrial biodiversity & ecosystems** | Expansion and adaptation of terrestrial protected areas | UNEP & Waldron (2022)[163] | Additional expenditure for expansion and maintenance of terrestrial protected areas |
| | Ecosystem-based adaptation outside protected areas | Not costed | N/A |
| **Coastal systems & low-lying areas** | Coastal protection and hardening | UNEP (2023)[164] | Cost of coastal protection and beach nourishment |
| | River flood protection | | Investment and maintenance costs for river flood protection |
| | Integrated coastal zone management | Not costed | N/A |
| | Restoration and creation of coastal habitats | Not costed | N/A |
| **Infrastructure and built environment** | Resilient energy and transport subsectors | UNEP (2023)[32] | Climate-proofing new energy and transport infrastructure |
| | Urban green and blue infrastructure | Not costed | N/A |
| | Resilient built environment | Not costed | N/A |
| **Fisheries, aquaculture and marine ecosystems** | Sustainable and adaptive fisheries and aquaculture production | Not costed | N/A |
| | Expansion and adaptation of marine protected areas | UNEP & Waldron (2022)[31] | Additional expenditure for expansion and maintenance of marine protected areas |
| | Ecosystem-based adaptation outside protected areas | Not costed | N/A |

[163] UNEP (2022)
[164] UNEP (2023)

| | | | |
|---|---|---|---|
| **Education** | Resilient education sector | IMF (2024)[30] | Climate-proofing existing and new education infrastructure |
| **Adaptation for business and industry** | Resilient tourism industry | Not costed | N/A |
| | Resilient other industries & commerce | Not costed | N/A |
| **Cross-sectoral enablers** | Governance and capacity building | UNEP (2023)[165] | Adding 12.5% markup for capacity-building, governance and implementation based on evidence shared in UNEP (2023) |
| | Decision-support tools and analytics | | |
| | Forward planning, risk-management and risk-spreading | | |

Next, we analyzed CAPEX and OPEX for each intervention to support accurate assessment of economic benefits. The sources we used for the cost estimates did not directly indicate the share of investment for each intervention, that is CAPEX/OPEX, and we therefore made broad assumptions based on existing literature. These are summarized in the table below.

**Table 5: Overview of CAPEX/OPEX Assumptions**

| INTERVENTIONS | ASSUMPTIONS | CAPEX% | OPEX% | SOURCE FOR ASSUMPTIONS |
|---|---|---|---|---|
| **Agricultural interventions** | Assumption that 100% of infrastructure and irrigation are CAPEX and 100% of R&D are OPEX. Irrigation % based on Rozenberg & Fay (2019). | 91% | 9% | Rozenberg & Fay (2019) |
| **Health interventions** | Assumption that from all costed measures, including reducing implications of climate change on people's health, developing health information and monitoring systems, and health workforce training, and making health infrastructure climate-resilient, 20% of investments is to climate-proof health infrastructure (CAPEX), based on McKinsey (2023). | 20% | 80% | McKinsey (2023) |
| **Water and sanitation interventions** | Assumed CAPEX/OPEX split related to WASH investments from Rozenberg & Fay (2019). Cost estimates in this assessment are based on IMF (2024) that strictly consider WASH infrastructure. | 44% | 56% | Rozenberg & Fay (2019) |
| **Expanding terrestrial protected areas (PAs)** | Authors' interpretation of "minimal CAPEX" as highlighted in Waldron et al. (2020), with "a large number of countries stating that their existing CAPEX budgets were already very low or even zero" | 5% | 95% | Waldron et al. (2020) |
| **Coastal protection and hardening** | Assumed all sea dike costs from Lincke & Hinkel (2018), are infrastructure, and assumed all maintenance costs are OPEX. Taken scenario discount rate 0.0, RCP 2.6 high, SSP2, 2030 for all countries. | 46% | 54% | Lincke & Hinkel (2018) |

[165] UNEP (2023)

| | | | | |
|---|---|---|---|---|
| **River flood protection** | Assumed CAPEX/OPEX split from flood protection under 'preferred scenario', looking at % of GDP split. | 82% | 18% | Rozenberg & Fay (2019) |
| **Resilient energy and transport subsectors** | Assumed CAPEX/OPEX split from 'electricity' and 'transport' from Rozenberg & Fay (2019). Took average of these two. | 54% | 46% | Rozenberg & Fay (2019) |
| **Expanding marine protected areas (PAs)** | Authors' interpretation of "minimal CAPEX" as highlighted in Waldron et al. (2020), with "a large number of countries stating that their existing CAPEX budgets were already very low or even zero" | 5% | 95% | Waldron et al. (2020) |
| **Education interventions** | IMF (2024) considers (i) costs of retrofitting existing buildings; (ii) costs of upgrading new buildings. Assumed that these costs are only CAPEX related to infrastructure. | 100% | 0% | IMF (2024) |
| **Business and industry interventions** | N/A | N/A | N/A | N/A |
| **Cross-sectoral enablers** | Cross-sectoral enablers | 0% | 100% | N/A |

# 6. ECONOMIC BENEFITS

We provide a high-level indication of the economic benefits of investments in resilience. We reviewed the literature to compile estimates of two metrics for each intervention:

1. **Cost-benefit ratios**. These compare the direct costs and benefits of resilience interventions. They are useful as a metric to understand avoided losses, which is often the primary benefit of resilience investments. They also include economic and social and environmental benefits:[166]
    - ***Avoided losses***: Avoided losses—protecting lives and assets from climate and nature risks—are often the primary benefit of resilience investments. It is important to note that adaptation is never absolute, there is always residual risk.
    - ***Economic benefits***. Beyond risk reduction, resilience investments drive broader economic gains. For example, investing in seawalls or mangrove protection and restoration creates construction jobs, making these high-risk areas more viable for development and unlocking new economic opportunities.
    - ***Social and environmental benefits***. Beyond direct financial returns, resilience investments generate social and environmental benefits that strengthen communities and ecosystems. For example, restoring mangroves supports fisheries, forestry, and recreation, providing long-term social welfare and ecological value. These benefits often extend beyond measurable market returns, including enhanced well-being, cultural preservation, and ecosystem stability. However, because these benefits are non-monetary, they rely on assumptions and subjective valuation methods, such as estimating welfare improvements in financial terms. While they are important for decision-making, they should be approached with caution to avoid overstating their economic impact or misrepresenting them as direct contributions to GDP growth in macrofiscal frameworks.
2. **Economic multipliers.** We provide indicative, sectoral economic multipliers to understand the broader macroeconomic benefits of resilience investments. Like other public spending, resilience investments can generate economy-wide benefits. For example, investing in climate-resilient agriculture increases household incomes, leading to more spending on goods and services, which in turn supports businesses. These businesses can then pay workers and suppliers, which creates a ripple effect throughout the economy that amplifies the economic impact beyond the initial investment.[167]

The cost benefit ratios and investment multipliers we provide are high-level and indicative only, noting these vary widely between countries and sometimes across sources. Moreover pay-offs from specific investments may not easily translate into economy-wide multipliers that can guide macro frameworks (the "micro-macro paradox"). For this reason, the estimates provided here are highly preliminary and further work is needed to support their integration into macrofiscal frameworks and the DSA.

**Table 6: Overview of cost-benefit ratios for resilience interventions**

| SECTOR | INTERVENTION | COST-BENEFIT RATIO & TIMEFRAME | SOURCE |
|---|---|---|---|
| **Agriculture and food security** | Improving dryland agriculture crop production | 2-10 by 2030 | GCA (2019) |
| **Health** | Climate-proofing health facilities | 4.9 over 20 years | World Health Organization (2023) |

[166] GCA (2019)
[167] Corporate Finance Institute (2024)

| | | | |
|---|---|---|---|
| **Health** | Making water resources management more resilient | 2-6 by 2030 | GCA (2019) |
| **Water and sanitation** | Expanding terrestrial protected areas | 5 by 2050 | Waldron et al. (2020) |
| **Terrestrial biodiversity and ecosystems** | Sea wall improvement and maintenance | 2.5-5.2 present value of 50-year investment | UNFCCC (2024) |
| **Coastal systems and low-lying areas** | Mangrove preservation and restoration | 2-11 by 2030 | GCA (2019) |
| **Infrastructure and built environment** | Resilient energy and transport subsectors | 2-11 by 2030 | GCA (2019) |
| **Fisheries, aquaculture and marine ecosystems** | Expanding marine protected areas (PAs) | 5 by 2030 | Waldron et al. (2020) |
| **Education** | Education interventions | 4 by 2030 | GCA (2019) |
| **Cross-sectoral enablers** | Strengthening early warning systems | 4 by 2030 | GCA (2019) |

**Table 7: Overview of multipliers from public expenditure**

| SECTOR | SECTOR MULTIPLIER DEFINITION | SECTOR MULTIPLIER | SOURCE FOR SECTOR MULTIPLIER |
|---|---|---|---|
| **Agriculture and food security** | 1.36 | Agriculture multiplier | Waldron et al. (2020) |
| **Health** | 4.3 | A study in 2013 showing that the multiplier for government spending on health services in Europe is 4.3 (fiscal multiplier) | Reeves et al. (2013) |
| **Health** | 4 | A UK study shows that each GBP1 spent per head on the NHS results in a corresponding return on investment of GBP4 | NHS (2022) |
| **Water and sanitation** | 5 | Investment in water infrastructure globally can have a 5-time multiplier effect | ICE (2024) |
| **Terrestrial biodiversity and ecosystems** | 3.2 | Tourism multiplier | World Travel & Tourism Council (2012) |
| **Coastal systems and low-lying areas** | 1.5 | Multiplier of public expenditure and investments in infrastructure | World Bank (2022) |

| | | | |
|---|---|---|---|
| **Infrastructure and built environment** | 1.5 | Multiplier of public expenditure and investments in infrastructure | World Bank (2022) |
| **Fisheries, aquaculture and marine ecosystems** | 3.2 | Tourism multiplier | World Travel & Tourism Council (2012) |
| **Education** | 1.5 | Multiplier of public expenditure and investments in infrastructure | World Bank (2022) |
| **Adaptation for business and industry** | N/A | N/A | N/A |
| **Cross-sectoral enablers** | N/A | N/A | N/A |

# 7. EMDE AND SECTOR RESILIENCE INVESTMENT NEEDS ESTIMATES

The model developed for this paper estimates absolute investment needs for various resilience interventions. These figures were then converted into % of GDP provide a more meaningful comparison across country income groups. Percentage of GDP reflects the relative economic burden of an investment. For example, a $1 billion investment resilient infrastructure places a much greater strain on a smaller economy than on a larger one.

The GDP data used in this assessment comes from IMF (2025),[168] which provides current-price GDP estimates and inflation rates, and end of period consumer prices, with projections up to 2030. Population projections were sourced from the World Bank (2025),[169] enabling country income group estimates through 2030. To ensure consistency, all investment estimates were adjusted to constant 2023 US$ using end-of-year inflation data from IMF (2025). UNEP (2023) and UNEP (2022) provide figures in 2022 US dollars, while IMF (2024) uses constant 2020 US dollars. All estimates were inflated to US$2023 prices. Likewise, all 2030 GDP projections (in current prices) were converted to 2023 US$ for consistency.

[168] IMF (2025); IMF (2025)
[169] World Bank (2024)