UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

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TRADE AND ENVIRONMENT REVIEW 2021

Trade-climate readiness for developing countries

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Contents

Figures

Boxes

Tables

Note

Reference to dollar and $ indicate United States of America dollars, unless otherwise stated. Use of an en dash (–) between dates representing years, e.g. 2015–2018, signifies the full period involved, including the initial and final years. Decimals and percentages in this document do not necessarily add to totals because of rounding.

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For further information on the activities of UNCTAD's trade and environment, please consult the following website: https://unctad.org/topic/trade-and-environment.

4 February 2021

Acronyms and abbreviations

AR5	IPCC Fifth Assessment Report
CARICOM	Caribbean Community
CBI	Citizenship by Investment
CIMP5	IPCC Coupled Model Intercomparison Project Phase 5
CO_2	carbon dioxide
COP	UNFCCC Conference of the Parties
EEZ	Exclusive Economic Zone
FAO	Food and Agriculture Organization
GCF	Green Climate Fund
GCM	Global Circulation Model
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	greenhouse gas
ICT	Information and Communication Technologies
IPCC	Intergovernmental Panel on Climate Change
LDC	Least Developed Country
LDCF	Least Developed Country Fund
MPA	marine protected area
NAP	National Adaptation Plan under the UNFCCC
NAPA	National Adaptation Plan of Action under the UNFCCC
NDC	Nationally Determined Contributions under the UNFCCC
OECD	Organization for Economic Co-operation and Development
PPP	Public Private Partnership
RCP	Relative Concentration Pathway
SIDS	Small Island Developing States
SITC	Standard International Trade Classification
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

Executive summary

This edition of UNCTAD's Trade and Environment Review examines the physical impacts of climate change and their effects on developing country economies and trade; the vulnerabilities of developing countries to climate change; costs and finance for climate change adaptation; and finally, ways that developing countries can enhance their trade-climate readiness, i.e., enhance the resilience of their trade to climate change through adaptation actions and economic diversification. Special attention is given to examining the challenges faced by the poorest and most vulnerable developing countries, specifically the least developed countries (LDCs) and small island developing states (SIDS).

Accumulating anthropogenic emissions of greenhouse gases, leading to higher concentrations of these gases in the atmosphere, are causing the Earth's climate to change. Physical impacts resulting from climate change have already been observed in many countries, including warmer temperatures with longer and hotter warm spells, extended periods of drought, heavy rain and wind storms, stronger tropical storms and cyclones, desertification, sea level rise, beach erosion, saltwater infiltration of groundwater, algae bloom, and coral bleaching, among others.

In developing countries, many of these adverse impacts are already significant, introducing new development challenges. These challenges will grow and become more widespread in the coming years and decades as climate change progresses and the amplitude, frequency, and duration of its adverse impacts increase.

The severity and geographical distribution of the physical impacts of climate change in future decades will depend on past, present and future global greenhouse gas emissions. Future emissions will depend on the development paths countries pursue going forward. Mitigating climate change requires development paths wherein future greenhouse gas emissions are reduced substantially from current levels.

Even if all current country commitments to reduce greenhouse emissions under the aspirational UNFCCC Paris Agreement are achieved, warming of the atmosphere will continue for several decades and only cool gradually over the next few centuries. Ambitious mitigation actions cannot prevent climate change, but only limit the expected level of climate damages by 2100. Society is thus already committed to a certain level of warming and the numerous physical impacts that accompany it. As a result, adaptation is an imperative regardless of the level of progress achieved in mitigating global emissions.

Adverse changes in the climate will have economic, environmental, and social impacts. Anticipated impacts include land and ecosystem degradation; falling agricultural and fisheries productivity; damage to residential, commercial, and public infrastructure; declining tourism activity in adversely affected regions; reduced worker productivity due to higher temperatures and emerging health threats, and mass migration. And while these impacts progressively worsen as climate change intensifies over the long term, punctual impacts from stronger and more frequent tropical storms and cyclones can cause deeper economy-wide losses at any time.

The warming atmosphere and oceans are driving a poleward shift of climatic zones that will translate into a progressive redistribution of benefits and losses among human populations and ecosystems across regions and countries within them. Human, animal, and fish populations; optimal tourism sites; productive ecosystems; and high concentrations of tropical pests and disease vectors are projected to move poleward as climatic zones shift. Global economic and trade activity will reconfigure due to these movements, giving rise to new patterns of comparative advantage that will in turn generate new patterns of trade. The greatest benefits will accrue to the polar regions, and the greatest losses to tropical and subtropical regions where most of the world's developing countries are located.

Despite developed countries' dominant role in contributing to the rising atmospheric greenhouse concentrations, the burden of climate change adaptation will predominantly beset developing countries where the adverse physical impacts of climate change will be most pronounced. The agriculture, fishing, and tourism sectors will be the three sectors most vulnerable to adverse impacts of climate change.

Many developing countries, and particularly LDCs and SIDS among them, will face significant challenges to maintain production, and related employment and export levels in these sectors over the coming years and decades. Unless developing countries enhance their trade resilience ex-ante through adaptation measures and actions that reduce exposure and risk, they will export substantially less in climate-sensitive sectors ex-post as climate change impacts accumulate over time. When adaptation is neither possible or cost-effective, diversification within the sector, or economic restructuring to move resources to other less climate-sensitive sectors, can be pursued.

Adaptation to climate change is gaining increased attention in developing countries as confidence in climate change models grows and demonstrated international actions to mitigate greenhouse gas emissions remain limited and insufficient to significantly alter emissions trajectories from a business-as-usual scenario.

While developing countries urgently need to advance their adaptation efforts due to their substantial and numerous vulnerabilities, the adaptation costs they will incur are extremely high. The aggregate cost of adapting to climate change in developing countries has recently been estimated to range between $140–300 billion annually in 2030.

Developed countries committed to jointly mobilize $100 billion per year in climate finance to address the climate change mitigation and adaptation needs of developing countries in the form of the Green Climate Fund. However, from such finances, only $50 billion annually would be available for adaptation, falling short of estimated needs of $140–300 billion annually and resulting in an 'adaptation gap'. To fill this gap, national governments and the domestic private sector will need to finance many adaptation activities undertaken in developing countries.

Importantly, it is not only the physical impacts of climate change that will affect developing countries' export profiles, but also the adverse impacts on developing countries of 'response measures' aimed at mitigating climate change undertaken both domestically, and by other countries. Response measures could include fossil fuel subsidy elimination and/or the introduction of carbon taxes. Relative changes in producers' competitiveness and consumer demand levels will arise from the introduction of such measures in an implementing country, affecting both its import and export levels for certain goods and services. These measures can also 'indirectly' affect the trade of other countries whether the latter implement similar measures or not.

Response measures with more substantial 'direct' cross-border impacts are expected to be implemented by some countries. For example, some countries may introduce new product 'climate standards' that must be met by imported products, or impose border taxes on imported products based on the level of CO_2 emissions associated with the products' method of production, and possibly also based on CO_2 emissions associated with the transportation of products to the importing market. The latter measures are referred to as 'border carbon adjustments' or 'border carbon taxes'.

The impacts on trade resulting from carbon taxes, border carbon adjustments, and response measures cannot be generalized. For any given configuration of measures and sets of countries implementing them, modelling studies are required to provide an indication of the direction and magnitude of trade impacts likely to be experienced by exporting countries on a sectoral basis.

Climate change, and response policies designed to mitigate it, will have different and complex effects on world markets and trade affecting transportation costs, competitiveness, sectoral comparative advantages, and trade policies. Each developing country will have a unique trade-climate resilience pathway. This edition of the Trade and Development Review seeks to illustrate how to identify and pursue these pathways. National stakeholders will have to assess how the physical impacts of climate change, and potential response policies, will affect both domestic sectors, and the competitiveness and export capacity of other countries and regions that are competitors for the products they export. Based on such assessments, and the mobilization of required finance, national stakeholders can take steps to design and implement adaptation actions that can enhance their country's trade-climate resilience.

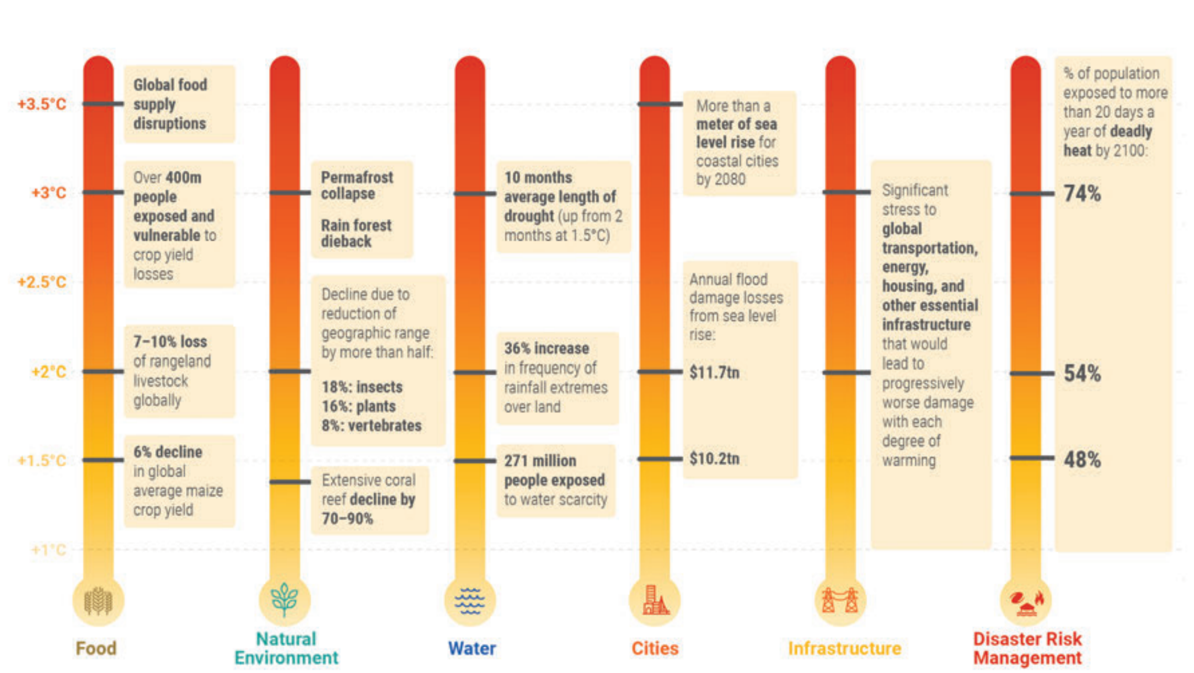
1. INTRODUCTION

Developing countries tend to suffer disproportionately from the damaging physical impacts of climate change due to a wide range of factors that create a specific set of vulnerabilities for each of them. These factors include their low geographical latitude and larges distances to major markets; being landlocked or surrounded by water; and having small economies, low levels of physical infrastructure and limited economic diversification. As such, developing countries are particularly vulnerable to ocean warming, sea level rise, altered temperature and rainfall patterns, and an increasing frequency of extreme weather events including drought and tropical cyclones. Within the next few decades, some may become unproductive or uninhabitable. The magnitude and scope of adverse impacts increases with the increasing temperatures associated with climate change as shown in Figure 1 where severe socioeconomic dislocations are predicted for global temperature of 1.5°C and higher. Preparations and actions need to be taken today to enhance countries' security and capacity to sustain both physical shocks, and related social, environmental, and economic impacts caused by climate change.

For developing countries reliant on trade for export earnings as well as energy and food imports, climate change will present significant economic challenges when their exports derive from sectors that will be most negatively affected by climate change, particularly from the agriculture, fisheries, and tourism sectors. By reducing the availability of factors of production – land, labour, and capital – as well as the efficiency with which these factors can be deployed, adverse climate changes can substantially reduce production and export levels. Moreover, climate change mitigation measures adopted at the international level may have trade-related implications for developing countries including reductions in, and higher costs for, maritime transport and aviation. The effects of international response measures are thus expected to further exacerbate challenges for developing countries with low connectivity and high transportation costs.

Rigorous national planning to design and implement adaptive actions to effectively respond to the physical and economic impacts caused by climate change can help a country to strengthen its 'trade-climate readiness'. Many developing countries will need to make structural changes in their economies to adapt their trade profiles so as to avoid or overcome disruptions caused by climate change. To date,

Figure 1. Some of the major environmental, social and economic impacts of climate change as a function of global temperature increase above pre-industrial levels



Source: Global Commission on Adaptation and World Resources Institute (GCA/WRI, 2019).

however, most adaptation efforts in developing countries have concentrated on building structural and physical infrastructure with relatively little attention given to adaptation in their economic and trade strategies.

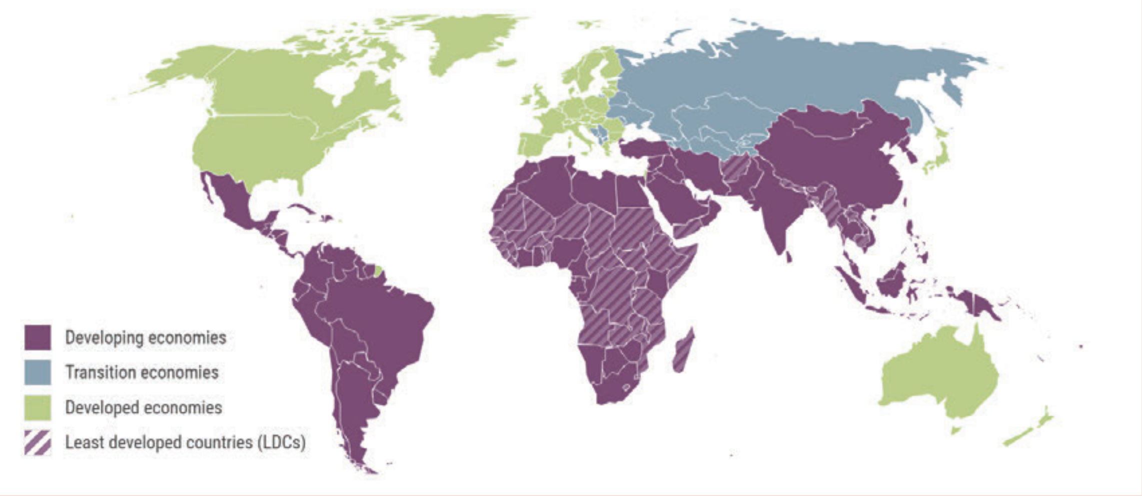
At the same time, accurate forecasting of the impacts of climate change on trade over the next three decades remains complicated because of uncertainties in both global emissions trajectories and climate feedback mechanisms; the latter can exacerbate adverse impacts beyond levels predicted by climate models. How other countries' climate change response measures may evolve and how they will affect trade and opportunities for sustained economic growth are also a matter of conjecture. For these reasons, the physical and economic impacts of climate change may be greater than predicted by current IPCC models.

Box 1. Developing countries, LDCs and SIDS

The map below presents the main UNCTAD country classifications showing both developing countries and LDCs (UNCTAD, 2020a). Most SIDS, which have very small geographical areas, are not large enough to be depicted on the map.

Since 1971, the United Nations has recognised LDCs as a category of States that are deemed highly disadvantaged in their development process, for structural, historical, and also geographical reasons (UNCTAD, 2020b). More than other countries, LDCs face the risk of deeper poverty and remaining in a situation of underdevelopment. Over 75 per cent of the LDCs' population still live in poverty. These countries are also characterised by their vulnerability to external economic shocks, natural and man-made disasters, and communicable diseases. Currently, the 47 LDCs comprise around 880 million people, 12 per cent of the world population, which face severe structural impediments to growth. At the same time, however, LDCs account for only about 2 per cent of world GDP and 1 per cent of world trade.

SIDS represent a group of countries around the world that share a common set of characteristics and vulnerabilities. All share geographic remoteness and low connectivity. Some of them are also LDCs, and their income levels are relatively heterogenous, but they generally hover between lower and upper-middle income groups. SIDS are located in the Caribbean, Pacific, and Africa-Indian Ocean regions. They share a common set of unique challenges, which include the fact that their slow and volatile economic growth performance is directly influenced by global economic shocks and natural disasters.



Developing countries can implement national, country-based processes to estimate the impacts of climate change on trade flows in key export sectors in the short, medium, and long term. Based on projected impacts, national stakeholders can design policies, actions, and infrastructure responses to enhance both trade and economic resilience in the coming decades. Such processes can also enhance countries' capacities to promote national interests in climate- and trade-related negotiations, and to design and implement Nationally Determined Commitments (NDCs) and National Adaptation Plans (NAPs) under the United Nations Framework Convention on Climate Change (UNFCCC) that are consistent with trade resilience objectives.

This edition of UNCTAD's Trade and Environment Review examines the physical impacts of climate change and their effects on developing country economies and trade; the vulnerabilities of developing countries to climate change; costs and finance for climate change adaptation; and finally, ways that developing countries can enhance their trade-climate readiness, i.e., enhance the resilience of their trade to climate change through adaptation actions and economic diversification. Special attention is given to examining the challenges faced by the poorest and most vulnerable developing countries, specifically the least developed countries (LDCs) and small island developing states (SIDS). References made to developing countries as a group, and to LDCs and SIDS, refer to the UNCTAD classification for these country groups (see Box 1).

2. THE PHYSICAL IMPACTS OF CLIMATE CHANGE AND THEIR EFFECT ON THE ECONOMY

2.1. Introduction

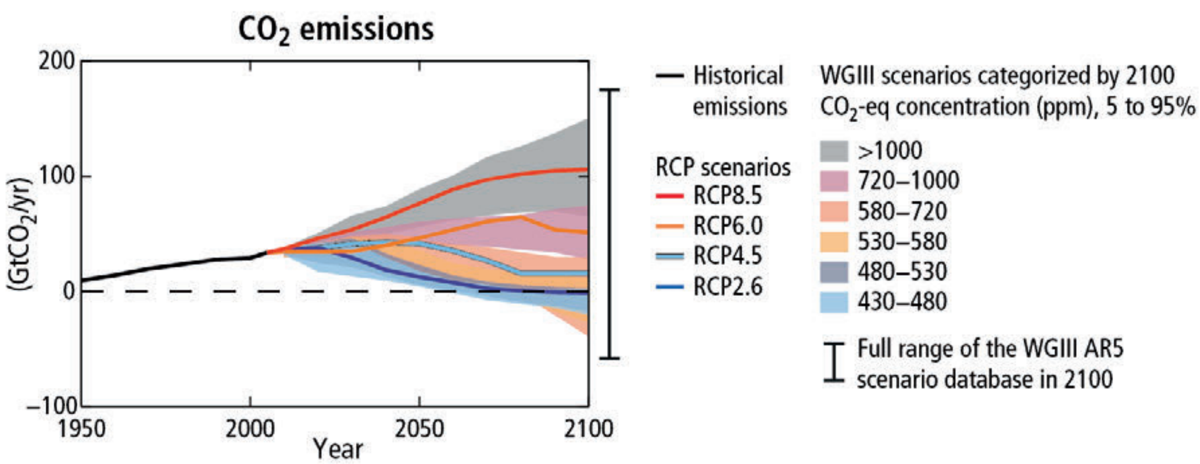
In its Fifth Assessment Report (AR5) the Intergovernmental Panel on Climate Change (IPCC) confirms that accumulating anthropogenic emissions of greenhouse gases, leading to higher concentrations of these gases in the atmosphere, are causing the Earth's climate to change (Stocker et al., 2013). Physical impacts resulting from climate change have been observed in developing countries including warmer temperatures with longer and hotter warm spells, extended periods of drought, heavy rain and wind storms, stronger tropical storms and cyclones, desertification, sea level rise, beach erosion, saltwater infiltration of groundwater, algae bloom, and coral bleaching, among others.

In developing countries, many of these adverse impacts are already significant, introducing new development challenges. These challenges will grow and become more widespread in the coming years and decades as climate change progresses and the amplitude, frequency, and duration of its adverse impacts increase.

Adverse changes in the climate will have economic, environmental, and social impacts. Anticipated impacts include land and ecosystem degradation; falling agricultural and fisheries productivity; damage to residential, commercial, and public infrastructure; declining tourism activity in adversely affected areas; reduced worker productivity due to higher temperatures and emerging health threats, and mass migration. And while these impacts progressively worsen as climate change intensifies over the long term, punctual impacts from stronger and more frequent tropical storms and cyclones can cause deeper economy-wide losses at any time.

This chapter describes the physical impacts of climate change and how they affect developing countries. Impacts already experienced, as well as future impacts projected by climate modeling, are presented. Adaptations that can be used to minimize the impact of climate change impacts on national economies and trade are illustrated.

Figure 2. IPCC GHG emission scenarios for the four different RCPs



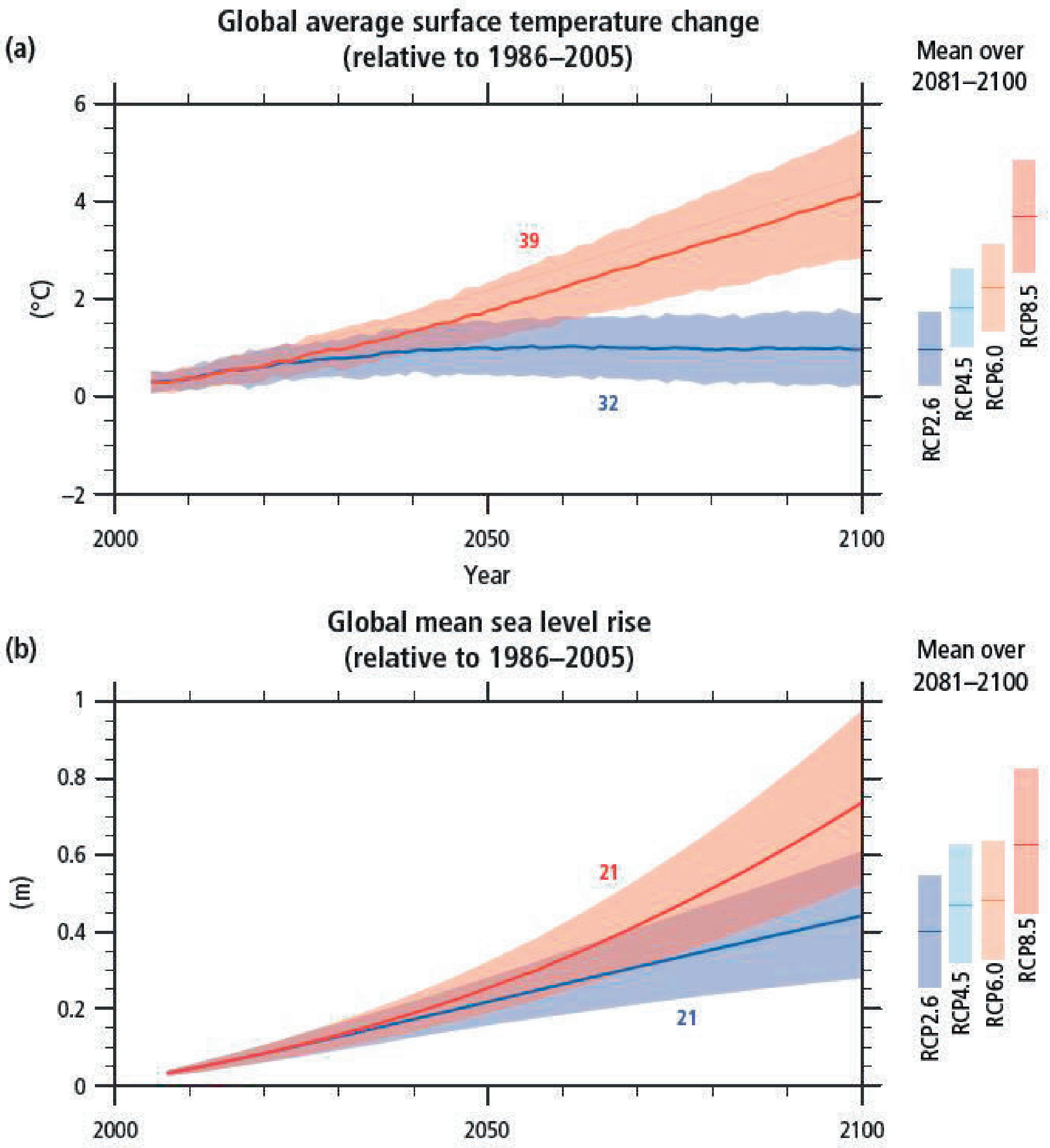
Note: The lines show CO_2 emission trajectories and the shaded areas show the range of uncertainty in the overall GHG emissions arising from atmospheric interactions with the ocean and biosphere.

Source: IPCC (Stocker, Qin, G.-K. Plattner, et al., 2014).

2.2. How climate change may evolve in the 21st century

The physical and biological mechanisms driving anthropogenic climate change are now well established and the phenomenon has been incontrovertibly confirmed through global observations (Stocker, Qin, G.-K. Plattner, et al., 2014). As GHG concentrations[1] in the atmosphere rise, an increasing proportion of thermal energy generated at the Earth's surface is retained in the atmosphere, causing, on average,

Figure 3. Increases in globally averaged (a) surface temperature and (b) sea level projected by the IPCC RCPs



Note: Increases shown are relative to the 1986–2005 period. Shaded areas show the range of predicted values among the CIMP5[3] models used by the IPCC to calculate the average trendlines (solid red and blue lines), and the numbers adjacent to the trajectories indicate the number of models included in the presented projections.

Source: IPCC (Stocker, Qin, G.-K. Plattner, et al., 2014).

global land and sea surface temperatures to rise, and the energy available to drive global atmospheric and oceanic circulation systems to increase.

Global circulation models (GCMs) of the Earth's climate system demonstrate that GHG emissions from anthropogenic sources are directly associated with observed changes in the Earth's climate. GCMs reveal that the impacts of climate change vary spatially; their intensity varies from one region to another, depending on a range of factors including a location's geographical latitude, its proximity to large land masses and ocean bodies, and its topography. A number of physical and biological feedback mechanisms also affect the scope and magnitude of impacts experienced at different locations. A full discussion of the scientific basis of climate change is available in IPCC AR5.[2]

The severity and geographical distribution of the physical impacts of climate change in future decades will depend on past, present, and future global GHG emissions. Future emissions will depend on the development paths countries pursue going forward. Mitigating climate change requires development paths wherein future GHG emissions are reduced substantially from current levels. Factors affecting emissions including population size, economic activity, lifestyle, energy use, land use patterns, technology, and climate policy, will evolve differently along varied development paths.

To estimate future emissions so that future climate change impacts can be projected, the IPCC uses a set of Representative Concentration Pathways (RCPs).[3] Each RCP represents an emissions scenario leading to a different atmospheric GHG concentration by 2100, and each is constructed for a different development path; for various levels of emissions reductions until 2100 ranging from sharp reductions to business-as-usual (no reduction effort).[4]

The IPCC RCP scenarios include a stringent greenhouse gas emissions mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0) and one baseline scenario, i.e., business-as-usual development path with high GHG emissions

Box 2. Even if global GHG emissions cease from today onwards, climate change is here to stay

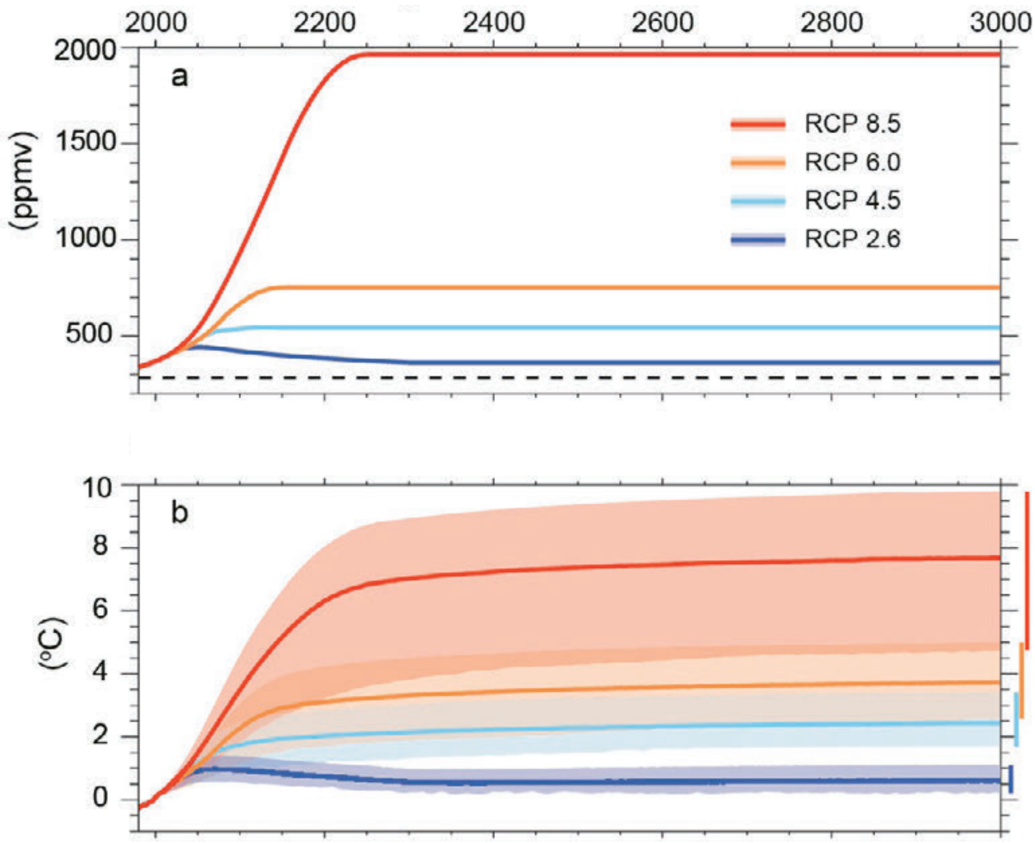
As a result of the significant lifetimes of major anthropogenic greenhouse gases, the increased atmospheric concentration due to past emissions will persist long after emissions are ceased (Solomon et al., 2009). For this reason, warming of the Earth's atmosphere and oceans will continue for several centuries even if the world ceases all GHG emissions today.

CO_2 and other GHGs have a long lifetime in the atmosphere. CO_2 emitted into the atmosphere can only be naturally removed through its absorption by vegetation and by the ocean (Collins et al., 2013). Taken together these processes can only absorb about 50 per cent of anthropogenic emissions with the result that about half of the CO_2 entering the atmosphere will continue to reside there for 100 years or more and thus accumulating in the atmosphere with time. Accumulated historical emissions are responsible for the present warming of the Earth's air, land, and oceans. And present emissions add to already raised concentrations of GHGs in the atmosphere causing continued warming in the future.

Furthermore, the rate of warming is now expected to accelerate faster than recent GCM model projections due to climate feedback processes not previously accounted for in modelling efforts. Feedback processes that will accelerate terrestrial warming include: increased heat retention in the atmosphere caused by rapid melting of polar ice sheets which reduces the Earth's surface albedo; release of methane from thawing permafrost in the warming arctic region; and reductions in the absorption of CO_2 by oceans as sea surface temperatures rise.

Due to these physical processes, even if all current country commitments under the aspirational UNFCCC Paris Agreement are achieved, warming of the atmosphere will continue for several decades and only cool gradually over the next few centuries. Modelling studies indicate that ambitious mitigation actions cannot prevent climate change but only limit the expected level of climate damages by 2100 (OECD, 2015). Society is thus already committed to a certain level of warming and the numerous physical impacts that accompany it. As a result, adaptation is an imperative regardless of the level of progress achieved in mitigating global emissions.

Figure 4. (a) Projected atmospheric CO_2 concentrations and (b) projected global mean surface temperature increase for the RCPs



Source: IPCC (Stocker, Qin, G.-K. Plattner, et al., 2014).

(RCP8.5). RCP8.5 assumes continued high population and relatively slow income growth with modest rates of technological change and energy intensity improvements, leading in the long term to high energy demand and GHG emissions in absence of climate change policies (Riahi et al., 2011). Scenarios without additional global efforts to constrain emissions lead to pathways ranging between RCP6.0 and RCP8.5 (Figure 2). RCP2.6 is representative of a UNFCCC 'Paris Agreement' scenario that aims to keep the average level of global warming less than 2°C (and potentially no more than 1.5°C) above average pre-industrial temperatures.

2.3. Global temperature and sea level changes

Globally averaged surface temperatures and sea level will both monotonically increase in the coming decades due to climate change. The degree of increase in temperature depends on the volume of accumulated GHG emissions present in the atmosphere which can be projected for each of the RCP development path scenarios assumed in the IPCC GCMs. Sea level rises due to the addition of water to the ocean from melting ice above the ocean surface (from polar ice sheets and ice shelves, and from glaciers throughout the world) and thermal expansion of ocean waters as its temperature increases. Figure 3 summarizes future temperature and sea level increases relative to the 1986–2005 period through 2100 for the different RCPs. It shows that globally averaged surface temperatures will rise by up to 5.5° C and sea level by up to 1 metre by 2100 for RCP 8.5. The lowest possible increases of average surface temperature and sea level would occur under scenario RCP 2.6; approximately 1.5° C and 0.4 metres respectively.

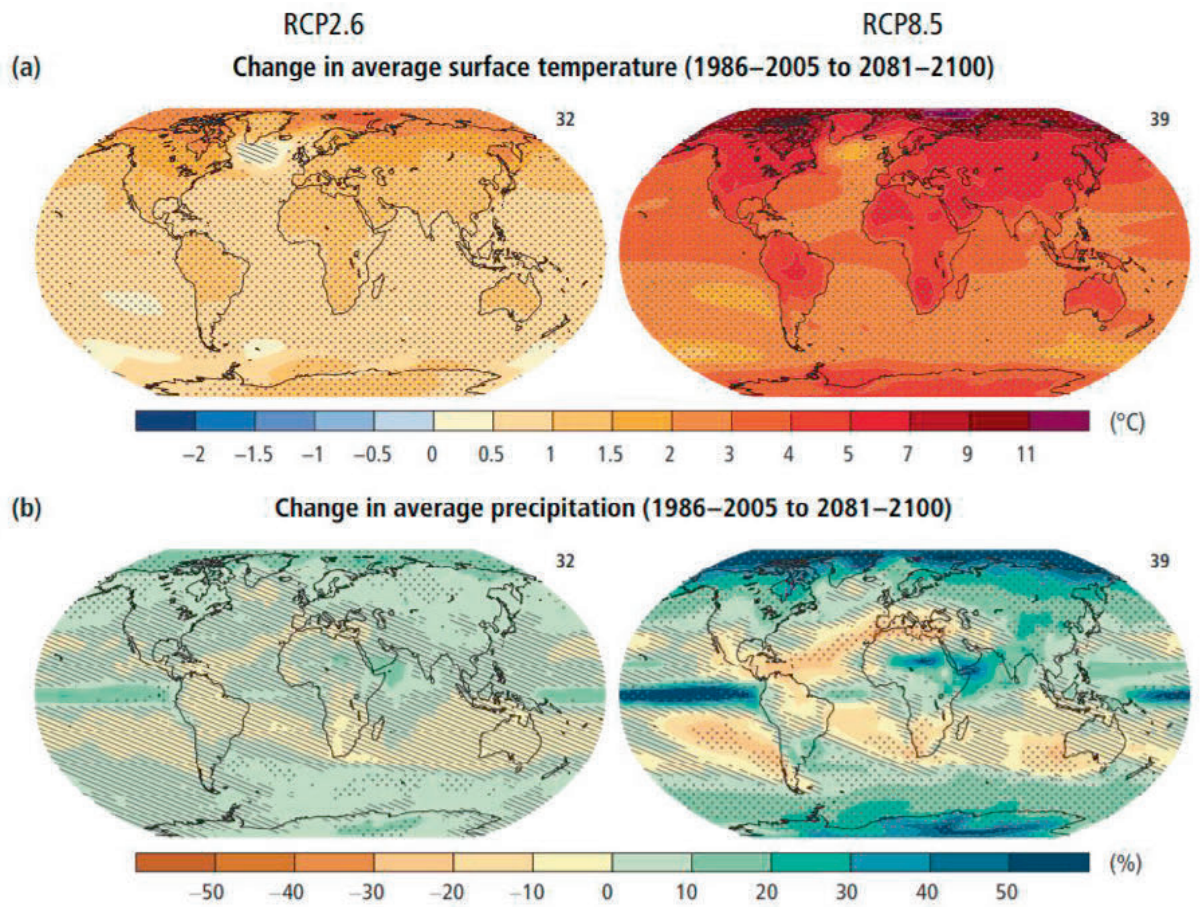
In the context of the presently experienced, and future warming, caused by climate change, it is important to recognise that continual warming will persist for several centuries regardless of the development path pursued due to the long lifetime of GHGs in the atmosphere. Even if society stops emitting CO_2 and other GHGs entirely today, warming of the atmosphere would continue for several decades and only cool gradually over the next few centuries (see Box 2).

For the each of the RCP scenarios, Figure 4 shows the long-term trends in CO_2 concentration levels and the corresponding trends in global average surface temperature to the year 3000. Each RCP models indicate that increased global temperatures will persist for several centuries and thus adaptations implemented in the coming years and decades will need to be maintained over the long term. Only in the case of the RCP 2.6 development pathway (Paris Agreement reductions met) will the global average surface temperature stabilize at about 1.5°C and decline slightly over the long term (Figure 4b lower violet coloured curve).

2.4. Other environmental changes caused by climate change

GCMs not only project future changes in atmospheric temperature and sea level, but depending on the specificity of the model, they also project future average changes in parameters such as cloud cover, storm frequency, monthly precipitation, prevailing wind speed, ocean surface temperature, ocean CO_2 concentration and acidity, glacial land cover and polar ice sheet extent, among other parameters. Moreover, because GCMs are longitudinally and latitudinally 'gridded' about the Earth's surface, in addition to globally averaged data, they also provide detailed

Figure 5. Change in average annual surface temperature (a) and change in average annual precipitation (b) based on multi-model mean projections for 2081–2100 relative to 1986–2005 under the RCP2.6 (left) and RCP8.5 (right) scenarios



Note: The number of models used to calculate the multi-model mean is indicated in the upper right corner of each panel.

Source: IPCC (Stocker, Qin, G.-K. Plattner, et al., 2014).

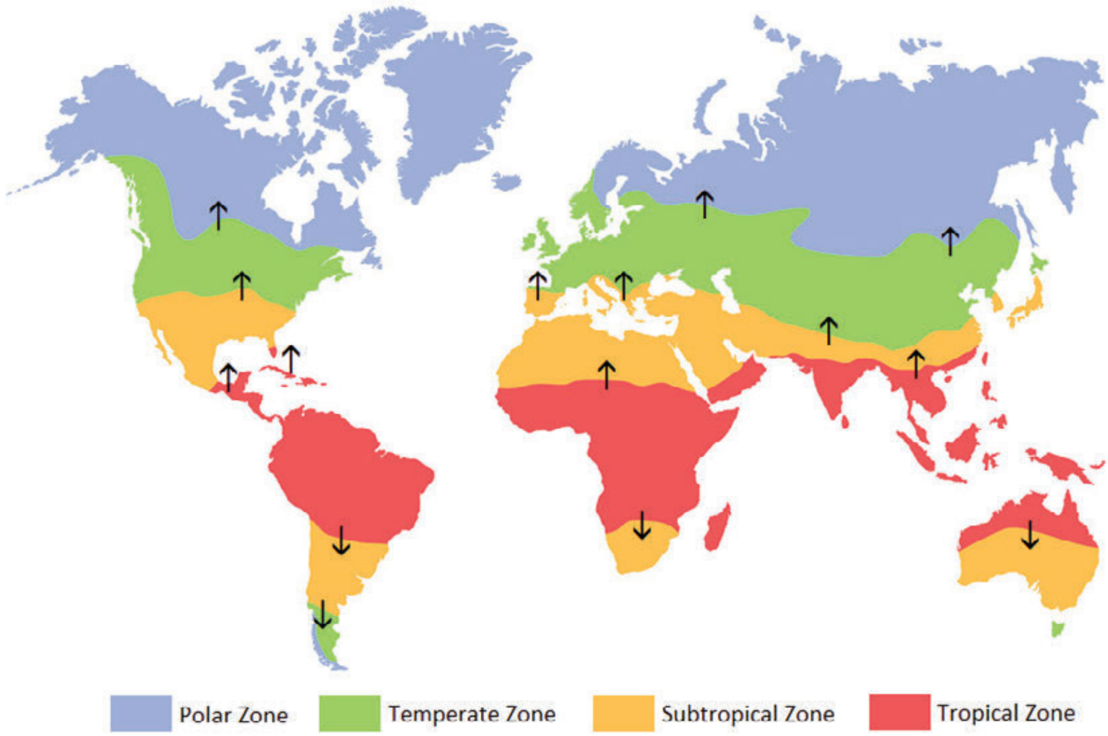
estimates of how these various parameters will change on sub-national, national, and regional scales. For example, Figure 5 shows the regional distribution of projected changes in surface temperature and precipitation for the lower and upper bound RCPs, i.e., RCP 2.6 and RCP 8.5.

Figure 5 indicates that surface temperature and precipitation changes vary considerably from their global averages for different geographical regions, thus highlighting that the physical impacts of climate change will affect some regions and countries more than others.

Climate change will expand the boundaries of the Earth's current climatic zones towards the Earth's poles (see Figure 6). As a result, countries in the tropical and subtropical zones, predominantly developing countries, will be most affected by rising temperatures and precipitation changes that negatively impact on their current agricultural and economic activities. On the other hand, countries in the temperate zone near the subtropical boundary, predominantly developed countries, will see climatic conditions become warmer and generally drier at lower latitudes and more humid at higher latitudes. Moreover, temperate zone boundaries with the polar zone will expand poleward potentially improving climatic conditions for human activities in these regions. There will, however, be other climatic changes in addition to temperature increases that complicate these generalizations. Such changes, which include increases in storm intensity and frequency, extended heatwaves and drought, stronger wind regimes, rising sea level, increased coastal erosion, warming ocean surface waters, and increased ocean acidification, among others, are expected to adversely affect all countries regardless of their geographic latitude.

There is now strong evidence indicating that the warming atmosphere and oceans are driving a poleward shift of climatic zones that will translate into a progressive redistribution of benefits and losses among human populations and ecosystems across regions and countries within them (Weatherdon et al. 2018, AR5 2015, Barange et al. 2014). Human, animal, and fish populations; tourism sites; productive

Figure 6. The Earth's climatic zones (pre-climate change)



Note: Arrows indicate the progressive poleward movement of zone boundaries over time as the atmosphere and oceans warm. A potentially large subset of human, animal and fish populations will migrate poleward as the atmosphere and oceans warm.

Source: Adapted from Rubel and Kottek, 2010.

ecosystems; and high concentrations of tropical pests and disease vectors are projected to move poleward as climatic zones shift. Global economic and trade activity will reconfigure due to these movements, giving rise to new patterns of comparative advantage that will in turn generate new patterns of trade (Gouel and Labourde, 2019). The greatest benefits will accrue to the polar regions and the greatest losses to tropical and subtropical regions (Weatherdon et al. 2018).

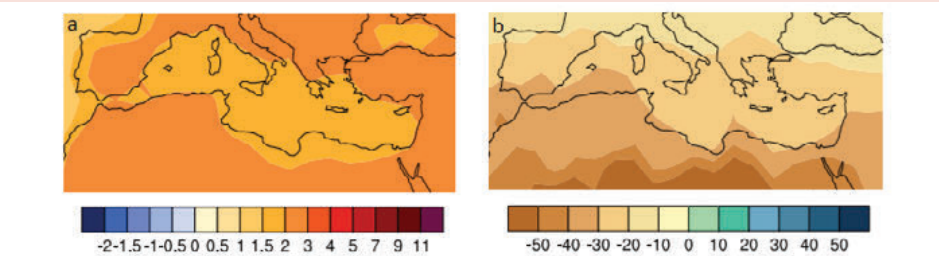
Geographically detailed, country-specific projections of climate parameters, including temperature and precipitation among others, can be generated by GCMs using high spatial resolution grids. Such GCMs and related models – whose results are largely available in the public domain – can be used by national producers and policymakers to assess how changes in climate parameters may impact the productivity of different economic sectors – notably agriculture, fisheries, infrastructure, transport, tourism – and the viability of freshwater resources, ecosystems, and human settlements. Nationally and regionally specific strategies to cope with, and offset, these impacts can be implemented to enhance trade-climate resilience in affected sectors. Box 3 focuses on projected climatic shifts for a particular region, the Mediterranean, showing how temperature and precipitation changes, as well as other climate change impacts, may evolve by 2050 in Mediterranean countries. It summarizes some of the regional impacts of climate change that national and regional adaptation strategies will need to address going forward.

High resolution GCM data can be used to project changes in climate parameters at the national level. The example of Jamaica is presented in Figure 7. As

Box 3. Climate change impacts in the Mediterranean region

The Intergovernmental Panel on Climate Change identifies the Mediterranean as one of the most sensitive regions in the world to climate change. Meteorological records clearly show that both developed and developing countries in the Mediterranean region have become warmer and drier over the past 50 years. IPCC climate models project that this warming and drying will continue and quicken in pace during the coming decades. Extremely high temperatures taking place in extended heat waves will continue to occur during the summer months. Dry spells and drought will increase in intensity and duration. As the accompanying maps show, by 2050, annual average temperatures are projected to be 2°C to 3°C higher than in 2020, and annual rainfall to fall by 10 to 40 per cent.

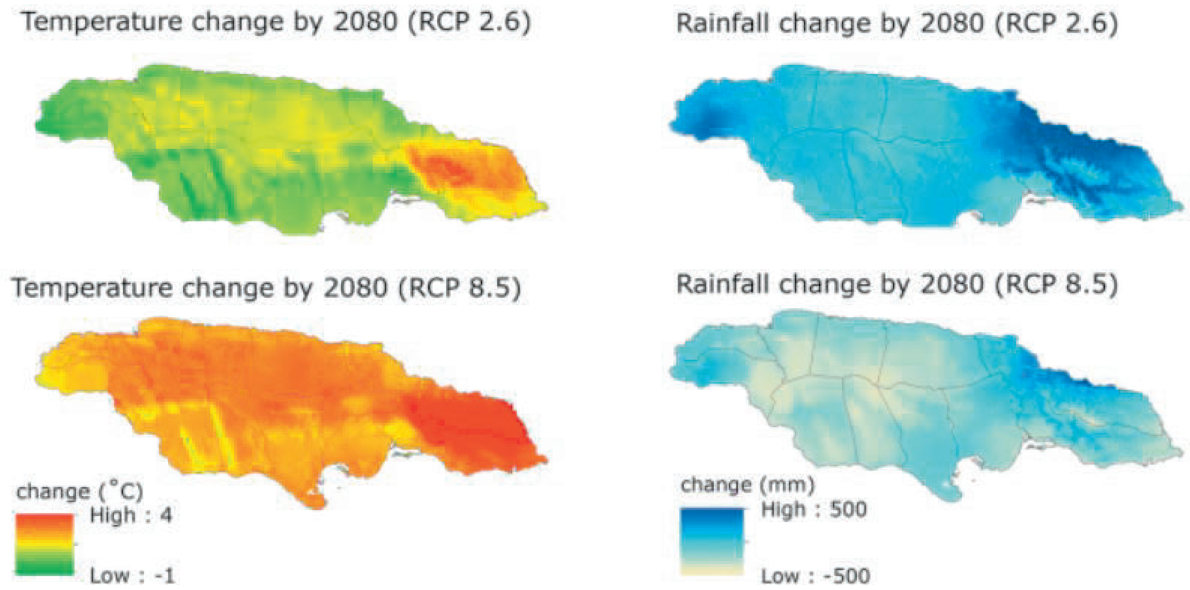
Changes in temperature and precipitation 2010–2020 and 2050–2070 under RCP 8.5



But even more damaging than these changes in annual average temperature and precipitation are extreme meteorological events resulting from climate change. These include heavy rainfall events leading to flash floods, strong winds and associated large tidal swells and storm surges causing coastal flooding, and concomitant heat waves and droughts leading to more frequent and extended forest fires. During extreme weather events, rising sea level, tide and storm surge will combine to raise the Mediterranean seas high enough to cause coastal flooding. Sea level rise of up to 25 cm by 2050, accelerating at increasing rate afterwards, is also expected to significantly impact the region in low lying coastal zones during the current century.

Sources: EEA, 2017; Galassi and Spada, 2014. Maps generated using Royal Netherlands Meteorological Institute Climate Explorer: http://climexp.knmi.nl/.

Figure 7. Projected changes in 2080 of temperature and precipitation relative to 1986–2005 averages in Jamaica under the RCP 2.6 and RCP 8.5 scenarios



Source: Rhiney et al., 2018.

expected, it reveals that temperature and precipitation anomalies from a 1986–2005 baseline are much higher for RCP 8.5 than for RCP 2.6. Research indicates that in Jamaica and the wider Caribbean region, climate (especially in terms of temperature and rainfall) could have significant adverse effects on the agricultural sector, including a general reduction in food production and the displacement of the livelihoods of smallholder farmers (Rhiney et al., 2018).

Country maps that enumerate and quantify the physical impacts of climate change are an essential for ingredient for building national adaptation plans to enhance trade-climate readiness. For some countries, such maps are available in the published literature and for others they can be readily generated from data in the public domain. Moreover, various data visualization tools are available to generate high resolution national maps of projected changes in climate parameters under the RCP scenarios (Dee et al., 2014).

2.5. Climate change impacts on developing country economies and trade

2.5.1. Agriculture and forestry

Seasonal temperature ranges and rainfall patterns are determinants governing the suitability and productivity of agricultural crops and livestock for any given location (Shukla et al., 2020). Crops cultivated, and livestock raised, in developing countries are predominantly species that are well adapted to the local climate, soil, and symbiotic interactions with other native species. However, even small changes in ambient conditions can negatively influence the viability and productivity of livestock and crops. Global agricultural production is thus anticipated to suffer major yield losses throughout the course of this century as the climatic conditions become progressively warmer and precipitation patterns change (Elbehri, 2015; Lobell et al., 2011).

In most developing countries, as the climate warms, agricultural production will place increasing demands on already limited local water supply for irrigation. Livestock production is expected to decline, particularly in Africa (Box 4), due to higher temperatures, increased drought, reduced grassland productivity, and diminished animal health. Extended dry spells and drought, accompanied by higher winds, will raise the risk, frequency, and extent of forest fires.

Some of the physical impacts of climate change that will negatively impact ambient conditions for the cultivation of crops, raising livestock, and agroforestry include:

- increase in seasonal temperatures.
- increase of diurnal temperature maxima and temperature range.
- increased duration of heatwaves and periods of drought.

- increase of daily sunlight exposure.
- increase in aridity and evapotranspiration rates of plants, soils, and bodies of water.
- increase in frequency and severity of forest fires due to extreme heat, drought, and higher winds.
- increased salinisation of groundwater in coastal regions due to seawater infiltration leading to water scarcity.
- reduction of groundwater levels.
- decrease in length of growing and grazing seasons
- decrease in grassland productivity affecting livestock grazing.
- decrease in humidity ranges and river flow.
- decrease in soil moisture and fertility.
- change in precipitation intensity and frequency.
- change in prevalent wind patterns.
- increase in extreme weather events.
- change in predator and prey relationships, introduction of invasive species from warmer regions.

These impacts can have substantial effects not only on production levels of primary agricultural and agroforestry commodities, but on the wider economy as well. In national economies with strong downstream linkages, reductions in primary agriculture and agroforestry production can trickle down and affect productivity in downstream sectors – such as food processing as well as leather and furniture manufacturing – by reducing the availability and increasing the prices of primary inputs (Ouraich and Tyner, 2014).

In addition, while productivity losses may be experienced for traditional agricultural and agroforestry commodities in developing countries, climate change is expected to improve agricultural productivity in developed countries in temperate and polar zones for agricultural products typically produced in developing countries (FAO, 2018). In this way climate change can lead to changes in comparative advantage in international production and trade by introducing new developed country producers into a market that was previously limited to developing country producers before significant climate changes had occurred. Competitiveness effects will also occur, inter-alia, among developing countries. For example, SIDS may be exposed to more frequent and destructive tropical cyclones, and low-lying countries will not be able to relocate production activities to higher altitude locations where temperatures would be cooler and hazards associated with sea level rise would be reduced.

To support national adaptation activities, country level projections on how quickly these impacts will occur, and how significant they will be, are needed as inputs to decision making by sectoral producers and policymakers. Partial to full resilience of exports to climate change can then be achieved when adaptation of agricultural production methods are implemented (Shukla et al., 2020), for example by:

- shifting cultivation and grazing activities to cooler winter months.
- switching cultivation to better adapted agricultural crops / species.
- relocating traditional crop cultivation zones, including to higher altitudes.
- introduction of new livestock species / breeds; and relocation of grazing zones, including to higher altitudes.
- increasing value added in commodities-based exports.
- developing more efficient irrigation systems.
- improving water resource management.
- maintaining crop residues on topsoil to enhance rainwater infiltration and reduce evaporation.
- eliminating trade measures and barriers such as agricultural subsidies, tariff escalation and simplifying rules of origin requirements in export markets that work against increasing economic diversification of production, and exports of higher value-added processed agricultural products by developing countries severely affected by climate change.

It may also be important to diversify out of severely affected sectors into other sectors that are less sensitive to climate change, including the manufacturing and services sectors. This will be critical for ensuring employment and future development prospects of affected regions.

2.5.2. Fisheries

The ocean plays a dominant role in regulating climate change (Reid and Hill, 2016; Li et al., 2020). Ninety-three per cent of the additional heat generated by anthropogenic GHGs is absorbed by the world's oceans; 6 per cent by melting ice and glaciers; and only 1 per cent by the atmosphere. In addition to absorbing heat, the ocean absorbs about 25 per cent of anthropogenic CO_2 emissions. Heat and CO_2 absorption results in significant changes in the oceans physical characteristics, including, sea level rise due to thermal expansion, higher temperatures, vertical stratification of ocean waters, deoxygenation, changes in salinity and evaporation rates, and increased acidity.

Box 4. Reductions in agricultural yields in Africa due to climate change

As the mainstay of Africa's economy, agriculture accounts for the majority of livelihoods across the continent. Africa is therefore a vulnerability 'hot spot' for the impacts of climate variability and change. Increasing temperatures and changing precipitation patterns in the coming decades will present significant adaptation challenges to African farmers. Key risks to agriculture include reduced crop productivity associated with heat and drought stress and increased pest damage, disease damage and flood impacts on food system infrastructure, resulting in serious adverse effects on food security across the continent. Under the business-as-usual RCP 8.5 scenario, major cereal crops grown across Africa will be adversely impacted. Yields are projected to decline for crop varieties but at different rates (see adjacent figure). The overall mean reduction in yield is projected to be 13 per cent in West and Central Africa, 11 per cent in North Africa, and 8 per cent in East and Southern Africa.

Source: WMO, 2020.

Inter-alia, these changes can influence large-scale ocean currents and atmospheric circulation patterns.

Taken together, the confluence of these changes in ocean characteristics has substantial implications for marine life as climate change progresses. The IPCC (Bindoff et al., 2019) and FAO (Barange et al., 2018) have projected the following impacts of climate change on marine life:

- reduced nutrient availability for fish populations due to reductions in primary production caused by ocean acidification.
- reduced vertical upward flow of nutrients and downward flow of oxygen due to vertical stratification of ocean water layers caused by a stable warmer surface layer.
- permanent or seasonal migration of fish species to cooler, more nutrient rich waters at higher latitudes and in deeper waters.
- reductions in polar sea ice will provide new fisheries grounds for migrant fish populations.
- in most regions, ocean acidification will result in reduced production of phytoplankton, zooplankton and crustaceous organisms at the bottom of the marine food chain (lower trophic levels), thus reducing nutrient availability for marine life at the top of the marine food chain (higher trophic levels).
- net nutrient productivity will increase at high latitudes.
- ocean acidification will continue to cause coral bleaching, reducing the productivity of natural fisheries nurseries.
- as surface level ocean temperatures become warmer and nutrient distributions shift, changes in catch levels will occur..

As these impacts progress, climate change will adversely affect the viability of the fisheries industry (Weatherdon et al., 2016):

- fisheries port infrastructure will be degraded by rising sea levels and increased storm activity, and associated coastline erosion.
- for fishing in the tropical zone, fishers' yields will decline due to out-migration of traditional species
- the incursion of novel invasive predatory and pathogenic species may further reduce available catch populations of traditional species.
- warmer coastal waters will lead to increased growth of seaweed and sargassum causing local outmigration of coastal fish populations, obscuring the conduct of artisanal fishing activities and hindering coastal tourism.
- in some regions, freshwater species will be negatively affected by increased water temperatures and reduced precipitation.
- increased saltwater incursion and infiltration into coastal zones, deltas, and estuaries due to sea level rise will negatively impact aquaculture production.
- in many countries, higher ambient temperatures, increased evaporation and reduced precipitation will raise costs and reduce productivity of aquaculture, while stressing local water supply.

While the climate change impacts affecting oceans – and in turn, fish populations and distributions – cannot be reversed, possible adaptations (Shelton, 2014) that can be implemented to sustain the fisheries sector include:

- shifting fishing seasons to adjust for temporal changes in fish population levels.
- shifting fishing areas to enhance yields as fish distributions change.

- shifting targeted fish to more abundant and or novel species suitable for human consumption.
- investing in increased boat sizes for artisanal fishers to allow access to more distant fishery grounds or by reserving certain marine zones for artisanal fishers.
- investing in fishing technologies that allow artisanal fishers to locate and track movements of fish schools.
- providing fishers in declining-yield fisheries with training and employment opportunities in aquaculture and value-added fisheries activities.
- encouraging fishers to diversify their employment profile by including part-time work in other less climate-sensitive sectors.
- investing in storm-resistant harbours, landings and storage facilities to prevent loss or damage from storms and extreme weather and sea surge events.
- investing in protective infrastructure such as seawalls, flood reservoirs, and the reforestation of mangrove areas.
- eliminating trade measures and barriers such as fishing subsidies, tariff escalation, and simplifying rules of origin requirements in export markets that work against increasing economic diversification of production and exports of higher value-added

Box 5. Adapting coastal fisheries to climate change

There are many international technical assistance projects, both completed and underway, that support local fishing communities in developing countries to enhance the resilience of their fishing activities to climate change. A few examples include:

Mozambique
In Mozambique's coastal zone, a $14 million project supported by the Global Environment Facility and implemented by UNDP provided financing for local communities to transition to climate-resilient higher income livelihoods (UNDP, 2017). Support was provided to assist fishers transition to alternative livelihoods in upstream fisheries services and downstream value-added industries. The project also provided training in practices that are viable in high climate variability scenarios to help ensure climate resilient food production.

Eastern Caribbean Countries
To increase resilience and reduce vulnerability to climate change impacts in the eastern Caribbean fisheries sector, a $43 million project supported by the Global Environment Facility and implemented by the FAO helped local fishers develop and implement adaptation measures in fisheries management in Antigua and Barbuda, Dominica, Grenada, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, and Trinidad and Tobago (FAO, 2014). Fisher communities gained Increased awareness and understanding of climate change impacts and vulnerability, and developed effective climate change adaptation in the fisheries and aquaculture sectors to enhance resilience to future climate change impacts.

Chile
Reducing vulnerability and increasing national adaptive capacity to climate change in in the fisheries and aquaculture sector is an important national development objective in Chile. Through a GEF funded project on Strengthening the Adaptive Capacity to Climate Change in the Fisheries and Aquaculture Sector, public and private stakeholders continue to strengthen institutional capacities for climate change resilience by enhancing the adaptive capacity to climate change of local fisheries and aquaculture, and by raising knowledge and awareness of climate change within Chile's fisheries and aquaculture communities (GEF, 2020).

Pacific Island Countries
Under the GEF funded Pacific Island Adaptation project, the Federated States of Micronesia, Samoa and Vanuatu developed coastal management capacity to increase their resilience to current and future impacts of climate change. In each country, vulnerability assessments, and the identification and evaluation of adaptation options was undertaken by national stakeholders to develop adaptation response strategies, policies and measures (UNDP, 2020).

processed fish products by developing countries severely affected by climate change.

Numerous international technical assistance projects assist local fishing communities in developing countries to plan and implement many of these adaptation measures (see Box 5).

2.5.3. Coastal tourism and related infrastructure

Coastal tourism, which comprises a major share of global tourism activity, is expected to suffer considerably from the physical impacts of climate change in the coming decades (Layne, 2017; Weatherdon et al., 2016; Grimm et al., 2018; van Lieshout et al., 2004). Adverse impacts affecting coastal tourism activities include:

- higher temperatures in already warm seaside destinations.
- warming oceans, and ocean acidification damage to near-shore coral reefs which reduces protection against coastal storm and tidal surges.
- sea level rise and beach erosion that damage tourism infrastructure including beachside resorts and hotels, seaports, airports, roads, and both electricity and water networks.
- water shortages for the industry due to saltwater intrusion of fresh groundwater resources.
- increasing frequency of abrupt extreme weather events associated with tropical storms and cyclones.
- stronger tides and flooding associated with tropical storms and sea level rise.
- seaweed and sargassum blooms which can render swimming and boating untenable in beach resorts
- reductions in marine biodiversity that reduce natural attractions offerings in tropical destinations.
- arrival and proliferation of invasive species such as jellyfish and sea snakes that negatively impact beach tourism.
- proliferation of dangerous pathogens and diseases such as malaria as temperatures warm and precipitation patterns change.
- increased competition for freshwater supply with the agriculture sector in countries where precipitation decreases.
- increased competition as climate changes support the development of new tourism destinations in poleward countries that become more attractive to tourists.

These impacts are expected to change global tourism patterns and flows, reshuffling the economic benefits of tourism among countries as climate change progresses. In addition, because developing country tourism infrastructure is financed mainly by foreign direct investment, the high costs of climate proofing infrastructure and increased risks of extreme weather and flooding, alongside the declining attractiveness of current tourism hotpots relative to new destinations, may lead many tourism investors to redirect their financial flows to other locations. The spread of tropical diseases, particularly malaria, will also impact on the attractiveness of destinations. Climate change will also give rise to the increased spread of malaria since the parasite is more vigorous in hot weather and mosquitoes thrive in hotter and wetter conditions that are expected in tropical and some subtropical regions (van Lieshout et al., 2004).

Adapting coastal tourism to climate change will require substantial investments in risk reduction infrastructure to ensure the adverse physical impacts of climate change do not significantly disrupt tourism activity going forward. Sea level rise represents a substantial threat to all developing countries with coastal tourism activities, and particularly for SIDS (Box 6).

Investment will be needed to relocate many existing coastal tourism facilities inland and to higher altitudes where possible. Housing and settlements for the local population working in the industry may also need to be relocated. Investment in seawalls will be needed to protect facilities and infrastructure that cannot be relocated. Water and electricity networks, as well as roads, airports, seaports, and other transportation infrastructure will also need to be climate proofed at considerable cost to local and national governments. Long-term development plans for new tourism attractions and infrastructure in other regions of affected countries which are at low risk of being negatively affected by climate change should also be considered. These new destinations could be centred on ecotourism, agrotourism, and cultural tourism themes.

2.6. Ultrascale visualization and assessment of climate change impacts

Global and regional projections of the future impacts of climate change provide general information needed to raise awareness of how the climate will change going forward, and to inform public opinion on the need to take actions to mitigate and adapt

Box 6. Sea level rise in the SIDS countries

Small island developing states (SIDS) as a group are recognised as being among the most vulnerable to global climate change (Nurse et al., 2014). SIDS possess varying segments of low-lying coastline that are exposed to sea level rise caused by climate change (Oppenheimer et al., 2019). Low-lying sandy shorelines and river deltas are particularly prone to sea level rise and growing storm surges that will arise from climate change. Both can cause beach erosion, inundation and flooding that damages natural tourism assets, collocated infrastructure, and coastal ecosystems. Damages could affect roads, seaports, airports, electricity and water networks, human settlements, and coastal resorts.

Climate change warming over the past century has already resulted in an annual rise in sea level of 1-3 mm/year in the Caribbean region (Cashman et al., 2010), and as climate change intensifies this rate continues to increase. Observations from 1993–2017 indicate a rise in sea level of 3-6 mm/year for the Pacific islands (Aucan, 2018). There are, however, notable differences between islands with some experiencing higher rates of sea level rise, reaching 7 mm/year for Solomon Islands and 12 mm/year in the Federated States of Micronesia (SPREP, 2016).

Under a business-as-usual RCP 8.5 scenario, the global average sea level rise is expected to climb at a rate of up to 16 mm/year and reach a total increase of 1 metre above current levels by 2100. However, sea level rise is not uniform; it varies latitudinally in response to geophysical and gravitational effects. For example, some models predict that as the gravitational field of polar ice caps diminishes when they melt, it will enhance the effect of the Earth's rotation to push water to the equator causing sea level rise in the tropical zone to be higher than the global average (Church et al., 2013).

The projected impacts of future sea level rise on SIDS economies are substantial. Almost one-third of Caribbean tourism resorts are at flooding risk from a sea level rise of 1 metre, and many more would have their beach assets substantially eroded. Sea level rise of 1 metre is projected to put 266 out of 906 tourism resorts and 26 out of 73 airports in the Caribbean at risk of inundation. An estimated 49 per cent of major tourism resorts in CARICOM would be damaged or destroyed by combined sea level rise and storm surge, and by enhanced erosion dues to sea level rise. Annual average losses from wind, storm surge, and inland flooding are estimated to be as high as 6 per cent of GDP in some Caribbean countries (Simpson, M. et al., 2011; Layne, 2017). For the Pacific island SIDS, similar region-wide assessments of damage to tourism and related infrastructure are not available, however, under a business-as-usual emissions scenario the total cost of climate change in the Pacific will continue to grow over the long term, and is estimated to reach 12.7% of annual GDP by 2100 (ADB, 2013).

Suva, Fiji

Castries, St. Lucia

Nassau, The Bahamas

Funafuti, Tuvalu

The geographical extent of sea level rise and the mean annual flood zones associated with sea level rise can be projected for future years for a given global emissions scenario (maps generated using Climate Central Surging Seas Tools - https://sealevel.climatecentral.org/maps).

Under the business-as-usual RCP 8.5 scenario, projected sea level rise and land projected to be below flood level in the year 2100 are shown for the capital cities of Fiji, Saint Lucia, the Bahamas and Tuvalu. While Fiji and Saint Lucia show considerable areas that are expected to be below flood level in 2100 under RCP 8.5, affected areas remain localized. However, for low lying island states such as the Bahamas and Tuvalu, affected areas are extensive, showing that most of land on New Providence Island of the Bahamas, and all of the land on Fongafale Island of Tuvalu, is projected to be below flood level in the year 2100 under RCP 8.5.

to climate change. Such projections also support intergovernmental negotiations on climate change. What the global and regional assessments do not provide are precise indications of the magnitude of physical impacts at national and subnational level. The latter are required by national stakeholders in order to assess the severity, geographical scope and timeframe of physical impacts that are likely to be encountered in their countries. Only after accurate national assessments are achieved can national stakeholders begin to develop effective adaptation actions, and set the required timeframe, and secure the resources needed, for their implementation.

Although climate model results published by the IPCC and other international organizations do not generally map detailed projections of physical impacts at the national and subnational level, climate models are gridded with geographic cells in the range of 50–100 km. Their results can thus be visualized at higher resolution than typically presented, and a wide range of so-called 'ultrascale' visualization tools are available in the public domain that provide quantitative projections of physical climate change impacts with 50–100 km resolution. Moreover, these ultrascale visualizations will improve in the future. Current efforts are seeking to decrease grid sizes of climate models to 1-2 km in order to provide more accurate sub-10km projections (Fuhrer et al., 2018; Schär et al., 2020). Such models may have results available in the public domain over the next few years.

Table 1. Summary of the main physical and economic impacts of climate change in developing countries to 2100

Main physical impacts of climate change	Main economic impacts of climate change
Scope and magnitude depends on the global development path pursued	Adaptation actions require national and local assessments and action plans
• Increased land and ocean surface temperature • Increase of diurnal temperature maxima and temperature range • Temporal shift of local seasons • Changes in the frequency of storm formation • Changes in principal storm locations, wind intensity, and precipitation levels • Increased duration of heatwaves and periods of drought • Increased evapotranspiration in soils • Changes in global and regional wind patterns • Invasion and/or proliferation of harmful species and pathogens • Increased Sea Surface Temperature • Thermal expansion of ocean water • Progressive melting of polar ice masses and continental glaciers increasing ocean volume • Sea Level Rise • Inland expansion of coastal flood zones • Seawater infiltration into coastal groundwater reservoirs • Reduced oxygen content of ocean water • Ocean acidification • Coral bleaching and damage to coastal coral barriers • Reduction in net primary nutrient productivity in marine food cycle • Poleward migration of marine species to cooler waters • Changes in ocean currents and atmospheric jet streams • Increase in seaweed and sargassum growth	• Reduced agricultural productivity in tropical and subtropical zones • Increased costs of agriculture for irrigation, fertilization and management of pests and diseases • Increased demand and declines in supply of freshwater resources • Increased costs for freshwater supply in agriculture and tourism • Reduced fisheries yields of traditional species in tropical and subtropical zones • Increased fishing effort and costs • Reduced coastal fish stocks affecting artisanal fishing, tourism, and livelihoods • Increased storms and extreme weather events impacting coastal tourism, agriculture, and the fishing industry • Reduction in attractiveness of tourism in locales experiencing higher temperatures and elevated extreme weather risks • Reduction in attractiveness of tourism in locales experiencing proliferations of seaweed and sargassum growth • Sea level rise and flooding damage to tourism infrastructure • Disruptions to trade-related transport • High costs and investment needs to climate proof and/or rebuild tourism, transport, and energy and water infrastructure • Increases in insurance costs for agricultural and fisheries producers, and tourism suppliers • Increased competition with poleward industries for agricultural and fisheries producers, and tourism suppliers

Source: UNCTAD based on a synthesis of references cited in this chapter.

Ultrascale visualization of the physical impacts of climate change permit national stakeholders to reliably identify location-specific impacts and more accurately gauge their magnitude and extent. Once the scope of physical impacts is known, stakeholders will be in a knowledgeable position to develop efficient and effective adaptation actions to mitigate the effects of these impacts on economic activities and trade. Table 1 summarizes the physical impacts of climate change and their economic impacts affecting developing countries that have been discussed in this chapter.

3. CLIMATE CHANGE VULNERABILITY IN DEVELOPING COUNTRIES

Chapter 2 indicated that developing countries in the tropical and subtropical zones will be adversely affected by climate change, and that agriculture, fishing, and tourism sectors will be their three sectors most vulnerable to climate change. Many developing countries, and particularly LDCs and SIDS among them, will face significant challenges to maintain production, and related employment and export levels in these sectors over the coming years and decades.

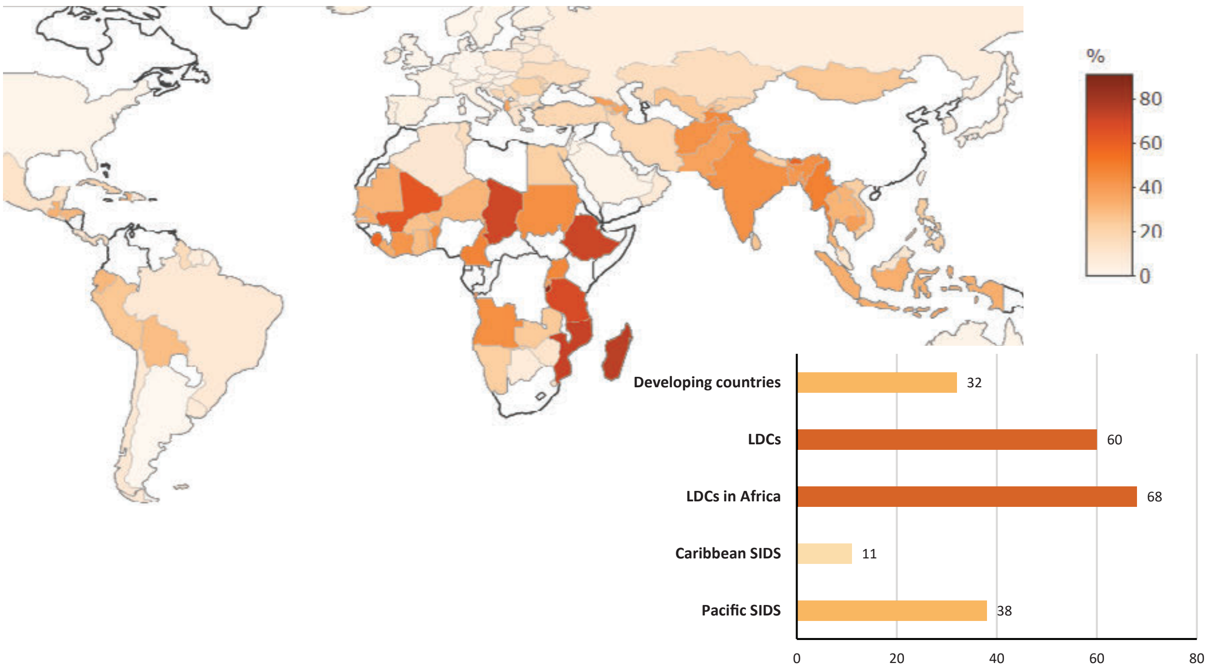
Moreover, within developing countries, people who are already most vulnerable and marginalized will also experience the greatest impacts (Osman-Elasha, 2009). In many settings, women will be more vulnerable than men to the adverse impacts of climate change because they are proportionally more dependent on threatened natural resources then men. In addition, women have less access than men to resources such as land, credit, agricultural and fishing inputs, decision-making structures, technology, training and extension services that would enhance their capacity to adapt to climate change.

After highlighting the importance of agriculture, fishing, and tourism in developing countries' employment and GDP, this chapter reviews the projected impacts of climate change on sectoral productivity and output with a view towards identifying, in Chapter 4, adaptation actions that can limit adverse economic and trade impacts.

3.1. Employment and output in climate-sensitive sectors

While the average share of developing country employment engaged in agriculture, forestry, and fishing is estimated to be 32 per cent (ILOSTAT, 2020), this figure varies considerably among countries. In LDCs the employment in these sectors is substantially higher, ranging between 40 and 80 per cent in most cases, with an average of 60 per cent across LDCs as a whole, and 68 per cent in African LDCs (UNCTAD, 2015). Figure 8 vividly shows the high proportions of employment sustained by agriculture, forestry, and fishing activities in Africa, with the highest levels evident in African LDCs. For SIDS in the Pacific this figure is also higher than the developing country average, at 38 per cent, but relatively low for SIDS in the Caribbean at only 11 per cent (ILOSTAT-KILM, 2020).

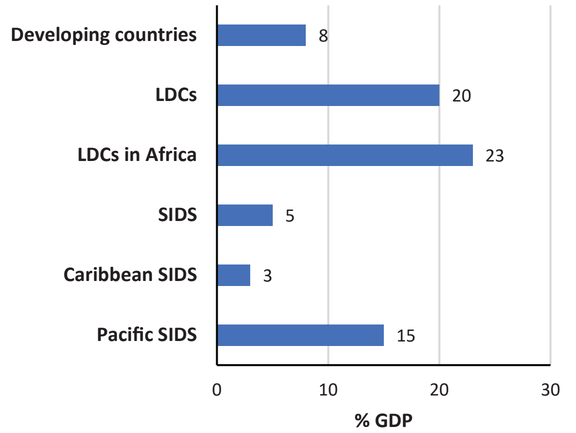
Figure 8. The percentage share of employment in agriculture, forestry, and fishing in 2019



Source: ILOSTAT, 2020; most recent data (data unavailable for countries in map shown in white).

Shares of agriculture, forestry, and fishing contributions to GDP are considerably smaller than their respective contributions to employment ranging from a low of 3 per cent in Caribbean SIDS to a high of 23 per cent in African LDCs (Figure 9).

Figure 9. The percentage contribution to GDP of agriculture, forestry, and fishing in 2018

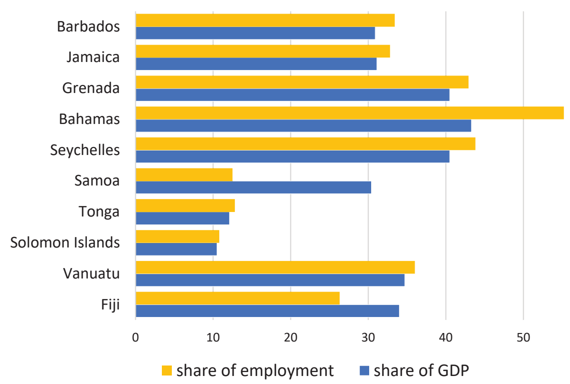


Source: UNCTADStat, 2020.

At the global level, 10.3 per cent of employment and GDP was associated with the tourism sector in 2019 (WTTC, 2020). In many developing countries, this share is larger, making tourism a principal generator of national income (UNWTO, 2014). For SIDS in particular, tourism is a mainstay of the economy; the sector contributes to more than 20 per cent of GDP in two fifths of the SIDS where data is available (UNCTADStat, 2020).

Published aggregated employment data for developing country groups is not available for the tourism sector, however, for many SIDS the shares of employment associated with the tourism sector are among the highest in the world. Contributions to employment and GDP for selected SIDS are presented in Figure 10. Data indicate a variable importance of tourism in SIDS economies. In most Caribbean and Indian Ocean SIDS, tourism plays a dominant role in their national economies, contributing to 30 to 50 per cent of employment and GDP. In Pacific SIDS, some countries such as Fiji and Vanuatu have substantial tourism sectors contributing from 25 to 35 per cent of employment and GDP, while for others such as Samoa, Tonga, and Solomon Islands, these figures range only between 10 and 20 per cent. Data on LDCs reveal that the contributions of tourism to their jobs and national income are largely similar to the global average (WTTC Data Gateway, 2020).

Figure 10. Tourism contributions to employment and GDP in SIDS in 2019



Source: WTTC, 2020.

3.2. Exports of products and services in climate-sensitive sectors

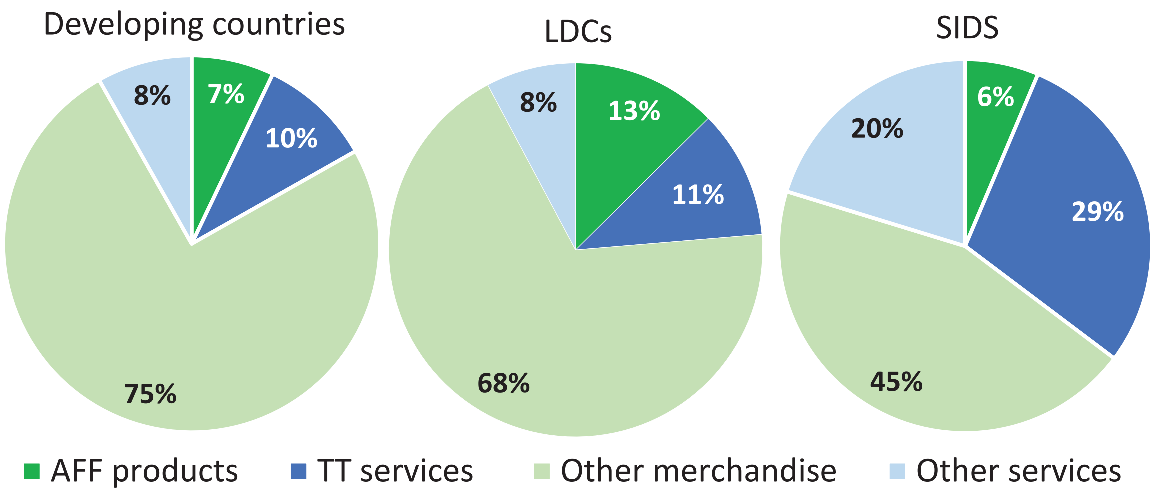
Developing countries are characterized by a wide variety of economic and trade profiles. The majority, 66 per cent, are commodity dependent; and in LDC the share goes up to 84 per cent (UNCTAD, 2019a). Many tend to be dependent on commodity exports. Climate change is a source of important shocks to commodity sectors, posing dire social and economic risks to people and countries dependent on commodities (UNCTAD, 2019b). In some developing countries with growing levels of value addition applied to commodities prior to their export, these risks are reduced.

There are also several developing countries that have managed to build a strong services sector, largely due to the role of information and communications technology, without ever establishing a strong manufacturing base (UNCTAD, 2019c). This has led to their establishment of export-oriented business process outsourcing services and call centres (Mode 1 services trade). Many developing countries have established services for foreign visitors in the tourism sector and other downstream sectors including financial, real estate, health, recreational, telecommunications, and transport services (Mode 2 services trade).

Figure 11 presents the export profiles of developing country as a group, and of both LDCs and SIDS. The presented data indicate the share of exports associated with 'climate-sensitive' products:

- agriculture, forestry, and fisheries products (AFF products); and,
- travel and transport services (TT services).[5]

Figure 11. Developing country export profiles in terms of shares of total (goods and services) exports



Note: Export shares of agriculture, forestry, and fisheries products (AFF products); travel and transport services (TT services) and other merchandise and services, as a share of total exports in 2019. AFF products and TT services are climate-sensitive export categories. AFF products are all primary commodities excluding fuels, ores, and metals, i.e., SITC 0+1+2+4-27-28 (SITC 4 classification). TT services are the sum of travel and transport services. Travel services includes goods and services acquired from an economy by non-resident travellers during visits shorter than one year. Transport services include all transportation services that involve carriage of passengers, movement of goods (freight), rentals with crew, and related supporting services. Travel and transport data used are for the latest available year which have been extrapolated to 2019 values using reported total services data for 2019.

Source: UNCTADStat, 2020.

Taken together, these two climate-sensitive export categories account for 17 per cent of developing country exports. For LDCs this figure is higher at 24 per cent, and higher still for SIDS at 35 per cent. These figures provide a gauge of the vulnerability, or level of risk exposure, of developing countries to adverse physical impacts of climate change. They indicate that at least a quarter of LDC exports and one third of SIDS exports risk becoming significantly impacted by climate change in the future.

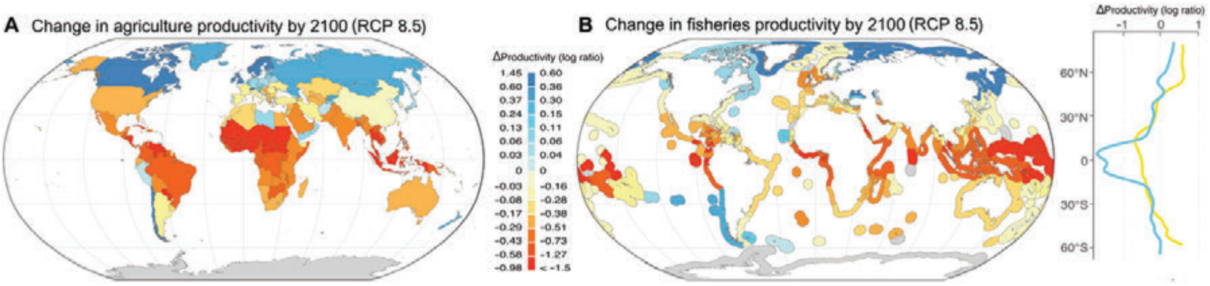
3.3. Projected declines in productivity and output

The distribution of benefits and losses resulting from climate change will have many sectoral facets, but with existing economic and modeling data this distribution can be viewed in terms of changes in agricultural and fisheries productivity. Thiault et al. projected changes in productivity of agriculture (maize, rice, soy, and wheat) and marine fisheries to the end of the century relative to current values under the RCP 8.5 business-as-usual scenario wherein adaptation actions are not implemented. Their results shown in Figure 12 clearly show the contrast between future impacts on agriculture and fisheries experienced by developing countries at lower latitudes (substantial losses) and developed countries at higher latitudes (a mix of limited losses and potential gains).

Relative to productivity levels in 2020, these model results project agricultural and fisheries productivity losses for LDCs and SIDS in the tropical zone of 20 to 30 per cent, and in the subtropical zone of 5 to 15 per cent, by 2100. These losses do not take into account adaptations that may be effected in the interim. Since adaptations are possible, and since global mitigation efforts may achieve lower emissions trajectories than the business-as-usual RCP 8.5 scenario, productivity levels in developing countries may not decline as much as these model results project.

Economy-wide impacts of climate change have also been modelled recently in several studies (Kahn et al., 2019; Burke et al., 2015; Kompas et al., 2018; Roson

Figure 12. Projected losses in agricultural and fisheries productivity in 2100



Note: Estimated changes in (A) agricultural and (B) fisheries productivity under a business-as-usual development path RCP 8.5 in 2100 relative to 2020. From higher to lower losses, the colours red, orange and yellow indicate losses in productivity. From lower to higher gains, the colours light blue to darker blue indicate productivity gains. The changes in productivity are expressed as logarithms, e.g., a productivity change of +1 (-1) indicates a gain (loss) in productivity of 10 per cent while a productivity change of +1.5 (-1.5) indicates a gain (loss) in productivity of 30 per cent.

Source: Thiault et al., 2019.

and Sartori, 2016). These models primarily project changes in GDP at national levels based on changes in temperature and the effects of temperature changes on worker productivity. As ambient temperatures rise in the coming decades due to climate change the impact of heat stress on labour productivity is likely to be among the most serious economic consequences of climate change (ILO, 2019).

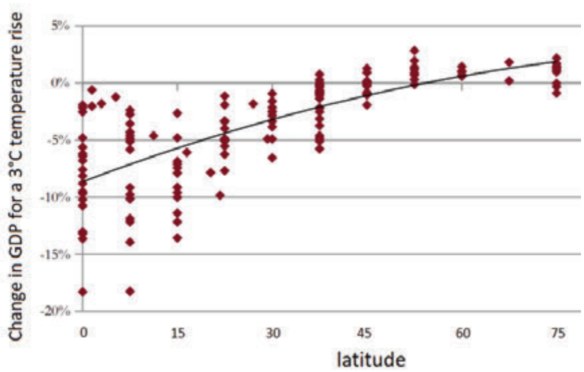
Based on empirical studies examining the effects of temperature on worker productivity since 1960, economic productivity is correlated to temperature in all countries, with productivity peaking at an annual average temperature of 13 °C and declining strongly at higher temperatures. The relationship has been observed to apply to both agricultural and non-agricultural activity in both developed and developing countries (Burke et al., 2015).

As average annual and daily temperatures rise due to climate change, economic losses are expected to occur across economies in the agriculture, industry, and services sectors. LDCs and SIDS in the Earth's tropical zone will be the most vulnerable countries to progressive climate change related heat stress increases because of their high starting levels of ambient heat and humidity exposure, and their relatively low capacity to finance adaptations (i.e., air conditioning, insulation, building improvements, tree cover for shade, etc.).

According to a recent modelling study, the impact of temperature caused by climate change, in the absence of mitigation policies, reduces world real GDP per capita by more than 7 percent by 2100 for the RCP 8.5 scenario; a level consistent with other recent studies projecting a 5 to 10 per cent decline (Kahn et al., 2019). Importantly, model results suggest that in addition to GDP losses, rising temperatures also lower long-term economic growth rates.

All studies show considerable variation in the impact of climate change on GDP, with countries in tropics experiencing the greatest losses. Figure 13 illustrates the relationship between countries' latitude and GDP change, for a 3°C increase in temperature, that has been reported in one recent study (Roson and Sartori, 2016).

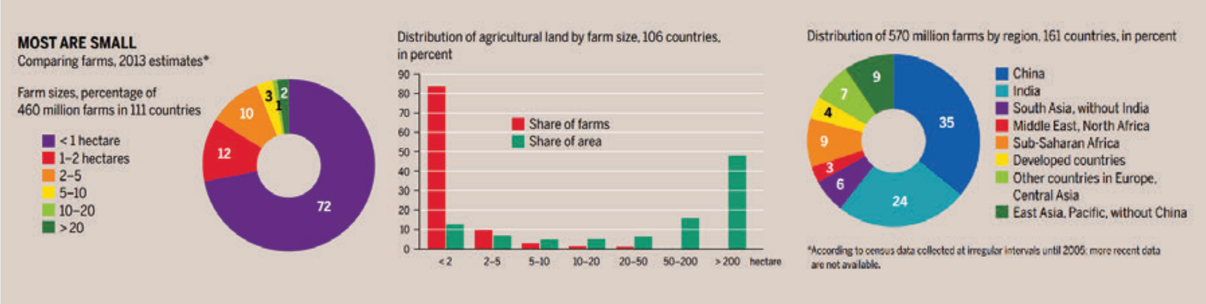
Figure 13. Variation of GDP with latitude



Source: Roson and Sartori, 2016.

Given the projected adverse impacts of climate change on developing countries' agriculture, fisheries, and tourism sectors it is important to review the underlying sources of vulnerability in each of these climate-sensitive sectors in order to identify ways in which risks and hazards can be reduced.

Figure 14. Developing country farms



Source: Heinrich Böll Foundation, 2015.

3.4. Agriculture: small farms facing big challenges

Agriculture will be heavily affected by climate change, with strong differences between regions. A large share of the population in developing countries depends on agriculture, forestry, fishing, and hunting for their livelihoods. In 2019, exports associated with these activities accounted for 9 per cent merchandise exports from developing countries; 16 per cent for LDCs and 12 per cent for SIDS (UNCTADStat, 2020).

The world's water supplies are already unevenly distributed, and climate change will exacerbate this situation. Climate change will reduce renewable surface water and groundwater resources in most dry tropical and subtropical regions. More than seventy per cent of agriculture around the world depends on rainfall as opposed to irrigation (Reddy and Syme, 2015). As a result, agriculture is very sensitive to changing patterns in precipitation, temperature, and extreme weather events. Increased water scarcity will significantly affect agricultural output in developing countries.

With limited land, technological, and financial resources, smallholder farmers will be least able to adjust to changes in temperature and precipitation. And because the size of the vast majority of farms around the world is less than 1 hectare, climate change is poised to dislocate productive activity for the majority of the world's farmers. Figure 14 shows that China and India account for almost 60 per cent of the 570 million farms currently active in 161 countries. Such smallholders are at the frontlines of current and projected climate change impacts. Climate change will alter market dynamics and change the suitability of land for crops, resulting in new supply, demand, trade, and price dynamics. These changes will give rise to new patterns of comparative advantage and competitiveness for agriculture, generally, and for individual crop and livestock varieties, specifically.

Globally, there will be a cumulative loss in crop productivity, although some countries at higher latitudes will experience gains. Given that food demand is inelastic, and that population growth will lead to a consistent increase in demand, food prices can be expected to increase substantially. Farmers in net food exporting developing countries may benefit if they adapt effectively, while net-food-importing countries will see expenditures for food imports rise substantially. Almost certainly, increased food prices will also lead to increased poverty among the poor. Farmers will need to reallocate their land to crops that have more productive yields as climatic conditions worsen, taking into account changing market dynamics (Gouel and Labourde, 2019). Supporting smallholders in such endeavors can help ensure food security and lessen the need for costly agricultural imports (Heinrich Böll Foundation, 2015).

3.5. Fisheries: fish on the move as waters warm

Fisheries are an important natural resource providing wealth, employment, tradition, and culture to developing countries. In many developing countries, they make a critical contribution to ensuring adequate protein intake and food security. Annual global per capita fish consumption grew from 9 kg in 1961 to 20.3 kg in 2017, providing an increasing share of protein intake around the world (FAO, 2020). Developing countries depended on fish for more than 11.7 per cent of their consumed animal protein in 2017, while in some SIDS this figure exceeded 50 per cent. The economic value and contribution of fish to food security make it critical that its place among diets in the future, particularly in island nations.

Nearly 60 million people work in primary fisheries and aquaculture production globally, and it is estimated that 200 million jobs are directly or indirectly connected with the fisheries sector (FAO, 2020). In developing countries, fisheries sector employment consists predominantly of small-scale artisanal fishers, in contrast to the industrial fishing mainly undertaken by large-vessel fleets from Asian countries, followed by the fleets from the Americas, Africa and Europe.[6]

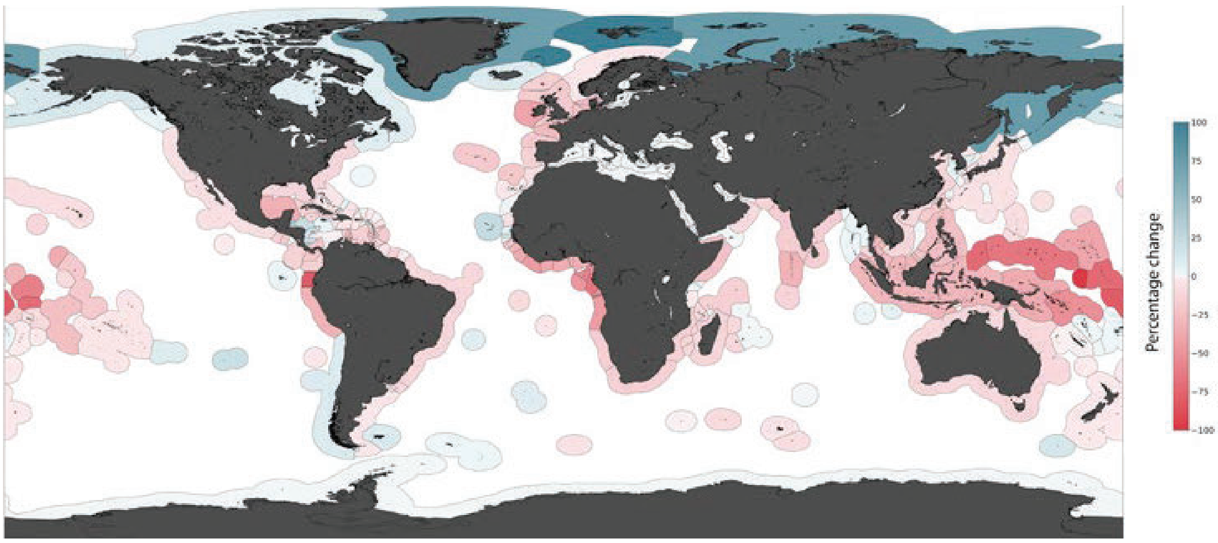
Global production reached 178 million tonnes in 2018, with 52 per cent derived from capture fisheries (both marine and inland) and 46 per cent from aquaculture. Total first sale value of fisheries and aquaculture in 2018 was $400 billion. Aquaculture production accounted for close to two thirds of this total at $250 billion. Aquaculture is also responsible for most of the increase in fish consumption since the late 1980s. However, intensive aquaculture needs to be sustainably managed, as it often takes place in and deteriorates mangrove areas which play a key role in carbon sequestration (Donato et al., 2011) and in protecting coastal communities from storm surge.

About 37 per cent of fish production enters international trade. Countries differ widely in their fish consumption choices, resulting in fish being a strongly traded commodity. Several countries have a fish trading profile whereby they export much of their extracted fish, and at the same time import other fish species for local consumption. Many developing countries import fish species that are not available in their waters to supply fish to the tourism industry, as international hotel chains often seek a specific set of fish choices for their customers.

Climate change will result in significant changes to the availability and trade of fish products, with potentially important political and economic consequences, especially for those countries most dependent on the sector. Ocean warming is expected to increase progressively, leading to changes in the distribution of fish stocks as species move to seas of cooler temperatures. As a result, marine fisheries production will increase in some countries, while decreasing in others (Laffoley and Baxter, 2016). Climate warming may also significantly affect aquaculture production in developing countries due to saltwater infiltration of production sites, limited freshwater supply, and increased risk of disease outbreaks associated with higher temperatures.

Models projecting changes in the availability of 779 commercial fish species under two emissions scenarios up to 2100, estimate that the average tropical country's Exclusive Economic Zone (EEZ) will lose 7 per cent of species fished in 2012 under a low emissions scenario (RCP 4.5). In addition, FAO's Climate and fisheries model projections in 13 marine regions suggest decreases in maximum catch potential in the world's EEZs of between 2.8 per cent and 12.1 per cent by 2050 (Barange et al., 2018). These figures increase to a loss of 40 per cent under the high emissions scenario (RCP 8.5). Northwest Africa, Southeast Asia, East Africa, Central America and the Caribbean are projected to suffer most.

Figure 15. Projected changes in maximum catch potential (%) under RCP8.5 by 2050



Source: Cheung, W.W.L. et al., 2018.

Box 7. Palau's National Marine Sanctuary

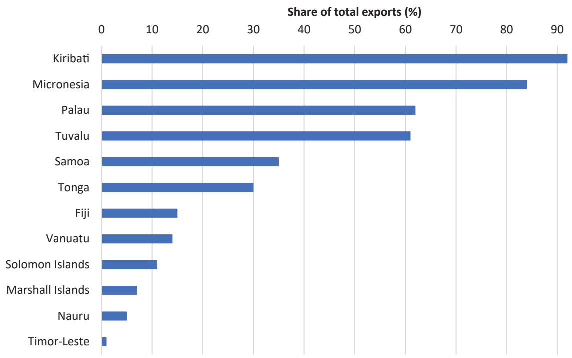
Representing one of the world's largest marine protected areas (MPA), Palau's National Marine Sanctuary was established in 2020 (GLISPA, 2015). The Sanctuary protects 80 per cent of Palau territorial waters from fishing and mining, thereby also protecting one of the world's largest tuna stocks. The rest of Palau's territorial waters are reserved for fishing. One observed consequence of the ban on fishing so far has been an increase in catch of species close to the shore. Palau officials are therefore working to ensure that the country's fishing fleet can access enough tuna in the 20 per cent of territorial waters still available for fishing.

Marine ecosystems are being altered by direct effects of climate change including ocean warming, ocean acidification, rising sea level, changing circulation patterns, increasing severity of storms, and changing freshwater influxes. As impacts of climate change strengthen they may exacerbate effects of existing stressors and require new or modified management approaches. MPAs provide an effective approach address multiple threats to the marine environment (Keller et al., 2009).

Countries will experience the long-term migration of fish species out of their EEZs for the first time, which may create incentives for overfishing right before the fish exit their seas, and to increased engagement in high seas fishing by their fishers.

Tropical and subtropical countries are expected to see the largest gaps between the quantity of fish needed for healthy nutrition and the local fish harvest. According to the projections shown in Figure 15, Pacific SIDS will experience the largest decrease in maximum catch potential under RCP 8.5 by 2050. This will certainly translate into substantial negative trade impacts since fisheries products are among their top exports. In all developing regions, countries will have to adapt their ocean/blue economy and fish trade strategies to the reality of the declines in their fisheries' potential yields.

Figure 16. Pacific SIDS fish exports



Source: UNCTADStat 2020.

For many Pacific SIDS, fish make up a predominant share of their export earnings (Figure 16). In 2018, fish exports represented more than half of all exports in several Pacific SIDS. Ocean warming and acidification is forecast to reduce fish production by twenty per cent in 2050, mainly due to the resulting ocean acidification, coral bleaching and changes in migratory patterns. Pacific SIDS may need to cover the shortfall in fish by catching more tuna, which is abundant in the region. According to models of the effects of ocean warming, skipjack tuna are expected to move eastward. As a result, it will be easier for fishers in Kiribati, Cook Islands and French Polynesia to catch tuna than in western Pacific states. In an effort to preserve Pacific tuna populations, Palau has established a marine protected area (MPA) which also serves to reduce the impacts of ecosystem stressors of climate change (Box 7).

In Southeast Asia, overfishing has resulted in a significant reduction of fish stocks in recent decades. Freshwater aquaculture and mariculture have been filling the gap created in marine fisheries. In light of ocean warming, marine fishery harvests in southeast Asia will decrease by between 20–30 per cent, accompanied by a loss of 20 per cent of marine biodiversity by 2050. Such a change will have serious implications for economies with shorelines in South East Asia and on the South China Sea because millions of people are employed in the fishing industry in this region (Laffoley and Baxter, 2016).

Another developing region with high dependence on fishing is the western Indian Ocean where overfishing and unsustainable fishing practices have affected fish stocks in several coral reef areas. Population growth, continued overfishing, and further damage caused by ocean warming will continue to reduce the contribution of coral reef fishing in the coming decades. This will result in diminished food security and livelihoods unless strategies are devised to counter this trend.

3.6. Within the services economy, tourism faces the greatest climate risks

The contribution of services to economies has increased over time. In 1980–2018, the share of services in GDP increased in all income level groups, including from 61 to 76 per cent in developed economies and from 42 to 56 per cent in developing economies (UNCTADStat, 2020). In 2018, as a share of national income, GDP generated by services reached 49 per cent in LDCs and 69 per cent in SIDS (Figure 16). While most services are supplied domestically, trade in services has assumed great importance over the past decade. As shown in Figure 17, from 2010–2019, services exports have increased by 55 per cent globally, and by 62 per cent and 103 per cent in SIDS and LDCs respectively.

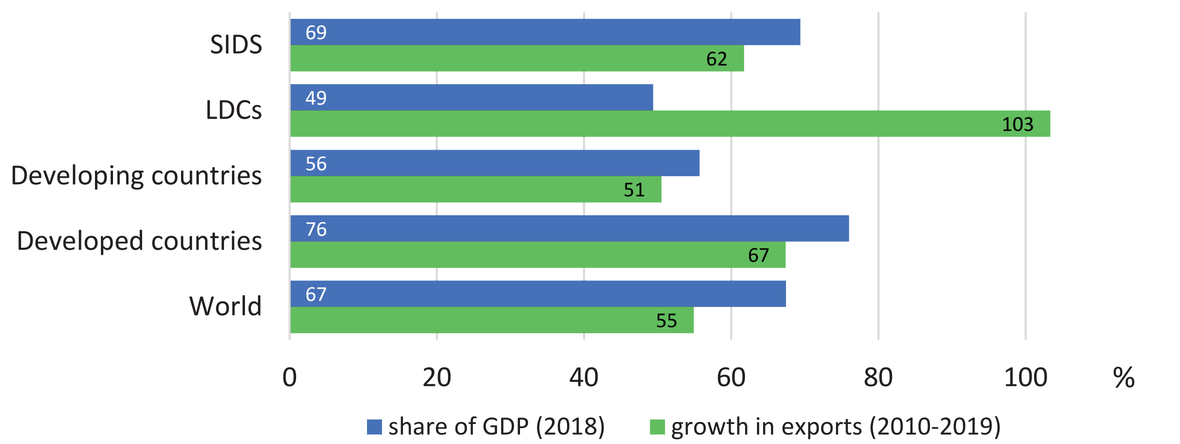
Developed economies continued to dominate in higher value-added services categories including insurance, financial, IP, and other business services exports with a share of 78 per cent of the total in 2019. As for developing countries, which accounted for 30 per cent of world services exports in 2019, transport and travel services, which include tourism, were their most important services exports.

Developing countries in Asia and LDCs experienced significant growth in services exports since 2010. Although transport and travel services still account for the predominant share of their services exports, higher value-added categories such as telecommunications, computer and information services, and financial services and other business services have been increasing, with annual growth rates of 13, 12 and 9 per cent, respectively. For LDCs and SIDS, rapidly growing travel and transport exports respectively accounted for 65 and 85 per cent of their services exports in 2019.

Although services trade has been observed to be more resilient to economic downturns in comparison to trade in goods, it remains vulnerable to the impacts of climate change. With substantial coastal infrastructure, tourism is especially vulnerable. Many developing countries, especially in the Caribbean, are obliged to invest heavily in climate proofing their tourism sectors by upgrading resorts or moving them inland. They are also gradually transitioning away from beach tourism to ecotourism which is less reliant on infrastructure.

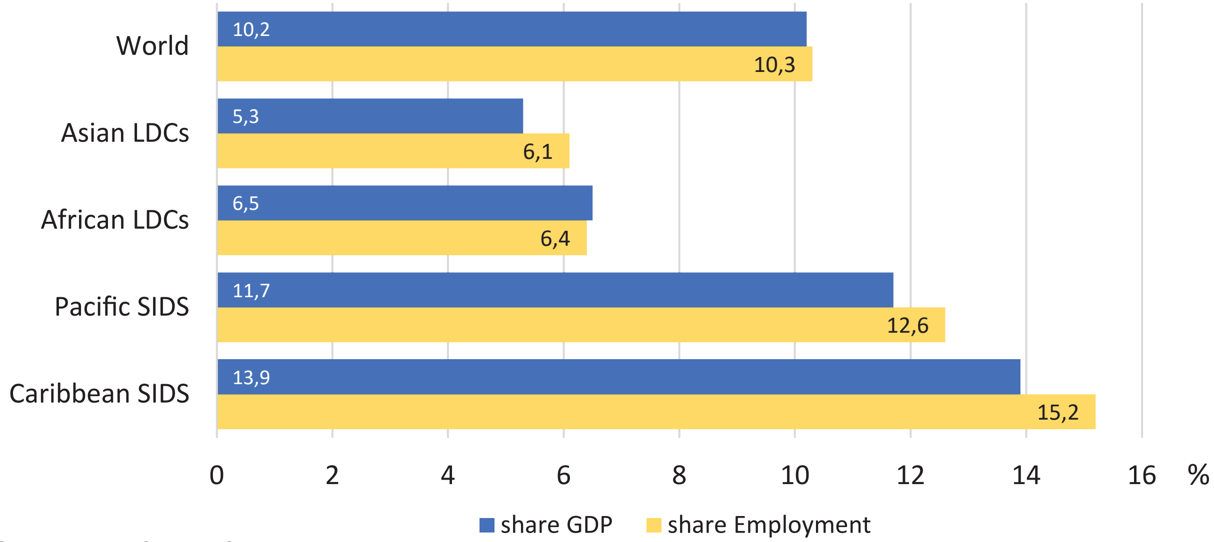
Services imports are also an important part of the overall services trade picture for developing countries. For example, given that agriculture is an important economic sector in developing countries, there is value in exploring ways in which services can enhance climate resilience in the sector. Information and communications technology (ICT) services are especially relevant in this context. Providing information on weather advisory services to smallholder farmers can help them prepare for extreme weather events, and access loans needed to respond to such events. Mobile-phone based weather and financial services can help smallholders that would otherwise remain beyond reach (FAO, 2019).

Figure 17. Services share of GDP and rate of export growth



Source: UNCTADStat, 2020.

Figure 18. Share of travel and tourism in GDP and employment



Source: WTTC Data Gateway, 2020.

Globally, travel and tourism generated $8.9 trillion ($24.3 billion/day) of income in 2019 (WTTC, 2020). This income, distributed among all countries at all levels of development, represents the sum of direct, indirect, and induced income associated with international and domestic tourism.[7] In terms of direct income related only to international tourism reported by countries as exports, travel and tourism generated $4.7 billion in 2019 (UNWTO, 2020a)[8] making travel and tourism the world's top services export and its 3rd highest sectoral export after chemicals and fuels (accounting for nearly 7 per cent of total global exports and 28 per cent of global services exports). Over 330 million jobs are directly or indirectly related to travel and tourism which equates to 1 in 10 jobs around the world. Tourism is also a major attractor of domestic and foreign investment accounting for $948 billion of capital investment in 2019.

The worldwide contribution of travel and tourism to GDP was 10.3 per cent in 2019, and its annual turnover has been growing at a faster pace than global GDP for the past 10 years. With growing developing country participation, tourism has become a major contributor to their income and growth. In over 150 countries, travel and tourism is one of five top export earners, and in 60 it is the number one export. It is the main source of foreign exchange for one third of developing countries and one half of LDCs, where it accounts for up to 40 per cent of GDP.

Tourism continues to demonstrate its importance to national economies with a consistent contribution to economic growth and development especially for developing countries where tourism impacts on the economic and social development are mostly positive. Figure 18 presents the total contribution of travel and tourism to GDP and employment in selected developing country regions.

Tourism is not only a major contributor to developing countries economies; it is also among their fastest growing sectors. Globally, the travel & tourism sector experienced 3.5 per cent growth in 2019, outpacing the global economy growth of 2.5 per cent for the ninth consecutive year (WTTC, 2020). Since 2010, the average travel and tourism growth rate has been 3 per cent for SIDS and 3.5 per cent for LDCs (WTTC Data Gateway, 2020), highlighting the importance of the sector in the economic growth of developing countries.

Tourism linkages to other economic sectors are diverse and deep (UNCTAD, 2010). The sector requires support – for example, to build and operate hotels, restaurants, and other tourism related facilities – through backwards linkages with basic infrastructure services such as energy, telecommunications, environmental, agricultural, manufacturing, and construction services. It also has a wide range of forward linkages with sectors supplying services consumed by tourists such as financial, telecommunications, retail, recreational, cultural, personal, hospitality, security, and health services. These strong linkages catalyze a multiplier effect that generates broad-based economic benefits at the national level as well as employment opportunities and poverty reduction at the local level.

Without strong tourism linkages such benefits do not materialize. At the same time, however, if tourism levels fall, sectors linked to tourism will also be adversely affected. In countries where tourism is a major contributor to the national economy, declines in tourism activity can lead to economy-wide domino effect impacts due to its strong downstream linkages. If a downturn in tourism activity is prolonged, decreased investment in the sector will also adversely affect upstream linked sectors such as the construction, energy and water services industries.

Tourism is especially climate-sensitive. As most types of tourism, coastal tourism especially, are weather dependent, tourism is a very climate dependent economic activity. As climate change progresses over the coming years and decades, there will be a gradual shift in locations that possess the ideal temperatures, minimal rain and storm conditions, abundant local food and water supply, low levels of pests and disease, and quality of beaches, needed to attract and accommodate tourists.

The significant contributions of travel and tourism to GDP, exports, employment and growth in developing countries risks reversals when climatic variables change. These risks are particularly high for SIDS where tourism accounts for more than 30 per cent of total exports in the majority of the 38 SIDS (UNWTO, 2020b). In some countries, this proportion is even higher, making them especially vulnerable to falling tourist numbers, as witnessed during the 2020 Coronavirus pandemic (Box 8).

Box 8. Coronavirus and SIDS

International tourist arrivals declined sharply by 47 per cent in SIDS during January–April 2020 and continued to fall throughout 2020 due to the Coronavirus pandemic. The road to recovery is set to be long. Such a major shock translates into a massive loss of jobs, a sharp decline in foreign exchange and tax revenues which curbs public spending capacity and ability to deploy the measures necessary to support livelihoods through the crisis. Women, who account for half of the workforce in almost all SIDS, and informal workers are particularly at risk.

Many SIDS have deployed measures to sustain businesses and jobs, often supported by international and regional institutions yet more support is urgent. The external debt of the SIDS accounts for 58 per cent of GDP on average and foreign reserves are generally low, with many SIDS possessing only the reserves sufficient for a few months of imports. Estimates also suggest that SIDS economies could shrink by 4.7 per cent in 2020 as compared to 3 per cent for the world economy. SIDS require international support to counter the devastating impact of Coronavirus on tourism, their economies and livelihoods.

Sources: UNWTO, 2020b; United Nations, 2018; UNDESA, 2020.

4. ADAPTATION COSTS AND FINANCING

Chapter 3 discussed the economic implications of climate change for major economic sectors in developing countries. This chapter aims to explore near- and long-term pathways that can help them cope with these impacts and pursue socio-economic development in a sustainable manner.

Actions to adapt to climate change by developing countries remain largely overdue on the economic and trade fronts. So far, developing countries have paid relatively little attention to long-term economic and trade strategies that increase their preparedness for both near- and long-term shocks. The longer they wait, the larger the future damage will be. An increase in awareness of how climate impacts affect their economies and trade is the first step that needs to be taken towards crafting policies and measures that can minimize future economic losses, while also taking advantage of new opportunities where relevant. Adaptation efforts with long term foresight and perspective are critical as they save resources many times over in comparison to no-measures scenarios that cope with future climate related damage as it occurs.

Many developing countries face common challenges when seeking to increase their trade-climate resilience through adaptation actions. They must find ways to better manage and decrease their high debt levels to be in a position to finance adaptation actions. Many must also finance the high cost outlays needed to recover from damages caused by an already increasing incidence of natural disasters.

There are various ways in which countries can take adaptation steps. Structural or physical adaptation involves the engineered and built environment, technological upgrades, ecosystem-based adjustments, and services. Social adaptation can be in the form of education, information, and behaviour modification. Institutional adaptation with a longer-term perspective is also important, involving structural changes in the economy, laws and regulations, and government policies and programs (Klöck and Nunn, 2019).

Some climate change mitigation actions can also be leveraged to support adaptation objectives. For example, moving to off-grid renewable energy solutions in rural areas can help developing countries improve their economic resilience, both in the form of reducing their dependence on fossil fuel imports, and enhancing their ability to maintain electricity supply during and immediately after extreme weather events.

Increasing forest stocks and advancing biodiversity conservation and restoration are also areas offering synergies for both mitigation and adaptation. It is estimated that nature-based solutions can offer up to 37 per cent of climate mitigation needed by 2030 to keep global warming below the 2 C° threshold (IPBES, 2019). Simultaneously, safeguarding and enhancing ecosystems contributes to the adaptation capacities and climate resilience of the 4.3 billion people who depend upon them for their livelihoods; mainly people in developing countries that will be affected most by climate change (UNCBD, 2016).

4.1. Costs and international public financing of climate change adaptation

Adaptation to climate change is gaining increased attention in developing countries as confidence in climate change models grows and demonstrated international actions to mitigate GHG emissions remain extremely limited and insufficient to significantly alter emissions trajectories from a business-as-usual scenario. The IPCC has enumerated and outlined the potential scope of the numerous adaptation actions that may need to be implemented for a wide range of economic sectors including in energy, water, transport, agriculture, forestry, fishing, mining, housing, health, and tourism among others (Agard, J. et al., 2014). Moreover, actions taken to address impacts in these sectors must be implemented in a holistic way since impacts on one sector of the economy will in turn affect other sectors though product and input markets.

Despite developed countries' dominant role in contributing to historical GHG emissions, the burden of climate change adaptation will predominantly beset developing countries where the adverse physical impacts of climate change will be most pronounced. And while developing countries urgently need to advance their adaptation efforts due to their substantial and numerous vulnerabilities, the adaptation costs they will incur are extremely high.

If the UNFCCC Paris Agreement goal of limiting climate change warming to 2°C is met, the aggregate cost of adapting to climate change in developing countries has recently been estimated by the United Nations Environment Programme (UNEP) to range between $140–300 billion annually in 2030, and between $280–500 billion annually in 2050 (UNEP, 2016; OECD, 2020). For higher emission scenarios of global warming, estimates of the adaptation costs in developing countries would be considerably higher, even in the near-term.

In implementing the Paris Agreement, countries are required to submit nationally determined contributions (NDCs) which detail the actions they plan to undertake nationally towards meeting the Agreement's global goal. Fifty countries have included adaptation actions in their NDCs. Based on these submissions, and extrapolating costs for other developing countries, the current global adaptation has been estimated to be approximately $115 billion a year (Hallegatte, S. et al., 2020).

In 2009, at the 15th Conference of Parties (COP15) of the UNFCCC, developed countries committed to jointly mobilize $100 billion per year in climate finance by 2020 to address the climate change mitigation and adaptation needs of developing countries in the form of the Green Climate Fund (GCF). The GCF is the world's largest dedicated fund assisting developing countries to reduce their greenhouse gas emissions and adapt to climate change.

The 2015 UNFCCC Paris Agreement issuing from COP21 reiterates developed countries' COP15 commitment to mobilize $100 billion annually. It was also decided at COP21 that developed countries intend to continue their existing collective mobilization goal of $100 billion per year through 2025, and that in subsequent years they will aim to increase this amount, taking into account the needs and priorities of developing countries (UNFCCC, 2020a). Under the Paris Agreement international public funds are to be managed and distributed by the GCF with an equal balance of funding between mitigation and adaptation efforts, As a result only one half of its funds will be allocated to adaptation activities.

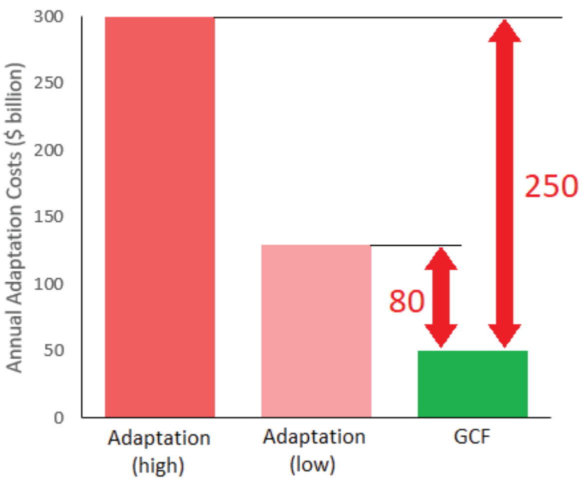
A recent stocktaking report issued by the OECD provides some insights into climate finance contributions and allocations (OECD, 2020). It finds that over the 2013–2018 period:

- total climate finance mobilized and provided by developed countries to developing countries reached $78.9 billion, primarily through the GCF[9.]
- within this total, international public climate finance provided by developed countries reached $62.2 billion while private finance mobilized reached $14.6 billion.
- finance for mitigation represented 70 per cent, and finance for adaptation 21 per cent, of the total with remainder targeting cross-cutting activity.
- the share of loans in total public finance provided was 74 per cent, the share of grants 20 per cent, and the remainder was mostly in the form of equity investments.
- financing for LDCs and SIDs represented only 14 per cent and 2 per cent respectively of total provided climate finance from 2016 to 2018.

Moreover, an overwhelming 80 percent ($47 billion) of all reported public climate finance was not provided in the form of grants, but rather as loans. Around half of this ($24 billion) was non-concessional, offered on commercial terms requiring burdensome terms of repayment from developing countries. Oxfam calculated that the 'grant equivalent' – the true value of the loans once repayments and interest are deducted – was less than half of the reported $47 billion amount (Oxfam, 2020). A bigger offering of concessional finance will be essential for developing countries to address the adaptation challenges that climate change poses to their development (Micale et al., 2018). Concessional financing is important particularly for middle-income developing countries such as the SIDS that have extreme economic and environmental vulnerabilities but often do not qualify for such funds due to very restrictive per capita income criteria which are often maintained in loan considerations in isolation from considerations of vulnerability. International public finance institutions should also include economic and environmental vulnerability indices in their decisions to authorize concessional financing. Many SIDS governments have called for more favourable access to concessional resources for all small islands by including a measure of vulnerability in assessments as to which countries should be eligible for concessional finance (Hurley, 2015).

The above figures reported by the OECD include the sum of all commitments and disbursements, but as these figures are not reported separately, it is difficult to ascertain to what extent the above 'provisions' (i.e., commitments pledged by governments including through multilateral entities) and 'mobilizations' (i.e., private sector commitments mobilized by developed countries) of finance have actually been disbursed. It is important to note that the OECD figures include not

Figure 19. Adaptation gap



Note: Assuming that the GCF is funded to a level of $100 billion annually, half of this amount, $50 billion, will be available to fund adaptation activities. However, over the next decade, estimated annual adaptation costs for developing countries range from $130 billion (low) to $300 billion (high) resulting in an 'adaptation gap' of $80–250 billion annually.

Source: UNEP, 2016.

only the GCF, but a wide range of other international public finance sources (see footnote 6 below).

To gauge the extent of approved funding and disbursements associated with the above figures, recent data reported by the GCF state that since GCF's inception, financing for approved activities was only $6.3 billion, and of that only $1.3 billion has been disbursed (GCF, 2020).

In the near term, it is immediately apparent that with such low approval and disbursement rates, the current costs of climate change adaptation in developing countries are not being adequately financed by the GCF. However, even with faster approvals and disbursements, and an assumption that the GCF target level of $100 billion annually is achieved, because of the need to balance mitigation and adaptation financing, at most only $50 billion would be available for adaptation activities; a number that falls short of the $130 and $300 billion estimates noted above. A recent report by UNEP refers to this shortfall as the 'adaptation gap', asserting that current adaptation costs are likely to be at least 2 to 3 times higher than international public finance for adaptation, with upper estimates as much as 5 times higher. The report estimates that to meet all finance needs and avoid an adaptation gap, the total finance for adaptation in 2030 would have to be approximately 6 to 13 times greater than international public finance today (UNEP, 2016). Figure 19 shows the magnitude of gap according to recent adaptation cost estimates.

Besides the GCF, other international public finance funds are available for adaptation. Although additional funding channels increase the options and possibilities for recipient countries to access international public finance, the presence of so many financing entities also makes the process more complicated, causing developing countries with limited capacity to duplicate time-consuming application and reporting processes among different international financial institutions, each having their own unique criteria and requirements.

The Adaptation Fund established under the UNFCCC Kyoto Protocol and administered by the World Bank which has committed $720 million to climate adaptation and resilience activities since 2010.[10] Another fund is the Least Developed Countries Fund (LDCF) established in 2001 under the UNFCCC and operated by the Global Environment Facility (GEF) which has provided $1.4 billion since 2001 for the preparation and implementation of National Adaptation Programmes of Action (NAPAs) in LDCs.[11] While a few other international public finance funds with more limited financial capacity exist, taken together along with the GCF, the net amount of international public funding available to finance adaptation activities in developing countries remains far inferior to the assessed needs of developing countries.

4.2. Filling the adaptation gap: other means of financing adaptation

Apart from international public finance provided and mobilized by developed countries for climate change adaptation in developing countries, there are numerous other sources of finance for adaptation at the national level (for a an accessible and comprehensive introduction see Burmeister et al., 2019).

Governments (national, sub-national and local) and the domestic private sector will need to finance many adaptation activities undertaken in developing countries. These sources of financing are especially important given the significant challenges developing countries face in promptly accessing international public financing, including a long and detailed application and accreditation process which often means that years will pass from the time of initial application to approval and disbursement. Moreover, because each source of international public financing has its own unique requirements which need to be adhered to when preparing project proposals and concept notes, for many smaller and urgent adaptation activities, the mobilization of needed financing may occur more rapidly from national sources than from international public finance sources.

Fortunately, climate change continues to reveal itself gradually. With the exception of the increased incidence of extreme weather events, many impacts such as temperature increases, precipitation changes, fish migrations, and sea level rise will progressively impact economic activity over the next few decades. This allows governments and producers to progressively enhance their climate resilience over the coming years, with a time period of up to 10 to 30 years – depending on projected timeframes for the emergence of adverse impacts – to fully implement needed adaptation actions for climate-sensitive sectors. This relatively long timeframe should allow governments and producers, that begin preparing today, adequate time for planning, securing finance, and conducting a phased roll-out of financing and implementation.

Governments have two guiding roles to play in catalyzing this gradual process of change. Firstly, by initiating climate resilience capacity building for producers through awareness-raising, outreach, extension services, information exchange, and stakeholder workshops. These activities can support farmers in changing their crops and cropping methods, as well as their fertilization, pest control, and irrigation practices. Fishers can be supported in changing their fishing methods and targeted species, and tourism services providers can be encouraged to diversify their product offering. Secondly, by revising new geographical zoning ordinances for agriculture and construction, building codes, regulations on water use, fishing zones and regulations, and providing incentives for farms and businesses (as well as property owners and investors) to locate/relocate in less climate-sensitive locations.

Within a decade, these government actions can greatly enhance future climate resilience. Small producers, small and medium sized enterprises, and large companies will seek to invest in their own resilience to ensure their survival and growth, and to protect their stakeholders and shareholders (Frei-Oldenburg et al., 2018). Private financial institutions, including banks, pension funds, and insurance companies, can also develop adaptation instruments and facilities that provide funding for adaptation through loans (Burmeister et al., 2019).

Associated changes in producers' *modus operandi* will be largely auto-financed by producers as they adjust their production methods over time to reduce their climate exposure. Although it will be difficult to measure and quantify, this mode of private sector auto-financing can contribute significantly to filling the adaptation gap. However, national, sub-national, and local governments need to get climate resilience laws, regulations, and incentives in place without delay to maximize future results.

Climate proofing existing and future infrastructure may not be achieved as easily. Re-engineering, relocating, and rebuilding roads, rail lines, bridges, sea walls, seaports, airports, and water, communications and electricity supplies, will require substantial financing by the national government. In some instances, public-private partnerships (PPPs) can also be used to include private participation in infrastructure projects. PPPs allow governments to share climate risks with private investors and reduce required government outlays (Gardiner et al., 2015).

Most capital expenditures on infrastructure will need to be made from the government budget. However, for many developing countries, national budgets have insufficient capacity to fund expenditures for climate change adaptation due to high debt servicing payments. Developing countries must find ways to overcome the high debt, low growth trap that they find themselves in (King and Tennant, 2014). Debt levels are particularly high for SIDS (Box 9). High debt limits opportunities for capital expenditure, requires high servicing costs, and discourages investment in climate adaptation. Policymakers often spend more time focusing on managing debt and the threat of debt crises, than on economic growth, social development and climate change. Most recently, the shock brought about by the Coronavirus pandemic illustrates that small and open economies do not have the resources needed to effectively respond to large-scale disasters and economic dislocations with financial response and recovery packages (UNDESA, 2020).

Developing countries can explore several pathways

Box 9. High debt levels limit SIDS' ability to finance adaptation actions

High debt levels of SIDS in the Caribbean severely limit their ability to finance climate change adaptation actions, even though, among countries, they will confront some of the most adverse impacts of climate change. SIDS are located in some of the most disaster-prone regions in the world and comprise two-thirds of countries with the highest relative annual losses due to disasters (OECD and World Bank, 2016).

SIDS are, on average, more severely indebted than other developing countries. External debt burdens have continued to rise from 51 per cent in 2009 to 61 per cent in 2019, with many individual SIDS obviously having considerable higher external debt-to-GDP ratios. In 2019, SIDS external debt obligations amounted to more than 172 per cent (or near double) of their export revenues, compared to around 100 per cent in 2011. Almost a quarter of SIDS export earnings are allocated towards servicing external public debt obligations (AOSIS, 2020).

Public debt is a key factor which impedes SIDS from increasing their trade-climate resilience. Building resilience at individual, institutional and private sector levels is essential to achieve sustainable development in SIDS, but available financing for this purpose is limited and difficult to access.

Debt levels also impede the ability of SIDS to diversify exports. When debt servicing levels are high, countries are less able to channel public funds towards the development of new export industries. Reducing and limiting debt levels remains challenging due to the recurrent need to allocate government funds to disaster recovery efforts. Therefore, debt levels, disaster financing, and economic prospects of SIDS, including their export competitiveness, are closely interlinked.

Among the three main SIDS regions, Caribbean SIDS have high levels of debt distress, and less concessional debt as a share of their total outstanding loan portfolio (UN-OHRLLS, 2020). Public debt-to-GDP levels in the Bahamas and Jamaica currently exceed 100 per cent. Many Caribbean SIDS are affected by high and rising public debt, with accommodative fiscal policies, natural disasters, and economic shocks contributing to the accumulation. SIDS in the Pacific region, in contrast to the Caribbean, enjoy relatively low public debt levels, which is partly explained by their typically low-income status, which allows them to secure external loans on highly concessional terms, reducing debt servicing needs. Public debt-to-GDP ratios are below 60 per cent in all Pacific SIDS, excepting the Marshall Islands. The third and final grouping of SIDS, in the Africa-Indian Ocean region, includes countries with quite different economic and socio-political histories, resulting in widely varying debt experiences. Mauritius and Cape Verde are strong recipients of remittances. Several countries, the Maldives in particular, have highly tourism-based economies that are prone to fluctuations in tourism revenues.

to reduce debt to sustainable levels so that national budgets can allocate funding to climate change adaptation projects. Undertaking policy, institutional and governance reforms may be needed to strengthen political and administrative oversight and avoid fiscal slippage, and to minimize contingent liabilities caused by loss-making public enterprises. Although they can be effective in reducing debt, fiscal consolidation is not likely to be a panacea as it will lead to cuts in capital expenditures. Furthermore, many developing countries have already undertaken austerity exercises that have adversely impacted their populations and curtailed demand for goods and services needed to sustain economic growth. Efforts should thus focus on economic growth to increase fiscal revenue and thereby reduce the share of debt servicing within budgets. And because climate-sensitive sectors such as agriculture, forestry, fisheries, and tourism contribute significantly to their export earnings and employment, climate change adaptation in these sectors is essential.

There are several innovative generators of funds to augment the national budget that many developing countries have used successfully which can be utilized to generate funds for climate change adaptation:

- Citizenship-by-investment (CBI) is a form of economic citizenship whereby an individual acquires

Box 10. Citizenship-by-investment (CBI) experiences in the Caribbean SIDS

St. Kitts and Nevis, in 1984, became the first country to introduce a CBI programme. Several other Caribbean SIDS have since followed its example, particularly in the last decade. Today, Dominica, Antigua and Barbuda, Grenada, St. Lucia and Vanuatu count among SIDS with CBI programmes. They have all launched CBI programmes as a means of raising funds to deal with the growing frequency and intensity of hurricanes due to the warming of the Atlantic Ocean. Funds raised contribute to adaptation and recovery costs. CBI programmes offer a quick and easily implemented approach to raising funds for climate resilience, often delivering finances much faster than international public funding.

Dominica is the most recent example of a Caribbean country that demonstrated the importance of CBI for climate resilience. It has beaches, rivers, and rainforests that are increasingly threatened by hurricanes and tropical storms, such as Erika (2015) and Maria (2017), both of which caused extensive damage to the island; devastating villages, homes, and roads. Erika resulted in $400 million of damages, equal to about three-quarters of Dominica's GDP. The CBI programme of Dominica, launched in 1993, provided a vital source of funding to reconstruct housing and infrastructure and restore the tourism industry in the wake of such disasters.

Since 2017, Dominica has spent over $200 million from CBI funds across various sectors to support climate proofing infrastructure, disaster recovery, as well as long-term economic diversification. This expenditure has had a critical impact on the country's recovery from recent tropical storms. CBI accounted for more than 40 per cent of Dominica's 2018/19 public expenditure and continues to grow.

The most important benefit of CBI in Dominica has been its contributions to financing the construction of public housing. CBI helped construct new, climate-resilient buildings inland. Following tropical storm Maria, CBI helped the government reinvigorate tourism, supporting the construction of six new five-star hotels, relocation of eco-friendly resorts inland, and updating of facilities. The country's geothermal energy programme is also partially funded by CBI. It will help reduce the cost of electricity for the hotel industry and the average consumer, while reducing CO_2 emissions. CBI also funds the medical sector by sending patients severely injured by storms abroad for advanced medical care when needed.

The 2019 CBI Index which scores CBI programmes according to seven criteria (freedom of movement, standard of living, minimum investment outlay, mandatory travel or residence, citizenship timeline, ease of processing, and due diligence), ranked Dominica first, closely followed by four other Caribbean countries. Since several Caribbean SIDS have already introduced CBI, there may be an opportunity for them to share experiences towards a CBI Code of Conduct[12] for the region and beyond, towards enhancing adaptive capacity, strengthening resilience, and reducing vulnerability to climate change.

an additional citizenship by making an economic contribution, often in the form of a substantial investment, to the country offering the programme. While CBI has been introduced across regions with various objectives, they are increasingly being used by SIDS as a means to fund short-term recovery from climate-induced natural disasters and long-term transitions to climate-resilient, service-oriented economies. Although earnings from CBI may be volatile, they can provide much-needed financing remedy in the absence of external funding options. Box 10 provides a summary of SIDS' experience with CBI.

- Investment instruments can be created to attract the repatriation of funds from their diaspora (citizens abroad) in infrastructure projects, including adaptation projects. Ethiopia issues bonds targeting its diaspora community to provide investment capital for the Ethiopian Electric Power Corporation which are invested in sustainable power generation and in projects to climate proof the energy sector.
- Many developing countries authorize foreign currency bank accounts to attract incoming diaspora remittances and investment. These funds help support countries' international foreign exchange reserve and ease balance of payments difficulties. The widespread acquisition by banks of new financial technologies also enables the transfer

of remittances at marginal cost, and national banks' departures from correspondent banking relationships. These actions can help promote trade and financial inclusion, while enhancing growth in export-oriented sectors.

- Funding from celebrities who are natives and/or residents of their countries could provide well needed financial support, especially if these celebrities are interested in establishing foundations that address climate change. Celebrities Rihanna and Usain Bolt have attracted funding for climate adaptation activities in Barbados and Jamaica respectively.
- Climate change adaptation fees can be imposed on international travellers arriving in a country for tourism. Bhutan has recently instituted a 'Sustainable Development Fee' to be paid by foreign visitors as a daily fee. Collected revenue are used to support environmental objectives.

In view of the magnitude of the global adaptation gap (Figure 10) and related difficulties to access adaptation financing at the national level, any corollary methods for countries to attract finance to adaption efforts is valuable. Leveraging climate change mitigation projects to support adaptation goals should thus be explored wherever possible. Over the past two decades, and at the current time, developing countries have found it much easier to access international public finance for climate change mitigation than for adaptation. By proposing mitigation projects with strong adaptation co-benefits, governments can enhance their countries' climate resilience.

Strengthening partnerships with multilateral lenders is also important. There are many current and upcoming international initiatives to alleviate the debt burden of developing countries. Hurricane clauses are loans that automatically postpone debt servicing in the event of a major natural disaster. Debt-for-adaptation or mitigation swaps reduce immediate debt burdens from climate-related disasters and increase resources targeted to climate-resilient development. Developing countries can pool insurance risk. This has been done by Caribbean countries through the Caribbean Catastrophe Risk Insurance Facility.[13]

5. PATHS TOWARDS ECONOMIC AND TRADE RESILIENCE

Looking at the big picture, climate change will have different and complex effects on world markets and trade due to climate induced changes in transportation costs, competitiveness, sectoral comparative advantages and trade policies. Trade patterns, flows, and volumes will progressively change due to future climate change impacts. Unless developing countries enhance their trade resilience *ex-ante* through adaptation measures and actions, they will export substantially less in climate-sensitive sectors *ex-post* as climate change impacts accumulate over time. When adaptation is neither possible or cost-effective, diversification within the sector, or economic restructuring to move resources to other less climate-sensitives sectors, can be pursued.

The relative net offset of negative – and in some areas, positive – impacts of climate change between countries will determine which countries will become more competitive (OECD, 2017). A negative impact on exports in one region will manifest itself as relative positive impact in another less affected region. While impacts on countries with a very diversified export profile can be absorbed, most developing countries with highly concentrated export profiles are likely to be worse off unless they are able to offset negative impacts through adaptation actions.

Each developing country will have to assess how climate change will affect its competitiveness and export capacity *vis-à-vis* countries and regions that are competitors for the products it exports. The changing landscape of demand and supply across regions will result in terms-of-trade losses for some countries and gains for others. At the same time, it will require adaptation efforts by other countries that had previously (before adverse climate change impacts emerged) been competitively producing and exporting products from climate-sensitive sectors such as agriculture, fisheries, and tourism. Climate change will also give rise to inverse trade effects wherein developed countries will become exporters of goods that they previously imported from developing countries. However, because adverse impacts of climate change on production will be more substantial in developing countries than developed countries, *ceteris paribus,* cases in which developing countries will become exporters of climate sensitive goods that they previously imported from developed countries are not expected.

The ability of developing countries to maintain productivity levels going forward will vary amongst them. In agriculture, for example, those that have limited arable land area will not have the option of increasing cultivated land area to offset productivity losses caused by climate change. Those that lack topographies possessing higher altitude land areas that can support the cultivation and grazing of traditional crops and livestock, will not have the option of relocating production activities to higher, cooler grounds that can sustain production as lower elevation land areas become unproductive. Additionally, developing countries with scarce water supply will not be able to increase irrigation levels in response to rising temperatures and higher evapotranspiration rates. Adaptation actions in other impacted sectors will similarly have limitations, that vary, based on each country's geographical and environmental specificities.

Geographic information systems (GIS), satellite imagery and related ICT technologies will be essential tools in countries' adaptation efforts. Together these technologies can help to increase preparedness for, and resilience to, climate change by enabling the monitoring of climate change impacts and providing guidance on adaptation actions. They can be used to collect, store, and analyse realtime and historical data, providing a platform for national experts to predict climate variability and extreme climate events, and for designing and simulating adaptation actions (Climate-ADAPT, 2020). They can also help communities to adapt to the impacts of climate change by, for example, providing fishers with weekly maps of the predicted density of fish at various offshore locations so that they can better target and optimise fishing effort (Geronimo et al., 2018), and by assisting farmers to identify the best crop varieties to grow and optimising how they are grown. For instance, scientists at the International Center for Tropical Agriculture in Colombia use weather and crop data collected from farmers through a mobile phone application to understand the impacts of climate change on rice yields. The Center's scientists then provide farmers with accurate, site-specific forecasts and advice on the best rice varieties to plant according to the specific conditions, which reduces farmers' losses and increases production yields (ITU, 2020).

5.1. Adapting to mitigation: the impact of response measures

Importantly, it is not only the physical impacts of climate change that will affect developing countries' export profiles, but also the adverse impacts on developing countries of response measures aimed at mitigating climate change undertaken domestically, and by other countries (Chan, 2016; Khor et al., 2017; Bacchus, 2019).

Impacts of the implementation of response measures is understood as the effects arising from the implementation of mitigation policies, programmes, and actions, 'in-jurisdiction', and 'out-of-jurisdiction' with cross-border impacts, taken by Parties under the Convention, the Kyoto Protocol, and the Paris Agreement to mitigate climate change (UNFCCC, 2020b).

A country's own domestic, or 'in-jurisdiction' response measures, will have economic effects on its consumers and producers. The elimination of national subsides for fossil fuels would be an example of a national response measure (aimed at reducing CO_2 emissions to mitigate climate change) that would raise the costs of production for products whose production relies significantly on fossil fuel inputs. In addition, without such subsidies consumers' disposable incomes would also decline due to higher relative costs for home heating and transportation in their consumption budget. These effects could reduce the competitiveness of producers' exports, and export levels, while also reducing import levels of products experiencing lower consumer demand, following the government's elimination of fossil fuel subsidies (Burniaux et al., 2011). The impact of a national carbon tax would have qualitatively similar impacts on trade (Chen and Guo, 2017).

As its exports and imports decrease slightly for certain products due to the higher fuel costs borne by domestic producers and consumers, fossil fuel subsidy elimination and/or the introduction of carbon taxes could have an impact on an implementing country's trade. By extension, due to relative changes in producers' competitiveness and consumer demand levels arising from the introduction of these measures in implementing countries, these measures could 'indirectly' affect the trade of other countries whether they implement similar measures or not.

Furthermore, because transportation services are an important input in international trade, transportation services companies based in countries imposing carbon taxes can be expected to raise fees for freight transport. Higher freight transportation costs would have an impact on both import and export volumes of developing countries, particularly remote SIDS with large distances to major world markets.

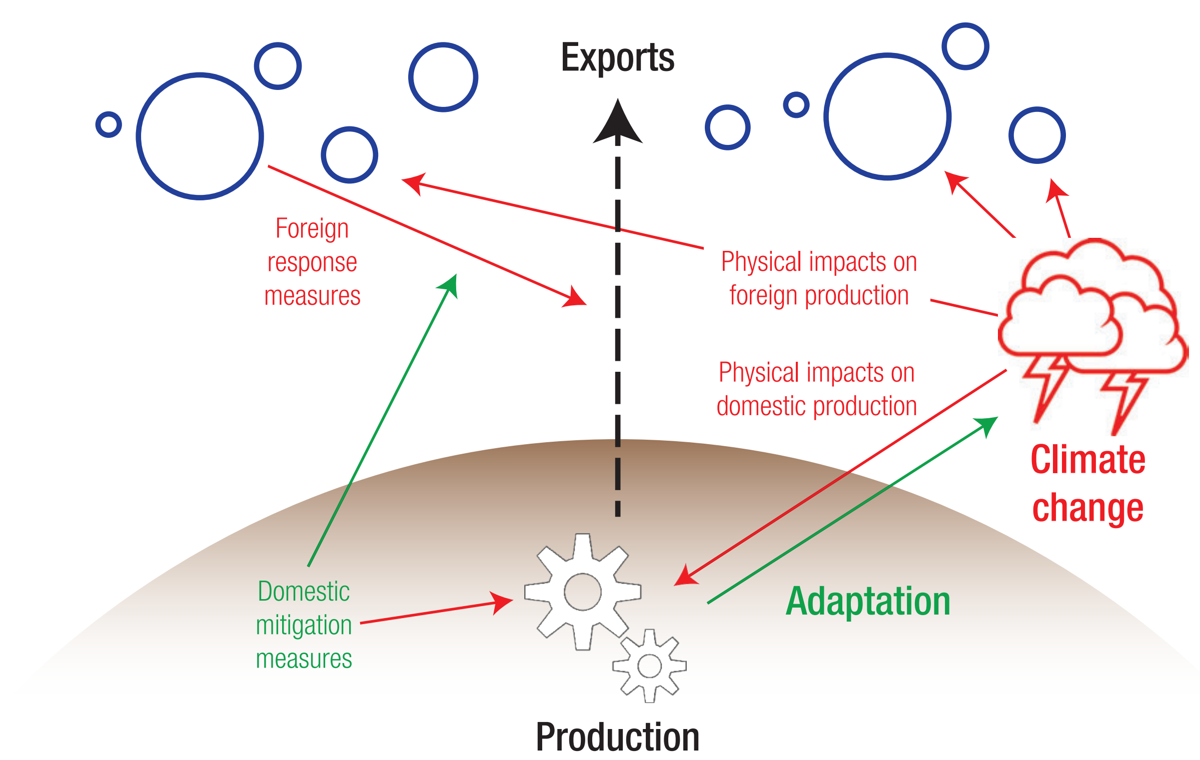
Response measures with more substantial 'direct' cross-border impacts are expected to be implemented by some countries. For example, some countries may introduce new product 'climate standards' that must be met by imported products, or impose border taxes on imported products based on the level of CO_2 emissions associated with the products' method of production, and possibly also based on CO_2 emissions associated with the transportation of products to the importing market. The latter measures are referred to as 'border carbon adjustments' or 'border carbon taxes' (Condon and Ignaciuk, 2013).

When applied by a country with a national carbon tax system, border carbon adjustment fees are imposed on products imported from a country without a national carbon tax system in order to 'adjust' the price of the imported goods to be equal to those produced domestically (assuming similar non-energy related production costs). Importantly, the border carbon adjustment fee would not applied to imported goods originating from a country that has a national carbon tax system.

The impacts on trade resulting from response measures including fossil fuel subsidy elimination, carbon taxes, climate standards, carbon border adjustments, and others, cannot be generalized. For any given configuration of measures and sets of countries implementing them, modelling studies are required to provide an indication of the direction and magnitude of trade impacts likely to be experienced by exporting countries on a sectoral basis.

Adjustments to the international trade regime may partially offset the potential negative impacts of future developed country response measures on developing countries. They could include revising trade policies and agreements so that the effective competitiveness of affected countries and sectors can be enhanced, or by offering time-limited exemptions to the imposition of border carbon adjustment fees on imports from developing countries. Further modelling results may shed light on how trade policies and agreements that can be designed to offset the adverse impacts of developed country response measures on developing country exporters..

Figure 20. Factors affecting a developing country's exports in a climate change world



Note: The figure shows schematically the various climate change related forces (shown as arrows) affecting a country's exports. Red coloured forces have the potential to reduce production and exports and green coloured forces can offset or mitigate these potential reductions.

The bottom-line message of the generalized picture summarized above, is that it will be imperative for developing countries to assess, sector by sector, how climate change, and both their own and other countries' response measures, will affect their production capacity and demand for their exports. Figure 20 illustrates the climate change related factors that will modulate developing countries' production capacity and export levels as climate change unfolds over the coming decades.

It is immediately apparent from Figure 20 that the only factors modulating exports that a country, on its own, can independently influence its domestic response measures and its domestic adaptation actions. It cannot influence the physical impacts of climate change. Nor can it determine other countries' response measures, although its domestic mitigation measures may affect how foreign response measures will apply to its exports. For example, by implementing a national carbon tax system its exports will be exempt from border carbon fees imposed by other countries. Additionally, through negotiations and agreements, developing countries may influence future international rules and disciplines on how foreign response measure will be applied to their exports. The bottom line emerging from a consideration of future climate-related factors affecting trade, is that designing and implementing effective domestic response measures and adaptation actions will constitute a country's only approach to ensuring its economic and trade resilience in a climate change world.

5.2. Adaptation actions

Chapter 2 enumerated the physical impacts of climate change that are expected to impact production in the agriculture, fisheries, and tourism sectors. As the scope and extent of these impacts varies considerable from one country to another, only through a national multi-stakeholder process can these impacts be assessed, financing needs estimated, and adaptation actions formulated. An illustrative list of selected generalized adaptation actions that may need to be effected in the agriculture, fisheries, and tourism sectors is provided in Table 2.

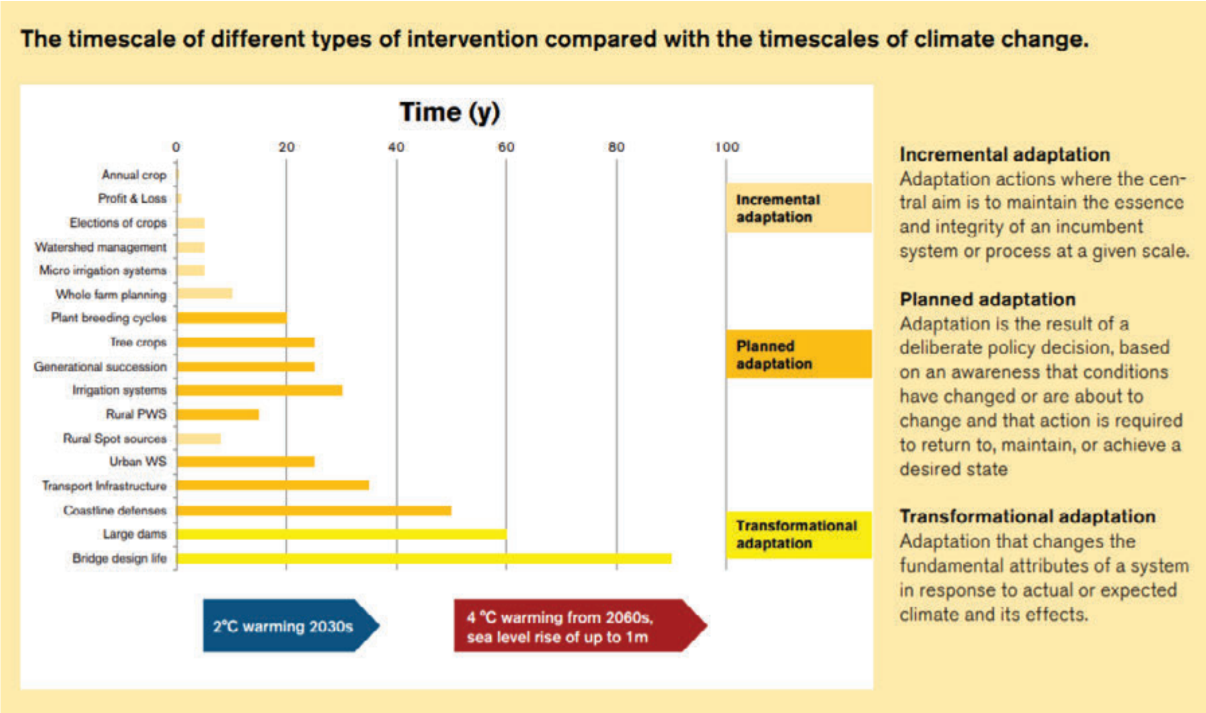
Table 2. Potential adaptation actions for agriculture, fisheries and tourism

Adaptation action	Agriculture	Fisheries	Tourism
Modify/improve methods of irrigation, fertilization, and management of pests and diseases	•		
Modify/improve crops selected for cultivation, planting/harvesting practices	•		
Modify/improve planting periods/seasons, co-cropping practices, crop rotation practices, irrigation practices	•		
Modify/adapt crop/fish storage and transportation practices	•	•	
Adopt methods to retain soil moisture	•		
Climate- and storm-proof water delivery and storm water drainage systems	•	•	•
Erect wind barriers and shading structures for protection from high winds and extensive sunlight	•		•
Increase supply of freshwater resources by accessing new geological supplies and through demand-side management	•		•
Raise producer and consumer preferences for novel agricultural and fisheries varieties and species which can be more productively produced/sourced in a climate change impacted environment	•	•	•
Improve fishing practices to make them more sustainable, selective, and multispecies sourcing		•	•
Adapt/replace fishing vessels for increased fishing effort, distances, and times at sea		•	
Equip fishing vessels with advanced navigation, location, and radar systems to enhance catch efficiency		•	
Gradually shift economic activity from wild catch fisheries to sustainable mariculture, aquaculture, and value-added fish processing, as well as other climate proof activities		•	•
Climate- and storm-proof energy, water, and telecommunications infrastructure	•	•	•
Climate- and storm-proof seaports, airports, and land-based transportation infrastructure	•	•	•
Erect/upgrade seawalls	•	•	•
Restore/establish coastal mangrove forests for sea-surge protection	•	•	•
Develop/enhance weather services and early warning systems for high wind, storm, drought, forest fire, and flooding events	•	•	•
Use climate forecasting to reduce production risks	•	•	
Use selective breeding methods for increased yield and resilience	•	•	
Develop and commercialize risk and natural disaster insurance instruments for producers	•	•	•
Provide producers with compensation for impacts through facilities offered by governments and cooperatives	•	•	•
Diversify producers' livelihood portfolios	•	•	•
Relocate coastal tourism facilities to inland, higher ground locations			•
Climate- and storm-proof tourism buildings, including by retrofitting			•

Sources: (IPCC, 2014; Howden et al., 2007; Shelton, 2014).

The potential adaptation actions presented in Table 2 vary significantly in terms of their scope, depth, time to implement, and cost. When assessing and planning adaptation actions, consideration must be given to the temporal dimensions of when the impacts will be experienced by producers; costs of specific actions; estimates of when financing will become available for their implementation; and timeframes for their implementation. Such an analysis will allow national stakeholders to elaborate a balanced adaptation action plan that comprises an effective set of short- and long-term measures. Figure 21 shows the temporal dimension for an adaptation action plan that includes incremental, planned, and transformational

Figure 21. The temporal dimension of adaptation action implementation



Source: Helvetas, 2015; Smith et al., 2011.

adaptation actions. Stakeholders should map out the temporal dimension of their selected adaptation actions to ensure not only that adequate resources will be available for their phased implementation over time, but that they will also be, *inter-alia,* effective, compatible, and consistent.

5.3. Diversification actions

As developing countries elaborate adaptation actions required to support future production and exports, limits in ambition will quickly be encountered due to financing constraints. It may be too costly to completely climate proof a productive sector, particularly highly climate-sensitive sectors such as agriculture, fisheries, and tourism. Diversification should be considered in such cases. Developing countries can explore options to diversify within sectors, and into new sectors, where their comparative advantage is expected to increase *vis-à-vis* competitors in the presence of future climate impacts.

Even if primary production in the agriculture and fisheries sectors experience climate-related declines, transitioning from exports of primary products to higher-value added downstream products can maintain sectoral employment and revenue levels, and the overall value of sectoral exports even as primary productivity declines. In tourism, developing countries can compensate for the declining numbers of recreational tourists by diversifying their offerings into ecotourism and cultural tourism as they face increasing competition from destinations that become more attractive for recreational tourism due to their more favorable weather conditions. Sector specific considerations for adaptive diversification in the agriculture, fisheries, and tourism sectors are briefly discussed below.

Diversification of agricultural activity entails entering higher value-added segments within the food and agriculture sectors, or retraining the agricultural workforce to move workers into other less climate-sensitive sectors. Partial to full resilience of exports to climate change depends on sectoral adaptation of production, for example through new and better production methods, switching cultivation to better adapted agricultural crops and species, relocating traditional crop cultivation zones, introducing new livestock species or breeds better suited to future climatic conditions, relocating grazing zones, increasing value added in commodities based exports, adopting more efficient irrigation systems, and improving water resource management.

For many developing countries, the product complexity of agricultural exports remains low and climate change will increasingly compel producers to increase value-added production in the sector in order to maintain income levels. The spectrum of diversification options in agriculture is wide, extending deep into the food, beverage, healthcare products, and textiles sectors. Country stakeholders need to better understand the cost, benefits, and limitations of various options to inform sectoral decisions (Carleton and Hsiang, 2016). Economic valuations that provide quantitative information on returns on investment in value-added processing often rely on broad estimates, which makes it difficult to optimize the priority, timing, and cost of sectoral diversification options. Hence countries must undertake self-assessments that provide foresight on how agricultural investments made today are likely to affect diversification outcomes in the future.

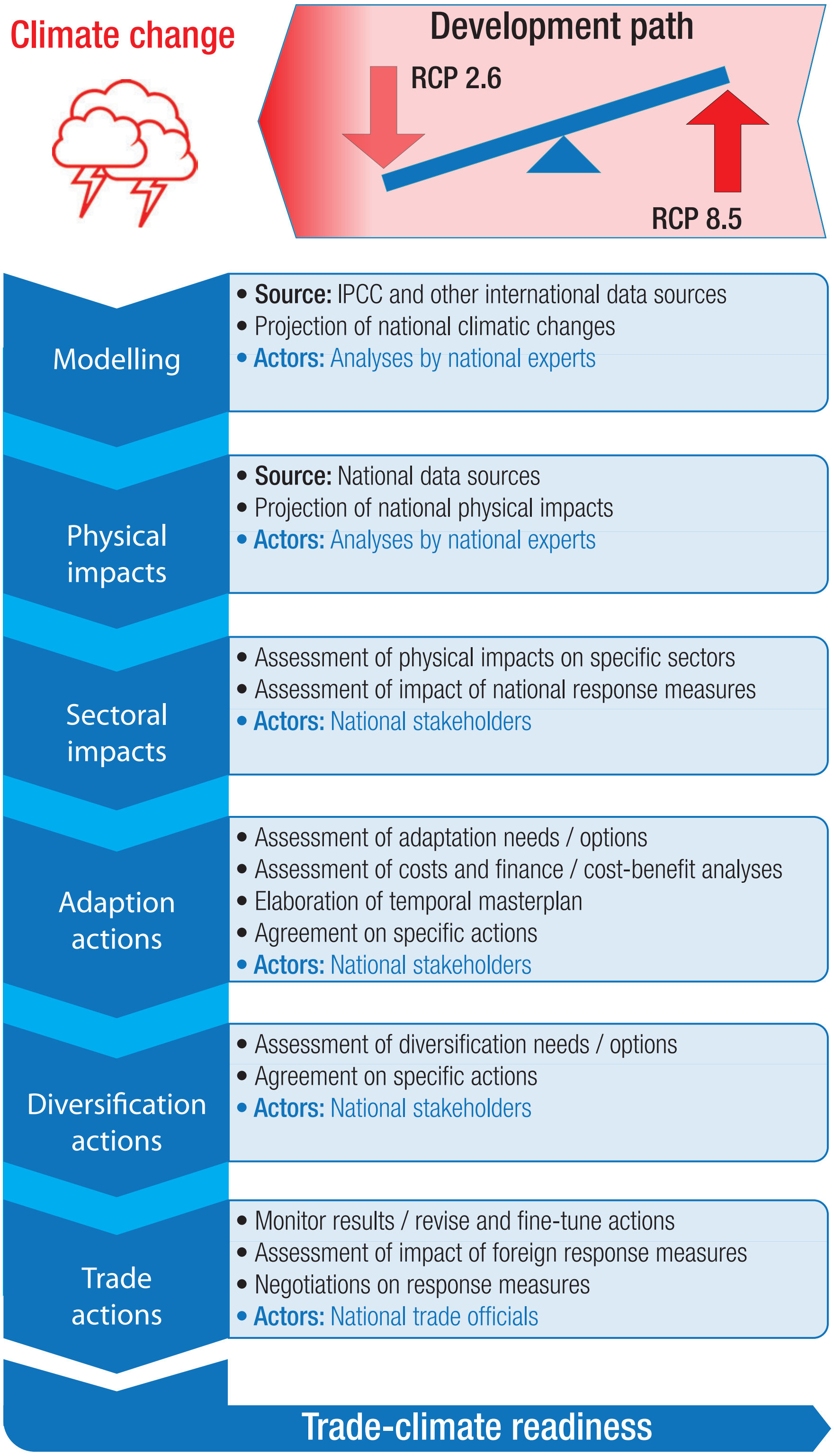
In fisheries-dependent developing countries, product diversification is possible within the realm of the blue economy. When countries can no longer maintain catch levels and become forced to rely on less fish, they can maintain sectoral production and employment levels by developing value-added downstream fish products. For example, fish-based ornaments and healthcare products can increase the value extracted per tonne of fish, while also supporting tourism. Sustainable multispecies mariculture will provide an opportunity to offset the growing gap between increasing food demand and lower catch levels. At the same time, to maintain wild capture fishery operations and optimize their future performance, it will be critical improve technical capacity, follow best practices, introduce sound regulation, make financing more available to producers, and improve fish stock management (Gaines et al., 2019).

Changing climatic conditions will affect tourism activity. Given the vulnerability of 'sea, sand, and sun' tourism to rising temperatures, sea level rise, and tropical storms, diversified tourism themes need to be developed. Options to be considered include ecotourism, cultural tourism, retirement tourism, wellness tourism, and medical tourism, among others. Agrotourism and recreational fishing tourism are other options that can yield double dividends by diversifying incomes for farmers and fishers impacted by climate change. When diversifying, tourism stakeholders should calibrate marketing efforts so that they consider the impact of geographic, climatic, and cultural distance on tourists' propensity to visit, their length of stay, and their expenditure levels (Jackman, 2020).

Diversification efforts also need to include a market diversification component for both goods and services exports. For goods this can take the form of expanding the portfolio of products shipped to major trading partners. If the exporting country has an indispensable product offering, it is more likely that their trading partner will remain accessible at a low cost with favorable trade preferences. Broadening and/or refocusing the spectrum of export markets can also be advantageous, redirecting exports to new markets where value-added production is in greatest demand. Additionally, there may be possibilities to diversify into sectors where comparative advantage is expected to increase relative to competitors due to future climate impacts. For tourism services, when demand from traditional source markets declines, new source markets should be explored. Particular consideration should be given to emerging developing countries as potential new tourism sourcing market opportunities.

Each country will have a unique trade-climate resilience pathway. In very general terms, this chapter identified potential pathways for developing countries to enhance their trade and economic resilience in sectors adversely impacted by climate change. Any national effort to strengthen trade-climate resilience will require a national stakeholder process to: assess the expected physical impacts of climate change and potential response policies, infer sectoral impacts, and develop and implement effective adaptation actions. This national process is illustrated schematically in Figure 22.

Figure 22. Path to trade-climate resilience



References

ADB (2013). *The Economics of Climate Change in the Pacific*. Asian Development Bank.

Agard, J., Briguglio, L. P. and Duvat-Magnan, V. (2014). Key Economic Sectors and Services. Available at https://www.cambridge.org/core/books/climate-change-2014-impacts-adaptation-and-vulnerability-part-a-global-and-sectoral-aspects/key-economic-sectors-and-services/E5F30E57AF3F1C3C87E98247403D8C71 (accessed 12 November 2020).

AOSIS (2020). AOSIS Statement on Debt. Available at https://www.aosis.org/wp-content/uploads/2020/07/AOSIS-Statement-on-Debt_verJune-29.pdf.

Aucan J (2018). Effects of Climate Change on Sea Levels and Inundation Relevant to the Pacific Islands. Available at /paper/Effects-of-Climate-Change-on-Sea-Levels-and-to-the-Aucan/013a0818af0fafefb69ad62e490d704a3344aa1 (accessed 30 October 2020).

Bacchus J (2019). What Is a Climate Response Measure? Breaking the Trade Taboo in Confronting Climate Change. *Confronting Climate Change*. (220):28.

Barange M et al. (2018). *Impacts of Climate Change on Fisheries and Aquaculture: Synthesis of Current Knowledge, Adaptation and Mitigation Options*. FAO. Rome.

Bindoff NL et al. (2019). Changing Ocean, Marine Ecosystems, and Dependent Communities. Report. ETH Zurich, 477–587. (accessed 30 October 2020).

Burke M, Hsiang SM and Miguel E (2015). Global non-linear effect of temperature on economic production. *Nature*. 527(7577):235–239.

Burmeister H, Cochu A, Hausotter T and Stahr C (2019). Financing adaptation to climate change – an introduction. Available at https://www.adaptationcommunity.net/wp-content/uploads/2019/10/2019-10_adelphi_Adaptation-Briefings_Financing-Adaptation_an-Introduction.pdf.

Burniaux J-M, Château J and Sauvage J (2011). The Trade Effects of Phasing Out Fossil-Fuel Consumption Subsidies. Available at https://www.oecd-ilibrary.org/content/paper/5kg6lql8wk7b-en.

Carleton TA and Hsiang SM (2016). Social and economic impacts of climate. *Science*. 353(6304):.

Chan N (2016). The New Impacts of the Implementation of Climate Change Response Measures Special Issue: The Paris Agreement. *Review of European, Comparative & International Environmental Law*. 25(2):228–237.

Chen W and Guo Q (2017). Assessing the Effect of Carbon Tariffs on International Trade and Emission Reduction of China's Industrial Products under the Background of Global Climate Governance. *Sustainability*. 9(6):1028, Multidisciplinary Digital Publishing Institute.

Cheung, W.W.L., Bruggeman, J. and Butenschon, M. (2018). Projected changes in global and national potential marine fisheries catch under climate change scenarios in the twenty-first century. *Impacts of Climate Change on Fisheries and Aquaculture: Synthesis of Current Knowledge, Adaptation and Mitigation Options*.

Church JA et al. (2013). *IPCC WG1AR5 Chapter 13 Sea Level Change. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC.

Climate-ADAPT (2020). Use of remote sensing in climate change adaptation. Available at https://climate-adapt.eea.europa.eu/metadata/adaptation-options/use-of-remote-sensing-in-climate-change-adaptation (accessed 7 December 2020).

Collins M et al. (2013). Long-term Climate Change: Projections, Commitments and Irreversibility. *Climate Change 2013 - The Physical Science Basis: Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. 1029–1136.

Condon M and Ignaciuk A (2013). Border Carbon Adjustment and International Trade: A Literature Review. *SSRN Electronic Journal*.

UNDESA (2020). COVID-19 likely to shrink global GDP by almost one per cent in 2020 April. Available at https://www.un.org/development/desa/en/news/policy/april-monthly-briefing.html (accessed 17 December 2020).

Dee D, Fasullo J, Shea D and Walsh J (2014). *The National Center for Atmospheric Research Staff (Eds.): The Climate Data Guide: Atmospheric Reanalysis: Overview & Comparison Tables.*

Donato DC et al. (2011). Mangroves among the most carbon-rich forests in the tropics. *Nature GeoScience 4:293-297*. 4(5):293–297.

EEA (2017). *Climate Change, Impacts and Vulnerability in Europe; 2017*. EEA Report No 1/2017,.

Elbehri A (2015). *Climate Change and Food Systems: Global Assessments and Implications for Food Security and Trade.* Food and Agriculture Organization of the United Nations (FAO).

FAO (2014). Climate Change Adaptation in the Eastern Caribbean Fisheries Sector | FAO | Food and Agriculture Organization of the United Nations. Available at http://www.fao.org/in-action/climate-change-adaptation-eastern-caribbean-fisheries/en/ (accessed 29 October 2020).

FAO (2018). *The State of Agricultural Commodity Markets 2018: Agricultural Trade, Climate Change and Food Security*. FAO Rome.

FAO (2019). *Synergy between Agriculture and Services Trade: Enabling New Growth Opportunities – Summary*. FAO. Geneva.

FAO (2020). The State of World Fisheries and Aquaculture 2020. Available at http://www.fao.org/documents/card/en/c/ca9229en (accessed 4 December 2020).

Frei-Oldenburg A, Stieglitz S, Stahr C and Eisinger F (2018). Climate Expert: a bottom-up approach to SME resilience to climate change. *Private-Sector Action in Adaptation: Perspectives on the Role of Micro, Small and Medium Size Enterprises*. UNEP DTU.

Gaines S, R C, C F and Y G et al (2019). *The Expected Impacts of Climate Change on the Ocean Economy*. World Resources Institute. Washington, DC.

Galassi G and Spada G (2014). Sea-level rise in the Mediterranean Sea by 2050: Roles of terrestrial ice melt, steric effects and glacial isostatic adjustment. *Global and Planetary Change*. 12355–66.

Gardiner A, Bardout M, Grossi F and Dixson-Declève S (2015). *Public-private Partnerships for Climate Finance*. TemaNord, No. 2015,577. Nordic Council of Ministers. Copenhagen.

GCA/WRI (2019). Adapt Now: A Global Call for Leadership on Climate Resilience - World. Available at https://reliefweb.int/report/world/adapt-now-global-call-leadership-climate-resilience (accessed 18 November 2020).

GCF (2020). GCF at a glance October. Available at https://www.greenclimate.fund/sites/default/files/document/gcf-glance_3.pdf.

GEF (2020). Strengthening the Adaptive Capacity to Climate Change in the Fisheries and Aquaculture Sector | FAO and the Global Environment Facility | Food and Agriculture Organization of the United Nations. Available at http://www.fao.org/gef/projects/detail/en/c/1056840/ (accessed 29 October 2020).

Geronimo R et al. (2018). Mapping Fishing Activities and Suitable Fishing Grounds Using Nighttime Satellite Images and Maximum Entropy Modelling. *Remote Sensing*. 101604.

GLISPA (2015). Palau National Marine Sanctuary. Available at http://glispa.org/11-commitments/201-palau-national-marine-sanctuary (accessed 17 December 2020).

Gouel C and LaBorde D (2019). *The Role of Trade in Adaptation to Climate Change*. VoxEU.Org.

Grimm IJ et al. (2018). Tourism under climate change scenarios: impacts, possibilities, and challenges. *Revista Brasileira de Pesquisa em Turismo*. 12(3):1–22.

Hallegatte, S., Rentschler J and Rozenberg J (2020). The Adaptation Principles: 6 Ways to Build Resilience to Climate Change. Available at https://www.worldbank.org/en/news/feature/2020/11/17/the-adaptation-principles-6-ways-to-build-resilience-to-climate-change (accessed 18 November 2020).

Heinrich Böll Foundation (2015). *The SOIL ATLAS 2015.*

Helvetas (2015). *Climate Change and Agriculture*. Helvetas Swiss Intercooperation.

Howden SM et al. (2007). Adapting agriculture to climate change. *Proceedings of the National Academy of Sciences*. 104(50):19691–19696.

Hurley G (2015). Financing for Development and Small Island Developing States: A Snapshot and Ways Forward.

ILO (2019). *Working on a Warmer Planet: The Impact of Heat Stress on Labour Productivity and Decent Work*.

ILOSTAT (2020). ILOSTAT. Available at https://ilostat.ilo.org/data/ (accessed 5 November 2020).

ILOSTAT-KILM (2020). Employment in agriculture (% of total employment) (modeled ILO estimate) | Data. Available at https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?name_desc=false (accessed 5 November 2020).

IPBES (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services. Zenodo. (accessed 6 December 2020).

IPCC (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability.*

ITU (2020). Frontier Technologies to Protect the Environment and Tackle Climate Change. Available at https://www.itu.int/en/action/environment-and-climate-change/Documents/frontier-technologies-to-protect-the-environment-and-tackle-climate-change.pdf.

Jackman M et al (2020). Distance Matters: The Impact of Physical and Relative Distance on Pleasure Tourists' Length of Stay in Barbados. *Annals of Tourism Research*. 80102794.

Kahn ME et al. (2019). Long-Term Macroeconomic Effects of Climate Change: A Cross-Country Analysis. No. w26167. National Bureau of Economic Research. (accessed 6 November 2020).

Keller BD et al. (2009). Climate Change, Coral Reef Ecosystems, and Management Options for Marine Protected Areas. *Environmental Management*. 44(6):1069–1088.

Khor M, Montes M, Williams M and Yu V (2017). Addressing the Impacts of Climate Change Response Measures on Developing Countries. Available at https://www.southcentre.int/wp-content/uploads/2017/11/RP81_Promoting-Sustainable-Development-by-Addressing-the-Impacts-of-Climate-Change-Response-Measures-on-Developing-Countries_EN.pdf.

Klöck C and Nunn PD (2019). Adaptation to Climate Change in Small Island Developing States: A Systematic Literature Review of Academic Research. *The Journal of Environment & Development*. 28(2):196–218.

Kompas T, Pham VH and Che TN (2018). The Effects of Climate Change on GDP by Country and the Global Economic Gains From Complying With the Paris Climate Accord. *Earth's Future*. 6(8):1153–1173.

Laffoley D and Baxter JM, eds. (2016). *Explaining Ocean Warming: Causes, Scale, Effects and Consequences*. IUCN, International Union for Conservation of Nature.

Layne D (2017). Impacts of Climate Change on Tourism in the Coastal and Marine Environments of Caribbean Small Island Developing States (SIDS). *Science Review 2017*. Commonweath Marines Economy Programme.

Li G et al. (2020). Increasing ocean stratification over the past half-century. *Nature Climate Change.*

van Lieshout M, Kovats RS, Livermore MTJ and Martens P (2004). Climate change and malaria: analysis of the SRES climate and socio-economic scenarios. *Global Environmental Change*. Climate Change. 14(1):87–99.

Lobell DB, Schlenker W and Costa-Roberts J (2011). Climate trends and global crop production since 1980. *Science*. 333(6042):616–620.

Micale V, Tonkonogy B and Mazza F (2018). Understanding and Increasing Finance for Climate Adaptation in Developing Countries. Available at https://www.climatepolicyinitiative.org/.

Nurse L et al. (2014). *Chapter 29: Small Islands. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* WMO.

OECD (2015). *The Economic Consequences of Climate Change.*

OECD (2017). International Trade Consequences of Climate Change. *OECD Trade and Environment Working Papers.*

OECD (2020). *Climate Finance Provided and Mobilised by Developed Countries in 2013-18.*

OECD and World Bank (2016). Climate and Disaster Resilience Financing in Small Island Developing States. Available at http://documents1.worldbank.org/curated/en/956251492596714376/pdf/114389-WP-v1-PUBLIC-R2-CDRFinSIDs-Summary-PRINT-FINAL-UPDATED.pdf.

Oppenheimer M et al. (2019). Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities. 126.

Osman-Elasha B (2009). Women in The Shadow of Climate Change. *The UN Chronicle*. (46(3–4)):54–55.

Ouraich I and Tyner WE (2014). *Climate Change Impacts on Moroccan Agriculture and the Whole Economy: An Analysis of the Impacts of the Plan Maroc Vert in Morocco*. WIDER Working Paper.

Oxfam (2020). Climate Finance Shadow Report 2020 October. Available at https://www.oxfam.org/en/research/climate-finance-shadow-report-2020 (accessed 22 November 2020).

Reddy VR and Syme GJ (2015). Chapter 1 - Introduction. In: Reddy V R, and Syme G J, eds. *Integrated Assessment of Scale Impacts of Watershed Intervention*. Elsevier. Boston: 3–21.

Reid PC and Hill C (2016). Ocean warming: setting the scene. *Explaining ocean warming: Causes, scale, effects and consequences*. 17.

Rhiney K, Eitzinger A, Farrell AD and Prager SD (2018). Assessing the implications of a 1.5 °C temperature limit for the Jamaican agriculture sector. *Regional Environmental Change*. 18(8):2313–2327.

Riahi K et al. (2011). RCP 8.5—A scenario of comparatively high greenhouse gas emissions. *Climatic Change*. 109(1):33.

Roson R and Sartori M (2016). Estimation of Climate Change Damage Functions for 140 Regions in the GTAP 9 Data Base. *Journal of Global Economic Analysis*. 1(2):78–115.

Rubel F and Kottek M (2010). Observed and projected climate shifts 1901-2100 depicted by world maps of the Köppen-Geiger climate classification. *Meteorologische Zeitschrift*. 135–141.

Shelton C (2014). Climate change adaptation in fisheries and aquaculture. *FAO Fisheries and Aquaculture Circular (FAO) eng no. 1088.*

Shukla, J. Skea, E. Calvo Buendia and Masson-Delmotte, H. (2020). *Summary for Policymakers — Special Report on Climate Change and Land*. IPCC.

Simpson, M., Scott, D and Trotz, U (2011). Climate Change's Impact on the Caribbean's Ability to Sustain Tourism, Natural Assests and Livelihoods | Publications. Available at https://publications.iadb.org/publications/english/document/Climate-Change-Impact-on-the-Caribbean-Ability-to-Sustain-Tourism-Natural-Assests-and-Livelihoods.pdf (accessed 29 October 2020).

Smith MS, Horrocks L, Harvey A and Hamilton C (2011). Rethinking adaptation for a 4°C world. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*. 369(1934):196–216.

Solomon S, Plattner G-K, Knutti R and Friedlingstein P (2009). Irreversible climate change due to carbon dioxide emissions. *Proceedings of the National Academy of Sciences*. 106(6):1704–1709.

SPREP (2016). PACIFIC ISLANDS AND SEA-LEVEL RISE. Available at https://www.sprep.org/attachments/Publications/FactSheet/Oceans/pacific-islands-sea-level-rise.pdf.

Stocker TF et al. (2013). *Climate Change 2013: The Physical Science Basis, Summary for Policymakers*. Cambridge University Press. Cambridge, UK, and New York, NY, USA.

Stocker TF et al. (2014). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of IPCC the Intergovernmental Panel on Climate Change*. Cambridge University Press. Cambridge.

Thiault L et al. (2019). Escaping the perfect storm of simultaneous climate change impacts on agriculture and marine fisheries. *Science Advances*. 5(11):eaaw9976.

UNCBD (2016). Biodiversity and the 2030 agenda for sustainable development. Available at https://www.cbd.int/development/doc/biodiversity-2030-agenda-policy-brief-en.pdf (accessed 6 December 2020).

UNCTAD (2010). The contribution of tourism to trade and development. Available at https://unctad.org/system/files/official-document/cid8_en.pdf.

UNCTAD (2015). *The Least Developed Countries Report 2015.*

UNCTAD (2019a). Commodity-dependent countries urged to diversify exports. Available at https://unctad.org/news/commodity-dependent-countries-urged-diversify-exports (accessed 16 December 2020).

UNCTAD (2019b). *Commodities and Development Report 2019.*

UNCTAD (2019c). Enhancing productive capacity through services. Available at https://unctad.org/system/files/official-document/c1mem4d20_en.pdf.

UNCTAD (2020a). UNCTAD Country Classifications. Available at https://stats.unctad.org/handbook/Annexes/Classifications.html (accessed 16 November 2020).

UNCTAD (2020b). Least developed countries. Available at https://unctad.org/topic/vulnerable-economies/least-developed-countries (accessed 16 November 2020).

UNCTADStat (2020). UNCTAD Statistics Database. Available at unctadstat.org.

UNDP (2017). Adaptation in the coastal zones of Mozambique. Available at https://www.mz.undp.org/content/mozambique/en/home/operations/projects/environment_and_energy/adaptation-in-the-coastal-zones-of-mozambique.html (accessed 29 October 2020).

UNDP (2020). Pacific Adaptation to Climate Change (PACC) | UNDP Climate Change Adaptation. Available at /projects/bf-pacc (accessed 29 October 2020).

UNEP (2016). *The Adaptation Finance Gap Report 2016*. Nairobi, Kenya.

UNFCCC (2020a). Climate Finance in the negotiations. Available at https://unfccc.int/topics/climate-finance/the-big-picture/climate-finance-in-the-negotiations (accessed 19 November 2020).

UNFCCC (2020b). Response Measures | UNFCCC. Available at https://unfccc.int/topics/mitigation/workstreams/response-measures (accessed 3 December 2020).

United Nations (2018). External debt sustainability and development Report of the Secretary-General. Available at https://unctad.org/system/files/official-document/a73d180_en.pdf.

UN-OHRLLS (2020). Assessment of Financing for Development Flows SIDS (2020). Available at https://www.un.org/ohrlls/news/assessment-financing-development-flows-sids-2020 (accessed 7 December 2020).

UNWTO, ed. (2020a). UNWTO World Tourism Barometer and Statistical Annex January. Available at https://www.e-unwto.org/doi/epdf/10.18111/wtobarometereng.2020.18.1.1 (accessed 13 November 2020).

UNWTO, ed. (2020b). *UNWTO Briefing Note – Tourism and COVID-19, Issue 2. Tourism in SIDS – the Challenge of Sustaining Livelihoods in Times of COVID-19*. World Tourism Organization (UNWTO).

Weatherdon LV, Magnan AK, Rogers AD, Sumaila UR and Cheung WWL (2016). Observed and Projected Impacts of Climate Change on Marine Fisheries, Aquaculture, Coastal Tourism, and Human Health: An Update. *Frontiers in Marine Science*. 3.

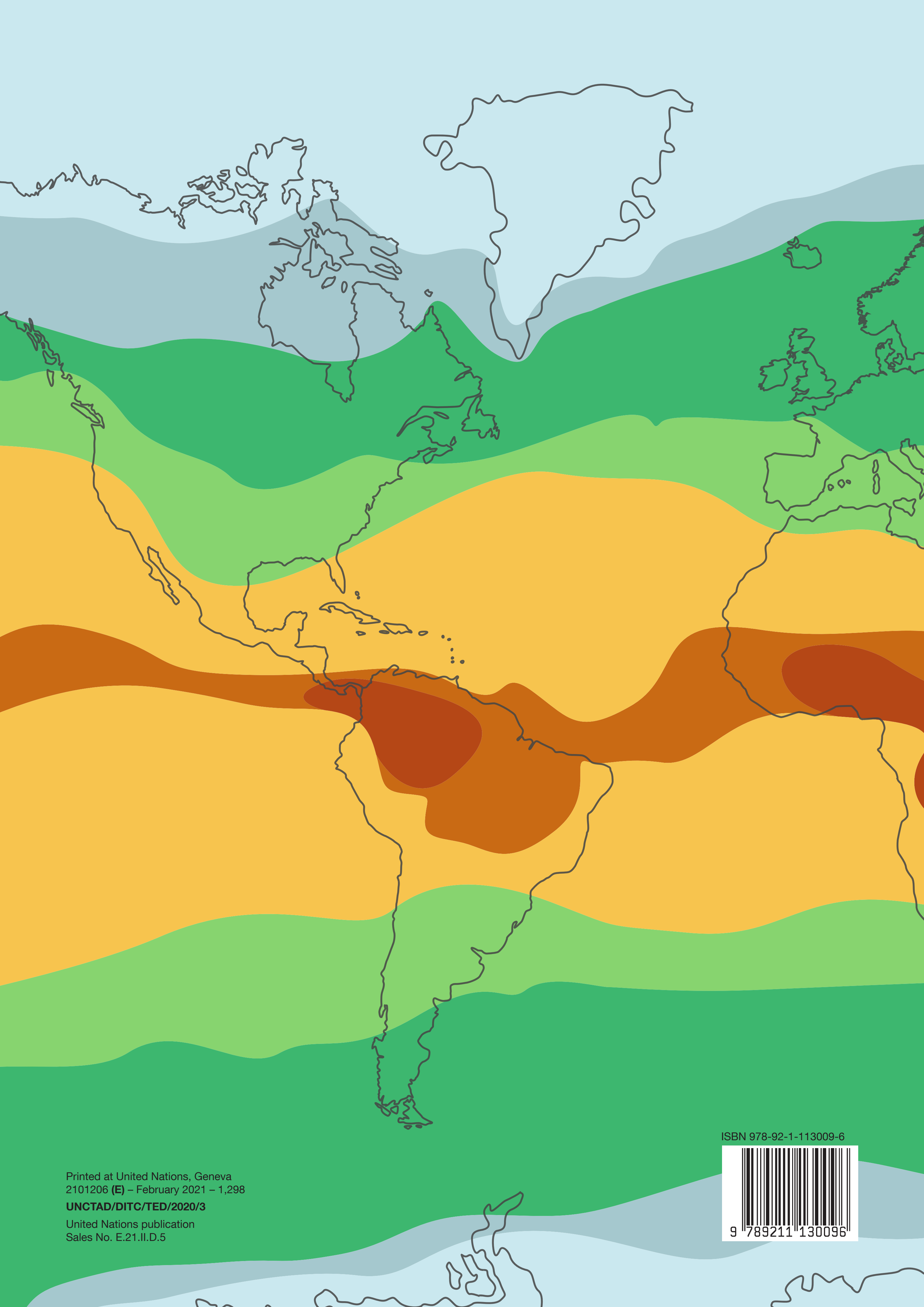
WMO (2020). *State of the Climate in Africa 2019*. WMO Document, No. 1253. World Meteorological Organization. Geneva.

WTTC (2020). *Global Economic Impacts and Trends 2020.*

WTTC Data Gateway (2020). WTTC Data Tool. Available at https://tool.wttc.org/ (accessed 13 November 2020).

Notes

1. The main greenhouse gases responsible for climate change are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases. The atmospheric concentrations of these gases increase in step with their continued emission from anthropogenic sources.
2. The full set of reports are available at https://www.ipcc.ch/assessment-report/ar5/.
3. The IPCC publishes modelling results that are calculated from an average of over 20 different independent models run by climate research groups throughout the world. The results presented in this report derive from the IPCC Coupled Model Intercomparison Project Phase 5 (CMIP5) that are published by the IPCC in its 5th Assessment Report.
4. The RCPs – RCP 2.6, RCP 4.5, RCP 6, and RCP 8 .5 – are labelled according to the radiative forcing value in W/m^2 of CO_2 equivalent GHG concentrations resulting in the year 2100 for each RCP development path. Radiative forcing is a quantitative measure of the capacity of the atmosphere to retain energy in the atmosphere.
5. The United Nations, including UNCTAD, classify ‘tourism sector’ trade within a travel and transport classification (see note of Figure 11), whereas the WTTC classifies the ‘tourism sector’ more accurately in terms of travel and tourism. While these classifications and their scope differ, both provide a measure of economic activity for the overall tourism sector.
6. FAO data (2019), Distribution of motorized fishing vessels by region, 2018.
7. See definitions, pp. 19, of WTTC, 2020.
8. Calculated from nationally reported international tourism receipts as expenditures by international inbound visitors, including payments to national carriers for international transport.
9. Figures reported by the OECD as international public climate finance aggregate funds from the Green Climate Fund (GCF), the Adaptation Fund, Climate Investment Funds (CIFs), Global Environment Facility (GEF), Nordic Development Fund (NDF), and multilateral public climate finance that covers climate-related commitments by multilateral development banks (MDBs), multilateral climate funds, as well as other multilateral organizations.
10. www.adaptation-fund.org.
11. www.un.org/ldcportal/least-developed-countries-fund-ldcf/.
12. www.cbiindex.com.
13. www.ccrif.org.



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