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Scientific Facts on

IPCC Climate Change technical report 2022: Impacts, Adaptation and Vulnerability

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GreenFacts

Context - These GreenFacts Highlights are the transcription without any comments or opinions of excerpts from the *Technical Summary* of the *Sixth Assessment Report* (AR6) published by the *International governemantal Panel on Climate Change* (IPCC)[1] of the *United Nations Environmental Programme* (UNEP) and approved by the IPCC member governments line by line.

It provides technical understanding and is developed from the key findings of chapters and cross-chapter papers as presented in their Executive Summaries and integrates across them.

More specifically, the *Working Group II* contribution to the ARS6 assessed the impacts of climate change, looking at ecosystems, biodiversity, and human communities at global and regional levels. It also reviews vulnerabilities and the capacities and limits of the natural world and human societies to adapt to climate change.

This is a faithful summary of the leading report
produced in 2022 by the Intergovernmental Panel on Climate Change (IPCC):
"Climate Change 2022: Impacts, Adaptation and Vulnerability"

The full Digest is available at: https://www.greenfacts.org/en/climate-change-ar6-impacts/

This PDF Document is the Level 1 of a GreenFacts Digest. GreenFacts Digests are published in several languages as questions and answers, in a copyrighted user-friendly Three-Level Structure of increasing detail:

- Each question is answered in Level 1 with a short summary.
- These answers are developed in more detail in Level 2.
- Level 3 consists of the Source document, the internationally recognised scientific consensus report which is faithfully summarised in Level 2 and further in Level 1.

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1. 1. What are the issues more specifically covered in these Highlights?

Besides the context, a brief summary and the subject of this report, the issues developed in the report and more specifically covered by these Highlights are:

- 4. **the three key components** associated to climate risks;
- 5. the **main climate changes impacts** observed since the former IPCC report;
- 6. the now **expected evolutions of global temperatures**;
- 7. the specific impacts of climate changes on **biodiversity**;
- 8. the damages caused **to terrestrial and freshwater marine ecosystems**;
- 9. the impacts on the various **water systems**;
- 10. the impacts on **agricultural activities and food security**;
- 11. the impacts of climate changes on **human health**;
- 12. the impact of climate change on **costal regions**;
- 13. **the vulnerability of more specifically affected people** and how it will evolve;
- 14. How will this affect more specifically **human migrations**;
- 15. the main impacts of climate change on **economic activities**;
- 16. **How for the world possible to act** facing climate change;
- 17. **the main possible adaptations** to climate change;
- 18. an **Ecosystem-based Adaptation**;
- 19. the **main limits and key barriers to the implementation of adaptation options**;
- 20. overcoming the **barriers of maladaptations** to climate change;
- 21. **How more systemic practices** play a role in the responses to climate change;
- 22. a specific focus to be given to **governance practices**;

[1] www.ipcc.ch/report/ar6/wg2/ [see https://www.ipcc.ch/report/ar6/wg2/]
Final full report [see https://report.ipcc.ch/ar6wg2/pdf/IPCC_AR6_WGII_FinalDraft_FullReport.pdf]
www.ipcc.ch/report/sixth-assessment-report-working-group-ii/ [see https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/]

2. 2. In brief

Even if the temperature goal of 1.5°C is still reached by 2100, a temporary temperature increase over “well below 2°C above pre-industrial” for multi-decadal time spans imply severe risks and irreversible impacts in many natural and human systems (e.g. glacier melt, loss of coral reefs, loss of human lives due to heat) even if the temperature goals are reached later *(high confidence)*. With progressive climate change, enabling conditions will diminish, and opportunities for successfully transitioning systems for both mitigation and adaptation will become more limited *(high confidence)*. Societal choices in the near-term will determine future pathways. ***(very high confidence)***.

Increased ecosystem carbon losses can cause large future temperature increases *(medium confidence)*. Overshoot substantially increases risk of carbon stored in the biosphere being released into the atmosphere due to increases in processes such as wildfires permafrost thaw *(high confidence)*. Species extinctions levels that are >1,000 times natural background rates as a result of anthropogenic pressures and climate change will increasingly exacerbate this *(high confidence)*.

With proactive, timely, and effective adaptation, many risks for human health and wellbeing could be reduced and some potentially avoided ***(very high confidence)***. Large-scale, transformational adaptation also necessitates enabling improved approaches to governance and coordination across sectors and jurisdictions to avoid future maladaptive actions *(high confidence)*.

Various tools, measures and processes are available that can enable, accelerate and sustain adaptation implementation *(high confidence)*, in particular when anticipating climate change impacts, empower inclusive decision making and action when they are supported by adaptation finance and leadership across all sectors and groups in society *(high confidence)*.

Multilateral governance practices and efforts for climate resilient development will be most effective when supported by formal (e.g., the law) and informal (e.g., local customs and rituals) institutional arrangements providing for ongoing coordination between and alignment of local to international arrangements across sectors and policy domains *(high confidence)*. Also local leadership especially amongst women and youth can advance equity within and between generations *(medium confidence)*. The COVID-19 pandemic demonstrated the value of coordinated planning across sectors, *(high confidence)*.

3. 3. What is the subject of this report?

This report is based on scientific understanding and its key findings are formulated as statements of facts. For all five major categories of risks about climate change, more evidence than in the previous report supports increase to *high level* and *very high levels* at lower global warming levels *(high confidence)*.

The report has a strong focus on the interactions and interdependence among the coupled systems climate, ecosystems (including their biodiversity) and human society. Indeed, there is not one single dangerous climate threshold across sectors and regions. These interactions are the basis of emerging impacts and risks from climate change, ecosystem degradation e.g., biodiversity loss, overall unsustainable consumption of natural resources, land and ecosystem degradation, rapid urbanisation, human demographic shifts, social and economic inequalities and a pandemia.

At the same time, the report offers opportunities for the future and adaptation measures are set against concurrently unfolding non-climatic global trends.

4. 4. What are the three key components associated to climate risks?

Vulnerability, adaptation and resilience are the three essential components characterising the climate risks:

- a) **Vulnerability** which is defined as the propensity or predisposition to be adversely affected and encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt of exposed human and natural systems is a component of risk.
- b) **Adaptation** is the process of adjustment to actual climate and its effects; human intervention may facilitate this. It plays a key role in reducing exposure and vulnerability to climate change in natural systems. Adaptation is subject to hard and soft limits. A hard adaptation limit is when no adaptive actions are possible to avoid intolerable risks while in a soft adaptation limit options may

exist but are currently not available to avoid intolerable risks through adaptive action.

- c) **Resilience** is defined as the capacity of social, economic and ecosystems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure as well as biodiversity in case of ecosystems. Resilience is a positive attribute when it maintains such a capacity for adaptation, learning, and/or transformation.

5. 5. What are the main climate changes impacts observed since the former 5th IPCC report (AR5)?

Widespread, pervasive impacts to ecosystems, people, settlements, and infrastructure have resulted from observed increases in the frequency and intensity of climate and weather extremes, including hot extremes on land and in the ocean, heavy precipitation events, drought and fire weather *(high confidence)*. These include increased heat related human mortality *(medium confidence)*, warm-water coral bleaching and mortality *(high confidence)*, and increased drought related tree mortality *(high confidence)*. Compounded and cascading climate risks, such as tropical cyclone storm surge damage to coastal infrastructure and supply chain networks, are expected to increase *(medium confidence)*.

Increasingly since AR5, these observed impacts have been attributed to human-induced climate change particularly through increased frequency and severity of extreme events. Risks to ecosystem integrity, functioning and resilience are projected to escalate with every tenth of a degree increase in global warming ***(very high confidence)*** and will also determine their future carbon storage capacity *(high confidence)*.

Population groups in most vulnerable and exposed regions to compound and cascading risks have the most urgent need for improved adaptive capacity *(high confidence)*. Projected increase in heavy rainfall events at all levels of warming in many regions in Africa will cause increasing exposure to pluvial and riverine flooding *(high confidence)*.

6. 6. What are the now expected evolutions of global temperatures?

Under the five illustrative scenarios, in the near term (2021–2040), the 1.5°C global warming level is *very likely* to be exceeded under the very high greenhouse gas emissions scenario and *more likely than not* to be exceeded under the low greenhouse gas emissions scenario. For the very low greenhouse gas emissions scenario, it is *more likely than not* that global surface temperature would decline back to below 1.5°C toward the end of the 21st century.

7. 7. What are the specific impacts of climate changes on biodiversity?

Biodiversity loss due to past global warming will continue to escalate with every increment of global warming ***(very high confidence)***. Near-term warming and increased frequency, severity and duration of extreme events will place many terrestrial, freshwater, coastal and marine ecosystems at high or very high risks of biodiversity loss *(medium to **very high confidence**, depending on ecosystem)*[2]. In terrestrial ecosystems, 3 to 14% of species assessed will likely face very high risk of extinction at global warming levels of 1.5°C, increasing up to to 39% at 4°C and to 48% at 5°C.

Global warming will progressively weaken soil health and ecosystem services such as pollination, increase pressure from pests and diseases, and reduce marine animal biomass, undermining food productivity in many regions on land and in the ocean *(medium* *confidence)*. Continued and accelerating sea level rise will encroach on coastal settlements and infrastructure *(high confidence)* and commit low-lying coastal ecosystems to submergence and loss *(medium confidence)*. The number of people at risk from loss of biodiversity associated to climate change will progressively increase *(medium confidence)*.

Effective ecosystem conservation on approximately 30% to 50% of Earth's land, freshwater and ocean areas, including all remaining areas with a high degree of naturalness and ecosystem integrity, will help protect biodiversity, build ecosystem resilience and ensure essential ecosystem services *(high confidence)*.

[2] Important to note that biodiversity is essential to the resilience of natural ecosystems in functions like pollination, climate regulation, flood protection, soil fertility, etc. It is also crucial to ensure the productivity of resources and the services that nature supplies to humanity for the production of food, fuels, fibres (a.o. wood and paper) and medicines.

8. 8. What are the damages caused more specifically to terrestrial and freshwater?

Climate change has caused substantial damages, and increasingly irreversible losses *(high confidence)*. The extent and magnitude of impacts in terrestrial, freshwater and coastal and open ocean marine ecosystems are larger than estimated in previous assessments *(high confidence)*. Impacts are evident on ecosystem structure, species geographic ranges and timing of seasonal life cycles. Projected climate change, combined with non-climatic drivers, will cause loss and degradation of much of the world's forests *(high confidence)*, coral reefs and low-lying coastal wetlands ***(very high confidence)***.

Approximately half of the species assessed globally have shifted polewards or, on land, also to higher elevations ***(very high confidence)***. Other impacts are approaching irreversibility such as the impacts of hydrological changes resulting from the retreat of glaciers, or the changes in some mountain *(medium confidence)* and Arctic ecosystems driven by permafrost thaw *(high confidence)*.

Hundreds of local losses of species have been driven by increases in the magnitude of heat extremes *(high confidence)* in the ocean ***(very high confidence)*** and loss of kelp forests *(high confidence)*. Some losses are already irreversible, such as the first species extinctions driven by climate change *(medium confidence)*.

9. 9. What are the impacts of climate change on the various water systems?

Challenges for water management will be exacerbated in the near, mid and long term, depending on the magnitude, rate and regional details of future climate change and will be particularly challenging for regions with constrained resources for water management *(high confidence)*. Roughly half of the world's population currently experience severe water scarcity for at least some part of the year due to climatic and non-climatic drivers *(medium confidence)*. Risks in physical water availability and water-related hazards will continue to increase by the mid to long-term in all assessed regions, with greater risk at higher global warming levels *(high confidence)*. Central to equity issues about water is that it remains a public good *(high confidence)*.

Projected climate-driven water cycle changes impacting humans and societal well-being, are including increase in evapotranspiration, altered spatial patterns and amount of precipitation. Associated changes in groundwater recharge, runoff and streamflow will impact terrestrial, freshwater, estuarine and coastal ecosystems and the transport of materials through the biogeochemical cycles *(medium confidence)*. By 2050, environmentally critical streamflow is projected to be affected in 40% to 80% of the world's watersheds, causing negative impacts on freshwater ecosystems *(medium confidence)*. Water supplies could degrade due to increased wildfire, combined with soil erosion due to deforestation *(medium confidence)*.

10. 10. What are the impacts of climate change on agricultural activities and food security?

With every increment of warming, exposure to climate hazards will increasingly add pressure on food production systems, undermining food security *(high confidence)* and adverse impacts on all food sectors will become prevalent, further stressing food security *(high confidence)*. Between 1.5°C and 2°C global warming, increases in frequency, intensity and severity of droughts, floods and heatwaves, and continued sea level rise will also increase risks to food security from moderate to high in vulnerable regions *(high confidence)*. Global marine aquaculture also will decline under increasing temperature and acidification conditions by 2100, with potential short-term gains for finfish aquaculture in some temperate regions).

Ocean warming and ocean acidification have already adversely affected food production from shellfish aquaculture and fisheries in some oceanic regions *(high confidence)*. Increasing weather and climate extreme events have already exposed millions of people to acute food insecurity and reduced water security, with the largest impacts observed in many locations and/or communities in Africa, Asia, Central and South America, Small Islands and the Arctic *(high confidence)*.

Although overall agricultural productivity has increased, climate change has slowed this growth over the past 50 years globally *(medium confidence)*, related negative impacts were mainly in mid- and low latitude regions but positive impacts occurred in some high latitude regions *(high confidence)*. In the meantime, these impacts will be reinforced by unsustainable agricultural expansion, driven in part by unbalanced diets, which increases ecosystem and human vulnerability and leads to competition for land and/or water resources *(high confidence)*.

Adaptation options exist through better management, governance and socioeconomic dimensions *(medium confidence)* to eliminate overexploitation and pollution *(high confidence)*, in particular to reduce vulnerability of fisheries, Indigenous knowledge and local knowledge can facilitate adaptation in small-scale fisheries, especially when combined with scientific knowledge and utilized in management regimes *(medium confidence)*.

Among others, genetic improvements through modern biotechnology have also the potential to increase climate resilience in food production systems *(high confidence)*.

11. 11. What are the impacts of climate changes on human health?

In all regions, extreme heat events have already resulted in human mortality and morbidity ***(very high confidence)***. Overall, more than half of the excess mortality is projected for Africa. The occurrence of climate-related food-borne and water-borne diseases has also increased ***(very high confidence)***. Water and food-borne disease risks have also increased regionally from climate-sensitive aquatic pathogens, higher temperatures, increased rain and flooding have increased the occurrence of diarrheal diseases, including cholera ***(very high confidence)*** and other gastrointestinal infections *(high confidence)*. Zoonoses that have been historically rare or never documented in Arctic and subarctic regions of Europe, Asia, and North America are emerging as a result of climate-induced environmental change ***(very high confidence)***.

Climate change will further increase the number of deaths and the global burden of non communicable and infectious diseases *(high confidence)*. As the likelihood of dangerous risks to human health continue to increase, there is greater need for transformational changes to health and other systems ***(very high confidence)***. Several chronic, non-communicable respiratory diseases are climate-sensitive based on their exposure pathways (e.g., heat, cold, dust, small particulates, ozone, fire smoke, and allergens) *(high confidence)*, although climate change is not the dominant driver in all cases.

Despite acknowledgement of the importance of health adaptation as a key component, action has been slow since AR5 *(high confidence)*. Globally, health systems are poorly resourced in general, and their capacity to respond to climate change is weak, with mental health support being particularly inadequate ***(very high confidence)***. In assessed regions, some mental health challenges, including anxiety and stress, are associated with increasing temperatures *(high confidence)*, trauma from weather and climate extreme events ***(very high confidence)***, and loss of livelihoods and culture *(high confidence)*. Financial constraints are the most referenced barrier to health adaptation and therefore scaling up financial investments remains a key international priority ***(very high confidence)***.

12. 12. What will be more specifically the impact of climate change on costal regions?

In the mid-term under all scenarios, coastal wetlands will likely face high risk from sea-level rise in the mid-term *(medium confidence)*. By 2050, more than a billion people located in low-lying cities and settlements will be at risk from coast-specific climate hazards, influenced by coastal geomorphology, geographical location and adaptation action, including in Small Islands *(high confidence)*.

Between 2010-2020, human mortality from floods, droughts and storms was already 15 times higher in highly vulnerable regions, compared to regions with very low vulnerability *(high confidence)*.

Sea-level rise, combined with altered rainfall patterns, will increase coastal inundation and water-use allocation issues between water-dependent sectors, such as agriculture, direct human consumption, sanitation, and hydropower *(medium confidence)*. Near- to mid-term sea-level rise will also exacerbate coastal erosion and submersion, and the salinisation of coastal groundwater, expanding the loss of many different coastal habitats, ecosystems and ecosystem services *(medium confidence)*. For example, in Europe coastal flood damage is projected to increase at least 10-fold by the end of the 21st century, and even more or earlier with current adaptation and mitigation *(high confidence)*.

13. 13. How is the vulnerability of people more specifically affected and will evolve?

Human and ecosystem vulnerability are interdependent *(high confidence)* and vulnerability to climate change is thus a multi-dimensional phenomenon, dynamic and shaped by intersecting processes *(high confidence)*.

As a matter of facts, since the previous report AR5, there is increasing evidence that degradation and destruction of ecosystems by humans increases the vulnerability of people *(high confidence)*. Sea-level rise, heat waves, droughts, changes in run-off, floods, wildfires and permafrost thaw disrupt key infrastructure and services such as energy supply and transmission, communications, food and water supply, and transport systems in and between urban and peri-urban areas *(high confidence)*. Globally, and even within protected areas, unsustainable use of natural resources, habitat fragmentation, and ecosystem damage by pollutants increase ecosystem vulnerability to climate change *(high confidence)*.

Future human vulnerability will continue to concentrate where the capacities of local, municipal and national governments, communities and the private sector are least able to provide infrastructures and basic services *(high confidence)*. Societies with high levels of inequity across gender, income, class, ethnicity, age and physical ability, marginalization, historical and ongoing patterns of inequity such as colonialism, and governance are less resilient to climate change *(high confidence)* and differs substantially among and within regions ***(very high confidence)***. The COVID-19 pandemic is also expected to increase the adverse consequences of climate change since the financial consequences have led to a shift in priorities and constrain vulnerability reduction *(medium confidence)*.

Maladaptation is also an unintended consequence dnd challenge including via increased greenhouse gas emissions, increased or shifted vulnerability to climate change, more inequitable outcomes, or diminished welfare, now or in the future. Unplanned rapid urbanization and urban key infrastructure systems are increasingly sites of a major driver risk creation that potentially drive compounding and cascading other risks *(high confidence)* particularly where increasing climate-driven risks affect key infrastructures.

Climate variability and extremes, particularly drought, are also associated with more prolonged conflict through food price spikes, food and water insecurity, loss of income and loss of livelihoods *(high confidence)*, with more consistent evidence for violent intrastate conflict but also low-intensity organized violence within countries *(medium confidence)*.

14. 14. How will this human vulnerability affect more specifically human migrations?

In the mid- to long-term, displacement will increase with intensification of heavy precipitation and associated flooding, tropical cyclones, drought and, increasingly, sea level rise *(high confidence)* with small island states disproportionately affected *(high confidence)*. Climate hazards associated with extreme events and variability act as direct drivers of involuntary migration and displacement and as indirect drivers through deteriorating climate-sensitive livelihoods *(high confidence)* even if compared to other socioeconomic factors the influence of climate on conflict is assessed as relatively weak *(high confidence)*.

Improving the feasibility of planned relocation and resettlement is a high priority for managing climate risks *(high confidence)*. Most climate-related displacement and migration occur within national boundaries, with international movements occurring primarily between countries with contiguous borders *(high confidence)*. While relocation may in the near-term appear socially unacceptable, economically inefficient, or technically infeasible, it may become the only feasible option as protection costs become unaffordable and technical limits are reached *(medium confidence)*.

15. 15. What are the main impacts of climate change on economic activities?

Recent estimates of projected global economic damages of climate impacts are overall higher than previous estimates and generally increase with global average temperature *(high confidence)*. Interconnectedness and globalization establish pathways for the transmission of climate related risks across sectors and borders, through trade, finance, food, and ecosystems *(high confidence)*.

Losses become systemic when affecting entire systems and can even jump from one system to another e.g. drought impacting on rural food production contributing to urban food insecurity *(medium confidence)*. At high levels of warming, climate impacts will pose risks to financial and insurance markets, especially if climate risks are incompletely internalized *(medium confidence)* such as sea level rise for coastal regions which will have large implications for economic activities, including shipping and ports *(high confidence)*.

In the meantime, while the overall economic consequences are clearly negative, opportunities may arise for a few economic sectors and regions, such as from longer growing seasons or reduced sea ice, primarily in Northern latitudes *(medium to high confidence)*.

16. 16. Is it still possible for the world to act facing climate change?

Climate change impacts and risks are becoming increasingly complex and more difficult to manage. Multiple climate hazards will occur simultaneously, and multiple climatic and non-climatic risks will interact, resulting in compounding overall risk and risks cascading across sectors and regions. Some responses to climate change result in new impacts and risks *(high confidence)*[3].

Near-term actions that limit global warming to close to 1.5°C would substantially reduce projected losses and damages related to climate change in human systems and ecosystems, compared to higher warming levels, but cannot eliminate them all ***(very high confidence)***. Transformation and system transitions in energy, land, ocean, coastal and freshwater ecosystems, in urban, rural and infrastructure and in industry and society make possible the adaptation required. Societal resilience is strengthened by improving management of environmental resources and ecosystem health, boosting adaptive capabilities of individuals and communities to anticipate future risks and minimize them. This removing drivers of vulnerability by bringing together gender justice, equity, Indigenous and local knowledge systems and adaptation planning ***(very high confidence)***.

Diversifying livelihoods improves incomes and reduces socio-economic vulnerability depending on livelihood type, opportunities, and local context but key barriers include socio-cultural and institutional barriers as well as inadequate resources and livelihood opportunities that hinder the full adaptive possibilities *(high confidence)*.

A key to enable and accelerate climate resilient development is to build adaptive and inclusive governance systems that are equipped to take long-term decisions to reoriente existing institutional capacity and differentiated policies and regulation from the local to global-scale institutions to become more flexible e.g., through capacity building and institutional reform *(medium confidence)*.

[3] See again in this context the question 21: Could more systemic views and management practices play a role in the management of responses and adaptations to climate change challenges?

17. 17. What are the main possible adaptations to climate change?

In a systemic context, sustainable development is fundamental to capacity for climate action, including reductions in greenhouse gas emissions as well as enhancing social and ecological resilience to climate change. Risk insurance can be a feasible tool to adapt to transfer climate risks and support sustainable development *(high confidence)*. They can reduce both vulnerability and exposure, support post-disaster recovery, and reduce financial burden on governments, households, and business. Carefully designed and implemented disaster risk management and climate services can increase the feasibility and effectiveness of adaptation responses to improve agricultural practices, income diversification, urban and critical services and infrastructure planning ***(very high confidence)***.

Increasing adaptation is being observed in natural and human systems ***(very high confidence)***, yet the majority of climate risk management and adaptation currently being planned and implemented is incremental *(high confidence)* such as reactive changes to usual practices often after extreme weather events, whilst evidence of transformative adaptation in human systems is limited *(high confidence)*.

Greatest adaptation gaps exist in projects that manage complex risks, for example in the food energy-water-health nexus or the inter-relationships of air quality and climate risk *(high confidence)*. However, most financial investment continues to be directed narrowly at large-scale hard engineering projects after climate events have caused harm *(medium confidence)*.

Effective management of climate risks is thus dependent on systematically integrating adaptations across interacting climate risks and across sectors ***(very high confidence)*** that more effectively anticipate multi-dimensional risks and accommodate community values than those with a narrow focus on single risks *(medium confidence)*. When organized collectively with multiple objectives and when assisted by mainstreaming climate considerations across institutions and decision-making processes, many forms of climate adaptation and integration of risks across sectors can be more effective, efficient and equitable *(high confidence)*. For example, transformations for energy that nclude the options of efficient water use and water management, infrastructure resilience, and reliable power systems, including the use of intermittent renewable energy sources, such as solar and wind energy, with the use of storage ***(very high confidence)***. In natural and managed ecosystems adaptation includes a.o. earlier planting and changes in crop varieties, soil improvement and water management for livestock and crops, aquaculture, restoration of coastal and hydrological processes *(medium confidence)*.

Furthermore, to give access to education and information, programmes using the performing and visual arts, storytelling, training workshops, participatory dimensional modelling, climate services, and community-based monitoring are other efficient ways to enhance climate literacy and foster behavioural change.

18. 18. What is an Ecosystem-based Adaptation?

Ecosystem-based Adaptation is defined as the use of ecosystem management activities to increase the resilience and reduce the vulnerability of people and ecosystems to climate change. Increasing the resilience of biodiversity and ecosystem services to climate change includes minimising additional stresses or disturbances, reducing fragmentation, increasing natural habitat extent, connectivity and heterogeneity, maintaining taxonomic, phylogenetic and functional diversity and redundancy; and protecting small-scale refugia where microclimate conditions can allow species to persist *(high confidence)*.

Restoration of ecosystems in catchments can also support water supplies during periods of variable rainfall and maintain water quality and combined with inclusive water regimes that overcome social inequalities, provide disaster risk reduction and sustainable development *(high confidence)*.

19. 19. What are the main limits and key barriers to the implementation of adaptation options to climate change?

There is increasing evidence on systemic barriers and limits to the implementation of adaptation and the speed of change which result from not managing adaptation options by combining and integrating the responses to all its constraints and limits *(high confidence)* in particular in vulnerable sectors, regions and social groups *(high confidence)*.

Evidence of maladaptation is increasing in some sectors and systems highlighting how inappropriate responses to climate change create long-term lock-in of vulnerability, exposure, and risks that are difficult and costly to change ***(very high confidence)***. Maladaptation occurs for many reasons including inadequate knowledge, short-term, fragmented, single-sectoral and/or non-inclusive governance planning and implementation *(high confidence)*. Climate adaptation capacity is reduced and vulnerability is amplified by inequities and poverty; by population growth and high population density, by land use change, especially deforestation, soil degradation, and biodiversity loss, high dependence of national and local economies on natural resources for production of commodities, weak governance, unequal access to safe water and sanitation services, and a lack of infrastructure and financing *(high confidence)*.

The key barriers to adaptation are limited resources as most of the adaptation options to the key risks depend on limited water and land resources *(high confidence)*. Among the other key barriers are lack of private sector and citizens engagement, insufficient mobilisation of finance (including for research), lack of political leadership, limited research and/or slow and low uptake of adaptation science, and low sense of urgency.

At higher levels of warming, hard limits, which are those for which existing adaptation options will cease to be effective and additional options are not possible, will increasingly emerge *(high confidence)*. The urban adaptation gap shows that for all world regions current adaptation is unable to resolve risks to current climate change associated hazards. For agricultural production, soft and hard limits are related to water availability and the uptake and effectiveness of climate-resilient crops which are constrained by socio-economic and political challenges *(medium confidence)*.

Prioritisation of options and transitions from incremental to transformational adaptation are limited due to vested interests, economic lock-ins, institutional path-dependencies, and prevalent practices, cultures, norms, and belief systems. In human and managed systems key determinants of such adaptation limits are financial constraints, particularly in low-income settings *(high confidence)*, while in natural systems key determinants for limits are inherent traits of the species or ecosystem ***(very high confidence)***. Financial barriers limit implementation of adaptation. Meanwhile, instruments such as behavioural nudges, redirecting subsidies, taxes, regulation of marketing, insurance schemes have proven useful to strengthen societal responses beyond governmental actors *(medium confidence)*. Other opportunities should thus be to integrate adaptation into institutionalised decision cycles (*e.g., budget reforms, statutory monitoring and evaluation, election cycles*) and during windows of opportunity: e.g. recovery after disastrous events, designing new or replacing existing critical infrastructure, or developing COVID recovery projects *(high confidence)*.

20. 20. How to overcome the barriers of maladaptations to climate change?

Maladaptation can be reduced by using the principles of recognitional, procedural, and distributional justice in decision making, responsibly evaluating who is regarded as vulnerable and at risk; who is part of decision-making; who is the beneficiary of adaptation measures, and integrated and flexible governance mechanisms that account for long-term goals *(high confidence)*. Decreasing maladaptation requires attention to justice and a shift in enabling conditions toward those that enable timely adjustments for damages to be avoided or minimised and opportunities seized *(high confidence)*. Insufficient financing is a key driver of adaptation gaps *(high confidence)*. For example, Africa faces severe climate data constraints, and inequities in research funding and leadership that reduce adaptive capacity ***(very high confidence)***.

Closing the adaptation gap requires thus moving beyond short-term planning to developing long term, concerted pathways and enabling conditions for ongoing adaptation to ensure timely and effective implementation *(high confidence)*. Integrated approaches such as the water/energy/food nexus and inter-regional considerations of risks can reduce the risk of maladaptation, building on existing adaptation strategies, increasing community participation and consultation and the integration of Indigenous populations.

A mix of infrastructure, nature-based, institutional and socio-cultural interventions can best address the risks. Flexible options enable responses to be adjusted as climate risk escalates and circumstances change which may increase exposure *(medium confidence)*. Urban adaptation measures have also many opportunities to contribute to *Climate Resilient Development Pathways (medium confidence)*.

Knowledge and Local Knowledge, focusing on the most vulnerable small-scale producers, anticipating risks of maladaptation in decision-making for long-lived activities including infrastructure decisions, and the impact of trade-offs and co-benefits *(high confidence)*. Such pathways require consideration of the United Nations' *Sustainable Development Goals*, as well as of gender Indigenous knowledge and local knowledge and practices.

21. 21. Could more systemic views and management pratices play a role in the management of responses and adaptations to climate change challenges?

Climate solutions for health, wellbeing and the changing structure of communities are complex, closely interconnected, and call for new approaches to sustainable development that consider interactions between climate, human and socio-ecological systems to generate climate resilient development *(high confidence)*. To rebalance the relation between human and nature, adaptation measures require transformation of the ways of learning knowing, and acting which integrate at the global system level its ecological, social, political and economical dimensions *(high confidence)*.

Meanwhile, scientific assessments of climate change have traditionally framed solutions around the implementation of specific adaptation and mitigation options as mechanisms for reducing climate-related risks. They have given less attention to a fuller set of societal priorities and the role of non-climate policies, social norms, lifestyles, power relationships and worldviews in enabling climate action and sustainable development. As a matter of facts, focus on climate risk alone does not enable effective climate resilience *(high confidence)*. It is when pursued in an inclusive and integrated manner that adaptation measures can really enhance human and ecological well-being.

A deliberate shift from primarily technological adaptation strategies to those that additionally incorporate behavioural and institutional changes, adaptation finance, equity and environmental justice, and that align policy with global sustainability goals, will thus facilitate transformational adaptation *(high confidence)*. Such system-level transitions in the five domains on which AR6 is focused are highly feasible. Moving towards different pathways involves confronting complex synergies and trade-offs between development pathways, and the options, contested values, and interests that underpin climate mitigation and adaptation choices ***(very high confidence)***.

22. 22. Should a specific focus be given to governance practices?

Climate governance arrangements and practices are enabled when they are embedded in societal systems that advance human well-being and planetary health ***(very high confidence)***. Enablers for climate governance include better practices and legal reforms but prevailing governance efforts have not closed the adaptation gap ***(very high confidence)***, in part due to the complex interconnections between climate and non-climate risk and the limits of the predominant development and governance practices *(high confidence)*.

Governance arrangements and practices are presently ineffective to reduce risks, reverse path dependencies and maladaptation, and facilitate climate resilient development ***(very high confidence)***. Indeed, institutional fragmentation, under-resourcing of services, inadequate adaptation funding, uneven capability to manage uncertainties and conflicting values, and reactive governance across competing policy domains, collectively lock in existing exposures and vulnerabilities, creating barriers and limits to adaptation, and undermine climate resilient development prospects *(high confidence)*.