The thirteenth meeting of the research dialogue, 2021

1–2 June 2021

Summary report by the Chair of the SBSTA

20 September 2021

Overview

Responding to the goals of the Paris Agreement requires a transformation in current systems to provide the mitigation and adaptation needed, whilst protecting the Earth systems that sustain life. This requires understanding of the interconnectedness between all parts of the Earth's climate system, natural world and people.

The thirteenth meeting of the research dialogue explored some of the latest knowledge on climate system dynamics, the role of nature, and building understand of climate change impacts and risks and implications for decision making. The meeting explored two themes:

Theme 1 (1 June) Climate system dynamics and modelling: New knowledge and its implications for decision making.

Theme 2 (2 June) Resilience for and by nature: Building knowledge and understanding to weave the protection and restoration of nature into decision making on mitigation and adaptation

This summary report provides an overview of the plenary presentations and discussions as well as the posters from the dialogue. Key messages from the plenary discussions are also provided.

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Abbreviations

AFOLU	Agriculture Forestry and Other Land Use	**IPCC**	Intergovernmental Panel on Climate Change
AOSIS	Alliance of Small Island States	**IPSL**	Pierre Simon Laplace Institute
AR5 / 6	IPCC Fifth / Sixth Assessment Report	**IUCN**	International Union for Conservation of Nature and Natural Resources
BCE	Blue Carbon Ecosystems	**JMA**	Japan Meteorological Agency
CBD	Convention on Biological Diversity	**JRC**	Joint Research Council of the European Commission
CDR	Carbon Dioxide Removal	**MEXT**	Ministry of Education, Culture, Sports, Science and Technology, Japan
CIRED	International Research Center on Environment and Development	**NAP**	National Adaptation Plans
CliC	Climate and Cryosphere	**NASA GEDI**	National Aeronautics and Space Administration Global Ecosystem Dynamics Investigation
CLIVAR	Climate and Ocean: Variability, Predictability and Change	**NbS**	Nature-based Solutions
CMCC	Euro-Mediterranean Center for Climate Change	**NDC**	Nationally Determined Contribution
CMIP5 / 6	Coupled Model Intercomparison Project Phase 5 / 6	**NGFS**	Network for Greening the Financial System
COP	Conference of Parties	**NOAA**	National Oceanic and Atmospheric Administration
CORDEX	Coordinated Regional Climate Downscaling Experiment	**PBL**	Netherlands Environmental Assessment Agency
GDP	Gross Domestic Product	**PIK**	Potsdam Institute for Climate Impact Research
EEZ	Exclusive Economic Zone	**RCP**	Representative Concentration Pathway
ESA CCI	European Space Agency Climate Change Initiative	**RD+D**	Research, Development and Design
ESM	Earth System Model	**REDD+**	Reducing Emissions from Deforestation and forest Degradation
FAOSTAT	UN Food and Agriculture Organisation Statistics	**RSO**	Research and Systematic Observation
GCOS	Global Climate Observing System	**SBSTA**	Subsidiary Body for Science and Technological Advice
GEWEX	Global Energy and Water Exchanges	**SDGs**	Sustainable Development Goals
GFCS	Global Framework for Climate Services	**SPARC**	Stratosphere-troposphere Processes And their Role in Climate
GHG	Greenhouse Gases	**SSP**	Shared Socioeconomic Pathways
GST	Global Stocktake	**UNCCD**	United Nations Convention to Combat Desertification
IAM	Integrated Assessment Model	**UNEP CCAC**	UN Environment Programme Climate and Clean Air Coalition
IFAD	International Fund for Agricultural Development	**UNFCCC**	United Nations Framework Convention on Climate Change
IIASA	International Institute for Applied Systems Analysis	**WASP**	World Adaptation Science Programme
IOC-R	Integrated Ocean Carbon Research	**WCRP**	World Climate Research Programme
IOC UNESCO	Intergovernmental Oceanographic Commission of the UN Educational, Scientific and Cultural Organization	**WMO**	World Meteorological Organisation

Key messages

<u>Climate system dynamics and modelling: New knowledge and its implications for decision making</u>

The World Climate Research Programme: Future Climate Research

- The WCRP strategic plan supports decision makers' requirements for decision-relevant, evidence-based climate implementation of adaptation and mitigation strategies and planning. Five lighthouse activities provide new scientific approaches, technologies, and institutional frameworks which are required to meet the strategic plan's objectives.
- WCRP climate research forums aim to increase the input of scientists from currently underrepresented regions within the programme.

Science for Society: CORDEX

- CORDEX continues to use high resolution climate change simulations to inform society about possible regional and local climate extremes to help decision makers prepare for climate change impacts and extremes, with future efforts focussed at finer scale.

Navigating climate projections for decision making at regional and local level

- In order to address adaptation challenges, the Lighthouse Activity My Climate Risk will navigate uncertainty in projections to develop a new framework for assessing and explaining regional climate risk to deliver climate information that is meaningful at the local scale.

New Climate and Adaptation Science and Implications for Decision Making

- The WASP is supporting the consolidation of the current large research endeavours on adaptation into a more coherent adaptation theory that ensures inclusion of the most vulnerable groups. This in turn can better guide science of, and for, adaptation and support adaptation policy and practice.
- More research is needed to create sets of adaptation metrics and indicators to contribute to measuring collective progress and support the Global Stocktake.

Insights from recent mitigation pathways and related activities by the scientific community

- A new generation of mitigation pathways are becoming available that explore different strategies for limiting temperature change including rapid, fundamental transformations and early upfront investments that lead in the long term to significant economic gains, even before accounting for the economic benefits of avoided impacts due to mitigation.
- The focus of climate scenarios is evolving to include the financial sector and cost-effectiveness assessments for mitigation as well as other new needs.

Country-level experience of incorporating scientific information for decision making and needed future directions for science and scientific capacity building

- Jamaica continues to strengthen science-based decision making by addressing climate data and knowledge gaps and streamlining climate research innovation and data analysis into each sector. Challenges include data and knowledge gaps, technical and human capacities, the need for more detailed and disaggregated data including at the sector and community level, the translation of research into policies and development plans, the connection between climate research and finance, and the limited availability of 'easy-to-use' analytical tools.
- The Cook Islands is developing a National Marine Spatial Plan and an Island Spatial Plan to reach a more holistic understanding of the ocean and assist in managing national marine resources and inform future progressive action through robust science and research. However more investment is needed on observation and research particularly on the deep sea, linked with traditional knowledge, to support decision making.

Resilience for and by nature: Building knowledge and understanding to weave the protection and restoration of nature into decision making on mitigation and adaptation

Current and projected relationships between climate change and biodiversity and system risks

- Across the ocean and land, rising temperature trends are negatively impacting species richness and biodiversity and projected to continue. Due to the narrow temperature changes that higher plant and animal species are adapted to, depending on the degree of climate change conditions, performance (such as carbon storage) will be negatively impacted and some parts of the planet (the ocean and land in the tropics) may become intolerable for higher organisms.
- Ambitious and sustained emissions reductions are crucial for maintaining and strengthening the biosphere's capacity to support both mitigation and adaptation. This must be combined with land and ocean management for conservation, restoration, and sustainability to protect biodiversity, enable food security for humankind, and help to avoid future pandemics.

Nature-based Solutions to climate change – relevance, scope, and future directions

- The need for more ambitious emission reduction is a priority but should be combined with protecting at least 30% of the land and ocean for conservation, restoration, and sustainability supported through nature-based solutions that synergise mitigation, adaptation and other ecosystem services. IUCN adopted the global standard for nature-based solutions in 2020.

Potential synergies between mitigation and adaptation for the land sink and how to evaluate opportunities and tradeoffs

- The land carbon sink is highly variable with uncertainty around the estimates of land use emissions, especially at the global level. Coordinated planning is needed to reconcile the large differences in land use CO_2 flux between global models and national GHG Inventories to tailor the needed decision making at the local and sectoral level and address knowledge gaps.
- Good guidance, well-considered trade-offs, consideration of compound impacts and the wider socio-ecological system must be part of the successful implementation of nature-based solutions, which can only be considered as a stop gap and do not lessen the urgency of reaching the mitigation goals of the Paris agreement.

Potential synergies between mitigation and adaptation for the ocean carbon sink and how to evaluate opportunities and tradeoffs

- The ocean carbon sink has been essential in mitigating climate change although urgent emissions reductions are needed to limit further deleterious changes in the ocean. The precise role of the ocean as a future carbon sink remains uncertain and more research is needed to better understand the ocean carbon cycle.
- The ocean provides a space for strengthening mitigation and adaptation action. All marine CDR techniques have limitations and trade-offs and require additional research and development to better understand some of the options available, and their policy implications. However, nature-based mitigation and adaptation action can be synergised while also positively impacting the ocean carbon sink. The coastal zone is a vital area of focus for increased research and decision making.

Going beyond what works in climate: Science and data for decision making and being future-fit

- Uptake of resilience measures requires wider engagement with "non-traditional actors" to help create a paradigm shift towards greater resilience and greater uptake of resilience measures that can be measured, tested and scaled. Evidence or anomalies that can encourage change must be built into adaptation to become a force by themselves and must be better researched.

I. Introduction

1. The foundation for the annual meetings of the research dialogue was given by the Conference of the Parties (COP) decision 9/CP.11 and further focus provided by conclusions of the SBSTA and COP decision 16/CP.17.[1] The meetings provide the opportunity to explore topics relevant to the Convention[2] and the Paris Agreement.[3] It enables engagement between a wide range of experts from the research community, Parties and non-Party stakeholders to support the implementation of the Convention and the Paris Agreement.

2. The thirteenth meeting of the Subsidiary Body for Scientific and Technological Advice (SBSTA) Research Dialogue[4] was held during the virtual UNFCCC May-June 2021 Climate Change Conference,[5] 31 May – 17 June 2021.

3. Prior to the Conference, the SBSTA Chair invited Parties and non-Party stakeholders to submit their views on possible topics and considerations for the thirteenth meeting of the research dialogue. The themes and topics for the meeting were guided by submissions,[6] and in consideration of the mandates and the wider context of ongoing work under the UNFCCC as well as the three recent IPCC reports (SR1.5, SRCCL, SROCC).

4. The thirteenth meeting explored the scientific research and implications of climate system dynamics and modelling for decision making and building knowledge and understanding to weave the protection and restoration of nature into decision making on mitigation and adaptation.

5. The dialogue addressed two themes over two days:

- Theme 1 / Day 1: Climate system dynamics and modelling: New knowledge and its implications for decision making.
- Theme 2 / Day 2: Resilience for and by nature: Building knowledge and understanding to weave the protection and restoration of nature into decision making on mitigation and adaptation.

6. Both days consisted of a 2-hour dialogue with presentations and Q&A. The posters were made available on the virtual gather.town software throughout the conference and a 1-hour poster Q&A session was held on both days of the dialogue to enable participants to ask questions of the poster presenters.

7. The meeting was chaired by the SBSTA chair Mr. Tosi Mpanu Mpanu, Democratic Republic of the Congo, and by co-facilitators of the negotiations on SBSTA agenda item 10 (a) – research and systematic observation, Ms. Elizabeth Bush and Mr. Ladislaus Chang'a.

8. An information note was made available in advance of the event to provide an overview of the themes addressed as well as guiding questions to help focus presentations and discussions.

9. Based on the mandates for the research dialogue, the guiding questions were:

- What are the latest climate research findings and implications for decision making?
- What are the views on needs and priorities for research, research capacity building, knowledge sharing and communication moving forward?
- What is needed to strengthen scientific support for decision-making?

10. This report provides a summary of the plenary presentations and discussions and the posters.

- Section II summarises the presentations, posters and discussion on Theme 1.
- Section IV presents the presentations, posters and discussion on Theme 2.

11. Eleven individual presentations were given during the dialogue. The poster session of the dialogue consisted of 20 posters.

[1] An overview of the mandates founding and guiding the research dialogue are available here: https://unfccc.int/topics/science/resources/research-background.
[2] Available at https://unfccc.int/resource/docs/convkp/conveng.pdf.
[3] Available at https://unfccc.int/sites/default/files/english_paris_agreement.pdf.
[4] See https://unfccc.int/event/thirteenth-meeting-of-the-research-dialogue.
[5] See https://unfccc.int/event/may-june-2021-climate-change-conference-sessions-of-the-subsidiary-bodies.
[6] Submissions were provided by Antigua and Barbuda on behalf of the Alliance of Small Island States, Bhutan on behalf of Least Developed Countries (LDCs), Portugal and the European Commission on behalf of the European Union and its member states, Japan, and the United States of America.

12. I encourage Parties to consider the information in this summary report as part of the basis for negotiations on research and systematic observation at upcoming SBSTA sessions.

II. Summary of plenary presentations and discussions and posters on Theme 1: Climate system dynamics and modelling: New knowledge and its implications for decision making

13. Presenters for Theme 1 were Mr. Mike Sparrow, WCRP Secretariat; Ms. Daniela Jacob, WCRP; Mr. Ted Shepherd, University of Reading, UK; Ms. Cynthia Rosenzweig, WASP; Mr. Keywan Riahi, IIASA; and Mr. Ajani Alleyne, Jamaica, and Mr. Isaac Glassie-Ryan, The Cook Islands, on behalf of AOSIS.

14. The recording of Day 1 of the 13th meeting of the research dialogue is available on-demand.

A. Presentations

1. The World Climate Research Programme: Future Climate Research

15. Mr. Mike Sparrow, WCRP, opened the dialogue with a presentation on the **WCRP strategic plan 2019–2028** outlining future climate research directions.[7] In the past, the WCRP has focused on fundamental science to advance understanding of the climate system and how it is being affected by humans. Moving forward, the new WCRP strategic plan takes into consideration the worldwide coordinated effort needed to provide decision makers with decision-relevant, evidence-based climate information, prepared by a scientific workforce that involves co-design and stakeholder engagement, for adaptation and mitigation.

The WCRP strategic plan supports decision makers' requirements for decision-relevant, evidence-based climate implementation of adaptation and mitigation strategies and planning. Five lighthouse activities provide new scientific approaches, technologies, and institutional frameworks which are required to meet the strategic plan's objectives

WCRP climate research forums aim to increase the input of scientists from currently underrepresented regions within the programme.

16. The new strategic plan is focused on four scientific objectives (figure 1):

a). **Fundamental understanding of the climate system**, which has core activities on the ocean, CLIVAR;[8] cryosphere, CliC;[9] atmosphere, SPARC,[10] and the water and energy cycle, GEWEX.[11] Two new projects focus on regional information for society and earth system modelling and observations, which brings modelling and observation activities closer together;

b). **Prediction of the near-term evolution of the climate system** (on timescales from years to decades);

c). **Long term response of the climate system -** the Coupled Model Intercomparison Project[12] (CMIP), currently in its sixth phase (CMIP6), is integral to activities under b) and c) and contributes scenario runs to the IPCC;

d). **Bridging climate science and society**, which examines the relationship between science and services for the community and provides advice to policymakers. For example, the World Meteorological Organisation (WMO) Global Annual to Decadal Climate Update[13] originated from a WCRP activity and is now run by the UK Met Office for the WMO.

[7] See https://www.wcrp-climate.org/.
[8] See https://www.clivar.org/.
[9] See https://www.climate-cryosphere.org/.
[10] See https://www.sparc-climate.org/.
[11] See https://www.gewex.org/.
[12] See https://www.wcrp-climate.org/wgcm-cmip.
[13] Available at https://hadleyserver.metoffice.gov.uk/wmolc/.

Figure 1
The WCRP Strategic Plan 2019–2028

Source: *Slide 4 of Mr. Sparrow's presentation*.

17. The WCRP has developed five lighthouse activities to provide the new scientific approaches, technologies, and institutional frameworks required to meet the strategic plan's objectives.[14] All of the lighthouse activities are listed below. Mr. Sparrow provided further detail on two of these activities in his presentation (see a) and b)):

a). **Explaining and predicting earth system change**: aims to design and implement major steps towards delivering an integrated capability for quantitative observation, explanation, and early warning and prediction of Earth system change on global and regional scales and at annual to decadal timescales. It incorporates information from modelling activities and observations and uses scientific understanding of process studies, such as those that can be used to understand attribution, prediction, and projections in the future;

b). **The WCRP Academy**: addresses the requirements of climate research education to build an enabling mechanism, and look at gaps. The Academy will work with all WCRP core activities, including the lighthouse activities. The WCRP Academy will begin with a stocktake to look at what already exists worldwide in terms of climate education and will then try to fill gaps and make recommendations;

c). **My Climate Risk**: was explained by Mr. Shepherd (see paragraphs 25–33 below);

d). **Safe Landing Climates**;

e). **Digital Earths**.

18. As part of its future-focused engagement, the WCRP has established **climate research forums**[15] focusing on different regions of the world to increase the input of scientists from underrepresented regions, such as the African continent and parts of East Asia. The forums are calls and workshops where scientists exchange ideas and discuss new activities and opportunities, including feedback on how to meet the requirements of the future.

19. The **WCRP Open Science Conference**[16] is planned for the beginning of 2023. It will focus on climate science for a sustainable future and the WCRP has opened the call for hosts around the world.

[14] See https://www.wcrp-climate.org/lha-overview.
[15] See https://www.wcrp-climate.org/wcrp-ip-consult.
[16] See https://www.wcrp-climate.org/news/wcrp-news/1671-wcrp-osc-2023.

2. Science for Society: CORDEX

20. Ms. Daniela Jacob, WCRP, provided updates from CORDEX,[17] which contributes to WCRP objective 4 – Bridging Climate Science and Society'. CORDEX aims to advance and coordinate science and the application of regional climate downscaled information and enables researchers to take the possible climate changes projected by global climate models to understand the consequences for, and provide reliable information on, local and regional phenomena.

CORDEX continues to use high resolution climate change simulations to inform society about possible regional and local climate extremes to help decision makers prepare for climate change impacts and extremes, with future efforts focussed at finer scale.

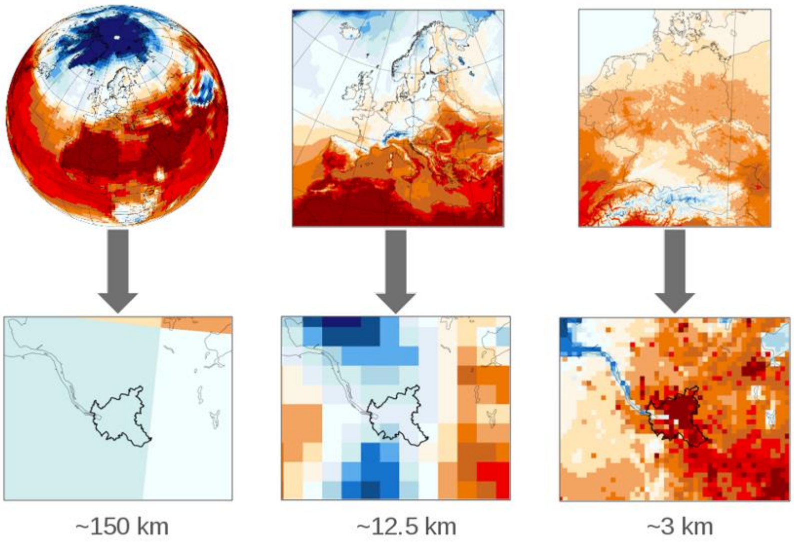
21. CORDEX uses high resolution climate change simulations to inform society about possible regional and local climate extremes such as the duration and frequency of heat waves, storms, heavy precipitation and other climate extremes. As shown in Figure 2, these high-resolution simulations allow researchers to focus on specific phenomena and regions, such as heat waves in cities.

22. **CORDEX flagship studies** include:

a). Pilot studies to inform society about possible regional and local climate extremes across different areas of the world to gather information on, for example, the influence of heavy precipitation on flooding, soil erosion, and thunderstorms. These studies contribute to a better understanding of where heavy precipitation is changing and provide climate services to help decision makers better prepare for disasters;

b). A new project focusing on regional climate change in urban areas which aims to increase understanding of the effects of climate change on health and our ability to work in urbanised areas. For example, it looks at issues such as the heat island effect, humidity, and air pollution and quality exploring how decision makers can connect early warning systems with climate change adaptation information to understand where more green spaces or water can protect people during strong heat waves.

Figure 2
Downscaling global models for local and regional use via CORDEX



Source: Slide 4 of Ms. Jacob's presentation.

23. All CORDEX data are available publicly, are open access, and are subject to quality control following WCRP and WMO standards. Datasets have been produced for regional domains all over the world and are all available in data archives. Scientists, politicians and stakeholders can access those data and use it to underpin climate adaptation efforts and formulate National Adaptation Plans, as has already been done via the open NAPs process.[18]

[17] See https://cordex.org/.
[18] See http://napexpo.org/opennap/index.php?title=Main_Page.

24. In the future, **CORDEX plans to produce more quality controlled, science-based data on an even finer scale**. The WCRP welcomes dialogue to understand which climate data and which parameters are of most use to decision-makers and stakeholders to protect themselves and their communities against disasters and the effects of climate change.

3. Navigating climate projections for decision making at regional and local level

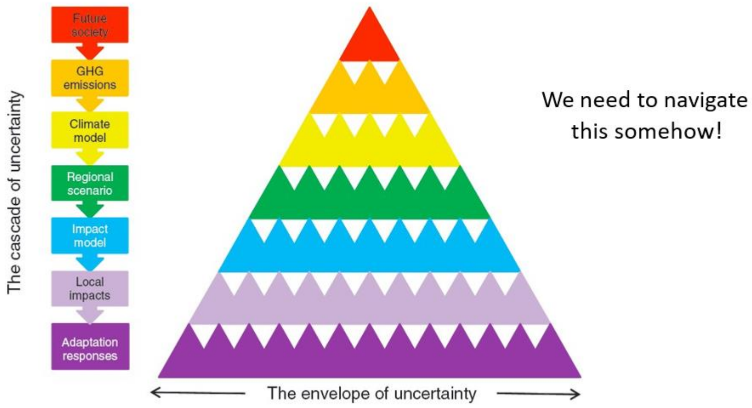
25. Mr. Ted Shepherd, University of Reading on behalf of the WCRP, presented on updates on climate projections for decision making at regional and local level and the lighthouse activity on My Climate Risk.

In order to address adaptation challenges, the Lighthouse Activity My Climate Risk will navigate uncertainty in projections to develop a new framework for assessing and explaining regional climate risk to deliver climate information that is meaningful at the local scale.

26. Time series of many global climate indicators related to thermodynamic aspects of climate change show clear long-term trends of climate change. However, aspects of climate change related to atmospheric circulation, such as the Southern Oscillation index - the atmospheric oscillation of the El Nino Southern Oscillation, and the All-India summer monsoon rainfall indices are highly uncertain. Regardless of these uncertainties, it is well known that circulation patterns exert a large influence on the climate, for example, the North Atlantic Oscillation affects the European climate by shifting the jet stream and creating wet and warm or cold and dry conditions.

27. Climate science seeks to make statements of confidence about what has happened with the climate system, and what will happen. In regard to atmospheric circulation, uncertainties in models from global to local can create a "cascade of uncertainty" (figure 3).

Figure 3
The 'cascade of uncertainty' which obscures the climate information content



A cascade of uncertainty proceeds from different socio-economic and demographic pathways, their translation into concentrations of atmospheric greenhouse gas (GHG) concentrations, expressed climate outcomes in global and regional models, translation into local impacts on human and natural systems, and implied adaptation responses. The increasing number of triangles at each level symbolize the growing number of permutations and hence expanding envelope of uncertainty. For example, even relatively reliable hydrological models can yield very different results depending on the methods (and observed data) used for calibration.
Source: Slide 4 of Mr. Shepherds's presentation; Wilby, RL and Dessai, S, Robust adaptation to climate change. Weather 65, 180–185 (2010). https://doi.org/10.1002/wea.543.

28. One way to manage the cascade is to aggregate spatially or in time and create general statements. An example of this approach is the statement in the IPCC AR5 narrative on the water cycle on precipitation patterns and long-term changes projected by climate models[19] "Changes in the global water cycle in response to the warming over the 21st century will not be uniform. The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase, although there may be regional exceptions". The statement achieves its reliability of identifying precipitation changes in the tropics by including the (very extensive) oceanic regions, but adaptation planners require to know specific information on precipitation over land. The final caveat increases reliability in the statement but decreases informativeness. In the IPCC AR6 Working Group I Summary for Policy Makers there is an acknowledgement of the uncertainty created by atmospheric circulation and more of an effort to provide

19 See IPCC AR5 WGI SPM E.2, SPM.8 https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_SPM_FINAL.pdf.

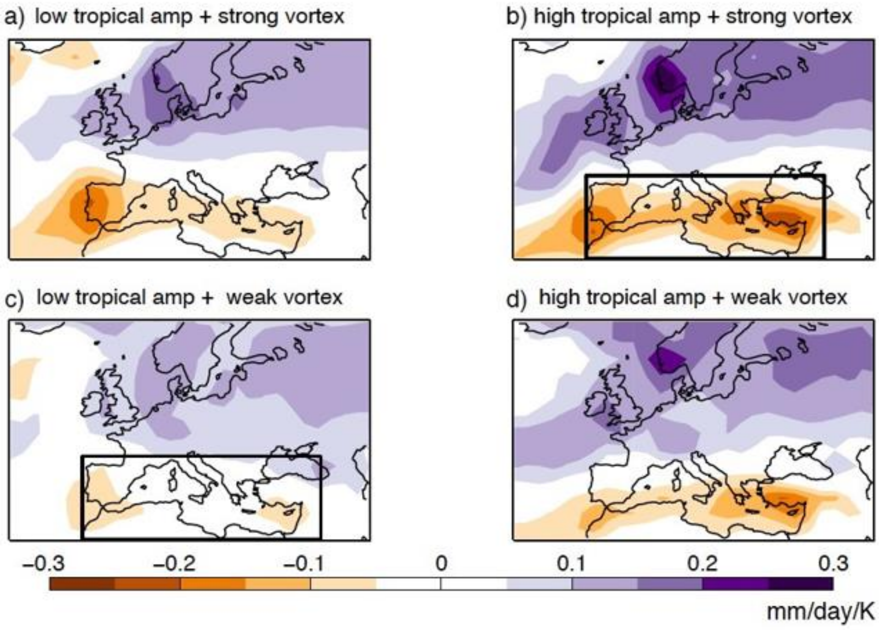
regionally differentiated information[20]. However, striking the right balance between accuracy and informativeness remains difficult.

29. Mr. Shepherd highlighted that scientists can be pressured to issue single, definitive statements. This can lead to generalisation of the response of parts of the climate system to climate change and makes statements less informative. To remedy this situation and better support decision making under uncertainty, a language is needed for describing the 'plural, conditional' state of knowledge on the climate system and future changes and risks.

30. **Using storylines can offer a powerful way of linking physical with human aspects of climate change to support decision making. Storylines can be used to reduce uncertainty by contextualising historical events and representing complex environments and future adaptation options**.

31. For example, in the Mediterranean where precipitation projections are reasonably robust, there can be significant quantitative uncertainty even for specified global warming levels due to possible different responses of the stratospheric vortex. This creates different storylines of future cold-season Mediterranean drying (figure 4).

Figure 4
Four storylines of future cold-season Mediterranean drying



Different combinations of tropical amplification and stratospheric vortex response create different precipitation responses over Europe.
Source: Slide 8 of Mr. Shepherd's presentation; Zappa, G, and Shepherd, TG, Storylines of Atmospheric Circulation Change for European Regional Climate Impact Assessment, Journal of Climate 30, 16, 6561–6577 (2017). doi.org/10.1175/JCLI-D-16-0807.1.

32. **Storylines can be linked to historical events to provide salience to risk and a narrative that gives an essential emotional element to decision making.** For example:

a). Heavy flooding in the Thames river valley, UK in early 2014 was an unprecedented event that was influenced by the jet stream, but there is no accepted view on whether the jet stream will have more or less influence on such events due to climate change in the future. Different storylines (causal accounts) of the event, and of potential future such events, can be represented through a causal network. This provides a way to represent complex environments and adaptation options, bringing meaning to the climate information (figure 5);

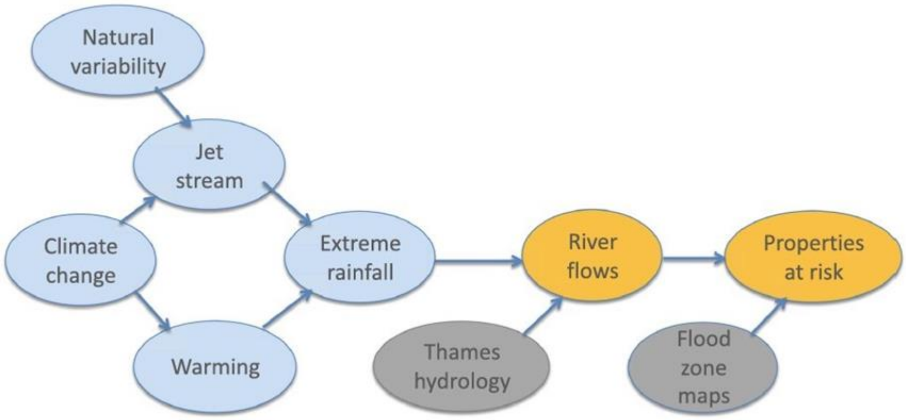
b). The urban heat island effect is a threat multiplier for heatwaves. The effect is a physical, quantitative effect for which there can already be a lot of information available, especially at the local scale. A recent report on urban heatwaves in the Hague, Netherlands,[21] showed that the highest temperatures occurred in the poorest neighbourhoods. This can be understood in the context of

[20] See IPCC AR6 WGI SPM B.3.2, SPM 3 https://www.ipcc.ch/report/ar6/wg1/.
[21] See https://resilientthehague.nl/site/assets/files/1142/3_pra_the_hague_small_file_size.pdf.

aspects of the built environment in these neighbourhoods and other factors, which supports understanding and infrastructure planning.

33. **To explore storylines of climate risk, interpreted not as a prediction, but as representing plausible futures, the 'My Climate Risk' Lighthouse Activity, will develop and mainstream a 'bottom - up' approach to regional climate risk, which starts from the decision context (and the decision scale) and enables relevant climate information to be brought into that context**.

Figure 5
Causal network for the 2014 Thames flooding event: an example of how to represent complex environments and adaptation options to support decision making



Source: Slide 8 of Mr. Shepherd's presentation; Lloyd, EA, and Shepherd, TG, Environmental catastrophes, climate change, and attribution, Annals of the New York Academy of Sciences, 1469, 1, 105–124 (2020). doi: 10.1111/nyas.14308.

4. New Climate and Adaptation Science and Implications for Decision Making

34. Ms. Cynthia Rosenzweig, WASP, presented on new climate and adaptation science and its implications for decision making.[22] WASP's work primarily focuses on current and future research gaps and providing policy relevant guidance on climate risks and vulnerable populations in the context of sustainable development.

The WASP is supporting the consolidation of the current large research endeavours on adaptation into a more coherent adaptation theory that ensures inclusion of the most vulnerable groups. This in turn can better guide science of, and for, adaptation and support adaptation policy and practice.

More research is needed to create sets of adaptation metrics and indicators to contribute to measuring collective progress and support the Global Stocktake.

35. Recent analysis of adaptation research literature using CMIP6 outputs shows that vulnerability, resilience, and adaptive capacity remain major topics for research. More recently urban topics are emerging to join rural issues as major areas of study (figure 6).

36. Although adaptation science is consistently focusing on what climate risks mean for the most vulnerable groups, considering also the context of sustainable development, **many climate risk management strategies exclude marginalised groups**. The differences in vulnerability emerging from research, such as that related to gender, indigenous peoples, youth, disability, and low-income groups, influence the extent to which individuals and communities can plan for and respond to climate change. These groups may also have less access to finance and information that is required for robust decision-making.

37. **Vulnerability and risk assessments play increasingly important roles in informing climate risk decision-making and adaptation**. There are many tools available for risk and vulnerability assessments for communities, biodiversity, and habitats.

[22] See https://www.unep.org/explore-topics/climate-change/what-we-do/climate-adaptation/world-adaptation-science-programme.

38. **Vulnerability and risk assessments must also consider limits to adaptation:**

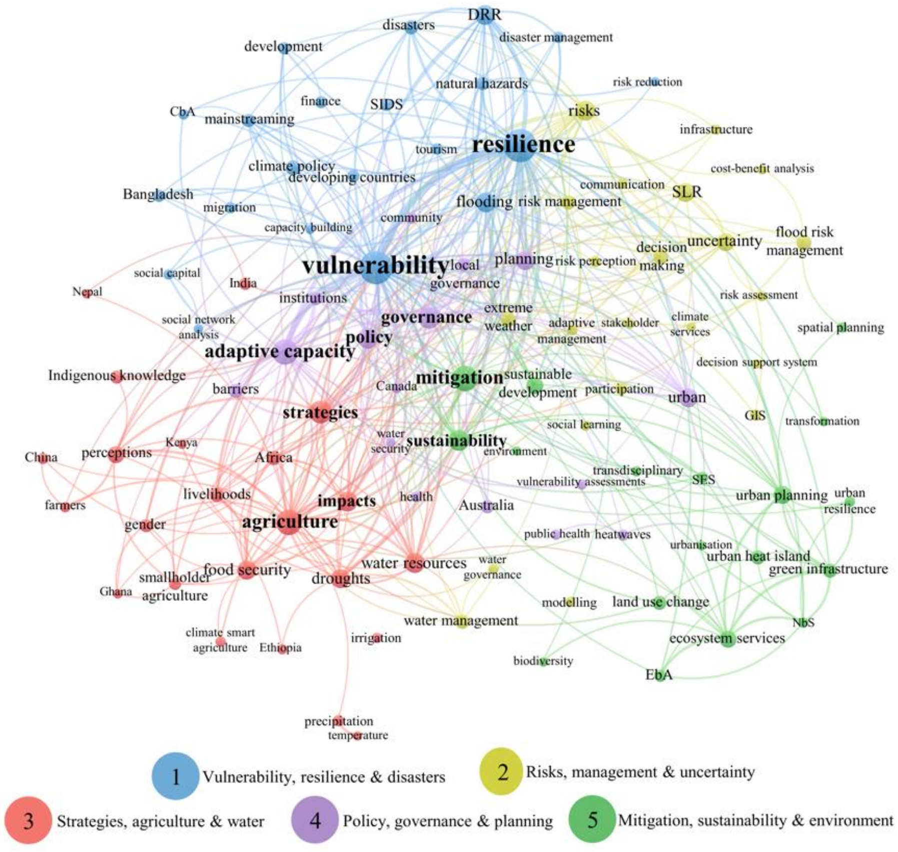
a). Although natural and social systems often have significant capacities to adapt, it is difficult to establish how this compares to the rate and magnitude of climate change;

b). There are biophysical limits to adaptation, for example in the maximum temperature tolerance of crops;

c). Change may not happen incrementally but as a series of tipping points, for example, the loss of ice sheets and the melting of permafrost. This could result in a rapid response from the climate system and cascading effects to other sectors and systems;

d). The effectiveness of adaptation is limited at high levels of climate change. Mitigation is urgent. The potential of adaptation actions such as nature-based solutions can be best realised by limiting the risks of dangerous levels of global warming and by scaling up ambition and action.

Figure 6
Networked policy topics covered by CMIP6



The size of the circle is proportional to the occurrence of the keyword, while links represent keywords used together in at least three publications with the line thickness proportional to the strength of co-occurrence. Minimum line strength links keywords that co-occur in five or more publications.
Source: Slide 4 of Ms. Rosenzweig's presentation; Nalau, J, Verrall, B, Mapping the evolution and current trends in climate change adaptation science, Climate Risk Management, 32, (2021). https://doi.org/10.1016/j.crm.2021.100290.

39. Considering the limits to adaptation, WASP also focuses on providing advice on loss and damage including to support the work under the Warsaw International Mechanism for Loss and Damage. **Strengthening research on loss and damage is needed to enable exploration of financial, technical and legal support where adaptation limits may be exceeded.**

40. This work must bring together emerging evidence of the hard and soft limits to adaptation. For example, a seawall that fails to prevent flooding due to combined sea-level rise and storm surges. Approaches for risk communication associated with acute and slow-onset extreme events can provide integrated decision support for preparation and response on loss and damage.

41. Closer integration and cooperation between physical and social science can already be seen in the progress on national adaptation planning, which is an important method of risk communication. 72% of

countries have at least one national level planning instrument in place that addresses adaptation, and 125 developing countries have begun the process of formulating and implementing their NAPs.

42. Adaptation research is expanding. There is an average annual increase in climate change adaptation publications of 28.5%. Topics and themes change over time, but core concepts (vulnerability, resilience, adaptive capacity) and sectors (water, agriculture) have remained relatively stable. The key challenge going forward is how to consolidate research into a more coherent adaptation theory that can guide adaptation science and support adaptation policy and practice.

43. The latest trends in adaptation science to support vulnerability and risk assessment include:

a). **Cascading risks** – Interacting stressors and interdependencies that affect the ability to adapt;

b). Multiple scales, levels and actors for decision making;

c). **Path dependency and transformative adaptation** to avoid maladaptive lock-in;

d). **Understanding systemic risks and community-based adaptation**.

44. **A major challenge for adaptation research is the creation of metrics for adaptation including for adaptation communications and the Global Stocktake.** [23] This is compounded by lack of clear, specific, and universally agreed definitions of key concepts as well as a large amount of unresolved methodological issues on measurement and aggregation of adaptation results, given the flexibility provided in providing information and the methodologies used. WASP is helping to create sets of metrics and indicators to contribute to the Global Stocktake.

45. Following the publication of WASP's first set of Science for Adaptation Policy Briefs[24] last year, in October 2021, WASP will publish a set of three new briefs on 'Cascading shocks and stressors', the 'Global goal on adaptation', and 'Early warning and forecast systems for adaptation'.

5. Insights from recent mitigation pathways and related activities by the scientific community

46. Mr. Keywan Riahi, IIASA, presented on insights from the integrated assessment modelling community on recent mitigation pathways and related scientific community activities.

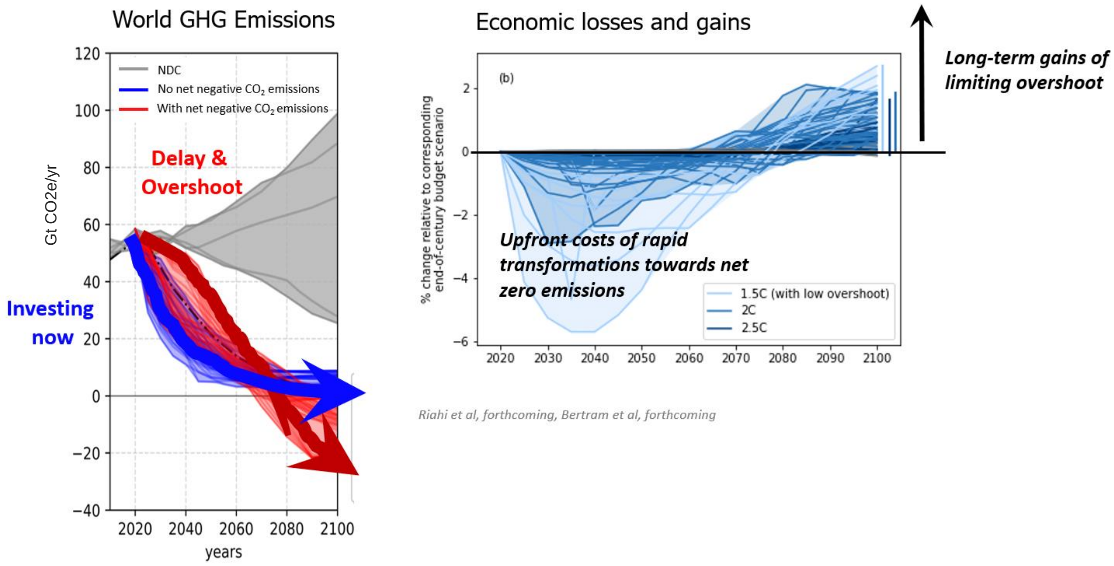
A new generation of mitigation pathways are becoming available that explore different strategies for limiting temperature change including rapid, fundamental transformations and early upfront investments that lead in the long term to significant economic gains, even before accounting for the economic benefits of avoided impacts due to mitigation.

The focus of climate scenarios is evolving to include the financial sector and cost-effectiveness assessments for mitigation as well as other new needs.

47. **Scientists are developing new mitigation pathways that explore different strategies for limiting temperature change** (figure 7). These pathways (right hand side of figure 7) consider early investments and rapid and fundamental changes towards achieving net global zero CO2 emissions early in this century to avoid temperature overshoot. Across all different experiments and modelling tools, **rapid and fundamental transformations and early upfront investments lead in the long term to significant economic gains**. These gains do not yet account for the additional benefits of climate mitigation in terms of avoided impacts. In comparison, conventional mitigation pathways (in red on the left hand side of figure 7) incorporate the inertias in the political and technological systems that lead to relatively delayed and late mitigation. These pathways require negative emissions in the long term in order to compensate for any overshoot of the 2 degree C temperature target of the Paris Agreement.

[23] See https://unfccc.int/topics/science/workstreams/global-stocktake.
[24] See https://wasp-adaptation.org/core-initiatives/science-for-adaptation-policy-briefs.

Figure 7
New scenario design: Rethinking the economic story

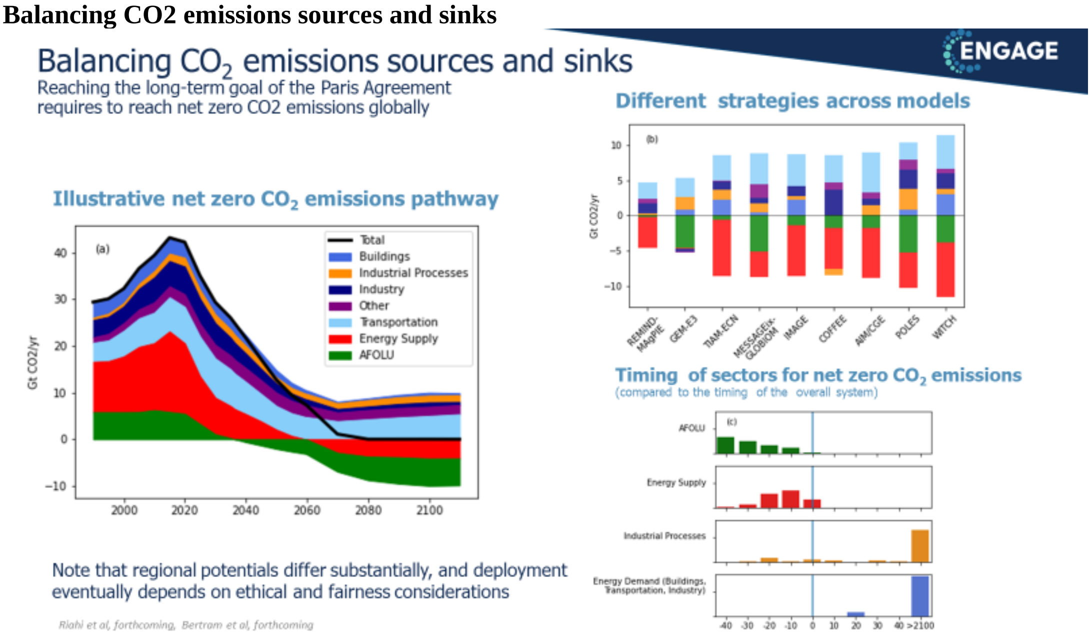


Pathways accommodating delay and overshoot that require net negative CO2 emissions (left, red)) incorporate the inertias in the political and technological systems that lead to relatively delayed and late mitigation, vs pathways that rely less on negative CO2 emissions by investing in mitigation (left, blue). On right, the long term economic gains in investing early in transformation to net-zero emissions.

Source: Slide 2 of Mr. Riahi's presentation; Riahi K et al, forthcoming, https://assets.researchsquare.com/files/rs-127847/v1_stamped.pdf ; Bertram et al, forthcoming.

48. **A current focus in the development of mitigation pathways is the balance between CO_2 emission sources and sinks**. In order to achieve the long-term goal of the Paris Agreement, it is necessary to reach net zero CO_2 emissions globally. Different sectors achieve net-zero at different times or may not achieve net zero over long time scales. Some sectors in the future will act as the sinks that create negative emissions, such as the energy sector and the forestry and land use sector, and will compensate for sectors producing residual emissions, primarily on the demand side, such as the transportation, industry, and buildings sectors (Figure 8).

Figure 8
Balancing CO2 emissions sources and sinks



Source: Slide 3 of Mr. Riahi's presentation; Riahi K et al, forthcoming, https://assets.researchsquare.com/files/rs-127847/v1_stamped.pdf ; Bertram et al, forthcoming.

49. The range of different modelling studies indicates that there may be residual emissions of 5 to 10 Gigatonnes in the long-term, which is equivalent to achieving decarbonisation of 75% to 90% of the system, leaving some residual emissions that need to be compensated for by negative emissions in other sectors.

50. Another important insight from these scenarios is that **different sectors achieve net zero CO_2 emissions at different points in time**. For example, the AFOLU and energy sectors achieve net zero earlier than the global system as a whole. Some sectors never achieve net-zero emissions. Similarly, different regions achieve net-zero at different times, and regional potentials differ substantially. Deployment eventually depends on ethical and fairness considerations. Higher potentials to achieve net zero emissions generally occur in regions with large land areas available to create negative emissions in the forest or in the energy sector.

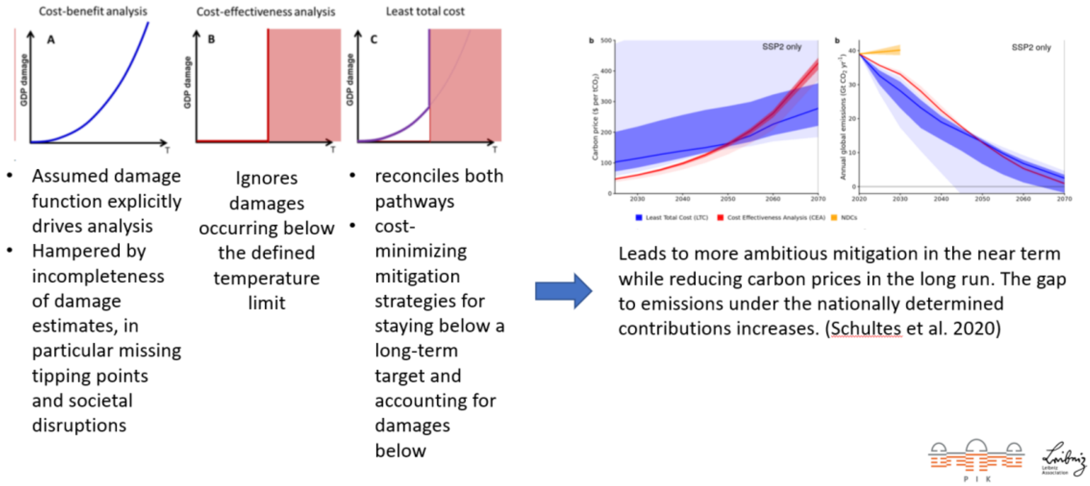
51. The modelling community is considering the feasibility of different global mitigation pathways in the literature. Rapid transitions can raise feasibility concerns in terms of technological changes, economic implications, cultural background, and institutional and governance situations.

52. One of the key conclusions from many feasibility assessments of different pathways that incorporate the social sciences is that the **institutional and governance challenges dominate technological and economic concerns in regions that require rapid mitigation but have low institutional capacity.**

53. **Another important new focus is the development and use of climate scenarios for the financial sector**. For example, the Network for Greening the Financial Sector[25] (NGFS) is a network of banks and financial institutions using scenarios to better understand the risks and opportunities of climate mitigation, such as how different targets align with strategy, policy and portfolios on the ground. This helps to shape and facilitate a research agenda that needs to bring together the integrated assessment modelling community and the finance community to better understand the finance dimension of the transformation.[26]

54. Work is also underway on the integration of impacts and mitigation assessments in new mitigation pathways, as discussed in the poster "*Integrating impacts in mitigation pathway analysis reinforces need for ambitious climate action*".[27] This process aims to improve understanding of the benefits of mitigation, which are currently absent from some modelling analyses. One conclusion from these studies clearly shows that **mitigation will occur sooner if the avoided costs of impacts that will be mitigated are taken into account** (figure 9).

Figure 9
Including impacts into integrated assessment leads to more ambitious mitigation



Source: Slide 7 of Mr. Riahi's presentation; Schultes, A et al, Economic damages from on-going climate change imply deeper near-term emission cuts, Munich Personal RePEc Archive, 2020/8/15. https://mpra.ub.uni-muenchen.de/103655/1/MPRA_paper_103655.pdf.

[25] See https://www.ngfs.net/en.
[26] See https://www.ngfs.net/en/publications/ngfs-climate-scenarios.
[27] See para 86.

55. A new research community paper has **identified seven different needs for important extensions of the SSP framework**:[28]

a). Improve integration of societal and climate conditions;

b). Improve applicability to regional and local scales;

c). Improve relevance beyond the climate research community;

d). Produce a broader range of reference scenarios that include impacts and policy;

e). Capture relevant perspectives and uncertainties;

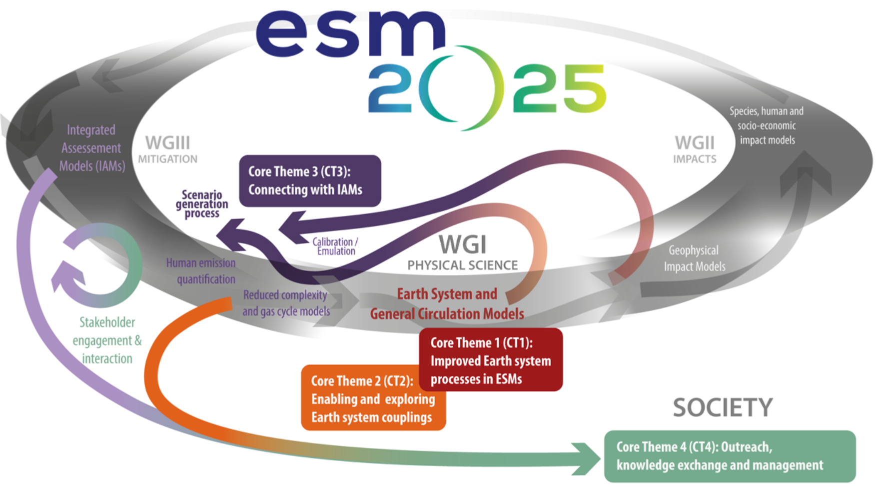
f). Keep scenarios up to date;

g). Improve relevance of climate change scenario applications for users.

56. A new project to address some of the new needs for SSPs is the **ESM 2025[29] project** which will attempt to create a better understanding of how the Paris Agreement can be achieved. It will further **integrate earth system information into mitigation pathways and will begin by improving key aspects of the next generation of earth system models such as the carbon, methane and nitrogen cycles**. Insights will be integrated into integrated assessment modelling. The activities will inform interactive tools for both policymakers and society at large (figure 10).

57. Mr. Riahi concluded his presentation by providing links to a number of different toolkits and portals that may be useful to policymakers, business actors, and finance actors that allow the exploration of mitigation pathways,[30] and links to major developments on the transparency of models.[31]

Figure 10
ESM2025: Earth System Models for the Future



ESM2025 connects Earth system modelling to society to inform the effective operationalisation of the Paris Agreement.
Source: Slide 10 of Mr. Riahi's presentation.

6. Country-level experience of incorporating scientific information for decision making and needed future directions for science and scientific capacity building

58. Mr. Ajani Alleyne, Jamaica, gave a presentation on Climate System Dynamics: New Knowledge and Its Implications for Decision Making.

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28 O'Neill, B.C., Carter, T.R., Ebi, K. *et al.* Achievements and needs for the climate change scenario framework. *Nat. Clim. Chang.* **10,** 1074–1084 (2020). https://doi.org/10.1038/s41558-020-00952-0.

29 See https://mpimet.mpg.de/en/communication/news/single-news/esm2025-erdsystemmodelle-fuer-die-zukunft.

30 See https://climatescenarios.org/.

31 See slide 12 of Mr. Riahi's presentation, available here: https://unfccc.int/sites/default/files/resource/RD13%20Presentation%20Day%201%20KRiahi.pdf.

Jamaica continues to strengthen science-based decision making by addressing climate data and knowledge gaps and streamlining climate research innovation and data analysis into each sector.

Challenges include data and knowledge gaps, technical and human capacities, the need for more detailed and disaggregated data including at the sector and community level, the translation of research into policies and development plans, the connection between climate research and finance, and the limited availability of 'easy-to-use' analytical tools.

59. The Climate Action Enhancement Package[32] program of the NDC Partnership assists with the research and technical development agenda in Jamaica, which is being produced in partnership with the CTCN.[33] The agenda will be used to consolidate, streamline and expand on scientific research, highlight knowledge gaps, and encourage new knowledge and innovation. This aims to result in more inclusive decision-making, which will allow for identification of strategies that maximise social benefits, protect environmental integrity and vulnerable groups, and facilitate long-term sustainable development.

60. Jamaica's vision 2030 national development plan includes climate and scientific data intended to link research with policy development and implementation. For example, the plan includes a strategy to use predictive tools for modelling hazard data, mapping and risk assessment, and bridging the gap between research and finance.

61. Jamaica has published the **State of Jamaican Climate Report** in 2012 and 2015. The 2019 report is being finalised. The report provides downscaled historic and predictive climate information that is used to inform resilience building, design national and local projects, and improve sector-based assessments for climate resilience, planning, and decision making. It will also **inform Jamaica's first National Adaptation Plan will be integrated into the Long-Term Low Greenhouse Gas Emission Development Strategy and the revision of Jamaica's Climate Change Policy Framework**.

62. **By addressing climate data and knowledge gaps and streamlining climate research innovation and data analysis into each sector, Jamaica raised ambition with an updated NDC**. Opportunities were identified to deepen energy sector emission reductions and allow for emission reductions from the forestry sector to be included.

63. New knowledge will expand early warning systems that increase the potential for mitigating loss and damage, keep the local government informed using real-time automatic weather stations, and upgrade radars to collect data for decision making to guide adaptation policies, projects, and other action.

64. **Challenges include data and knowledge gaps, technical and human capacities, the need for more detailed and disaggregated data including at the sector and community level, the translation of research into policies and development plans, the connection between climate research and finance, and the limited availability of 'easy-to-use' analytical tools**.

65. Institutional capacity building can be used to address these challenges regarding personnel systems, training, tools and equipment. A clear policy direction, data sharing and mandated legislation for data collection will ensure that data can be collected, shared and used on a continuous basis, and that new information is discovered and collected. Timely policy and planning reviews need to be performed in response to this new data. Funding must be coordinated around climate priorities, research, and innovation.

66. Mr. Isaac Glassie-Ryan, The Cook Islands, continued on the topic of country-level experience of incorporating scientific information for decision making and needed future directions for science and scientific capacity building from the perspective of the Cook Islands.

The Cook Islands is developing a National Marine Spatial Plan and an Island Spatial Plan to reach a more holistic understanding of the ocean and assist in managing national marine resources and inform future progressive action through robust science and research. However more investment is needed on observation and research particularly on the deep sea, linked with traditional knowledge, to support decision making.

67. Land area on the Cook Islands is limited but the national marine EEZ consists of 1.9 million square kilometres, much of which is deep sea. The size of this EEZ creates challenges, particularly in understanding conditions beyond shallower water, where snapshot assessments are not sufficient to assess changes over time. **There is therefore a necessity for research and a greater scale of observations now and over time.**

32 See https://ndcpartnership.org/caep.
33 See https://www.ctc-n.org/.

68. The Cook Islands is currently focussed on building a greater understanding of the deep sea. Little is known about the deep sea within the Cook Islands' EEZ, and observation of it is a far slower process than conducting observations on land, in lagoons, or in-shore, where existing resources and science practices can be used. These activities do not operate in isolation. They function alongside traditional knowledge, which provides a holistic understanding and subsequent approach to activities.

69. In contrast to land based, and shallow water surveys, deep sea observations require additional financing, technical capacity and other support to understand and analyse the outputs of research and systematic observation programmes and the information gathered. The Cook Islands carries this out under the Marae Moana framework, but further work is needed. **The success of future deep-sea research and observation programmes will require multi-year or decadal observation, to observe changes over time**.

70. Adaptation activities continue to be advanced, for example using data on weather patterns to improve cyclone shelters. A National Adaptation Plan with sectoral approaches is being developed that will use existing scientific information and best practices to plan future pathways for adaptation and other climate action.

71. **Despite the greater inclusion of scientific information within the decision-making process, increased availability of scientific information is needed in other areas, such as the EEZ and deep sea, to fill knowledge gaps, and technical and resourcing capacity constraints must be addressed**. The Cook Islands is developing a National Marine Spatial Plan and an Island Spatial Plan to reach a more holistic understanding of the ocean and assist in managing national marine resources and inform future progressive action through robust science and research.

Discussion

72. **How could the WCRP support climate vulnerability identification, climate risk prediction, define possible measures for climate resilience, and disseminate information, including on climate induced loss and damage, in mountainous regions with low data coverage?**

Mr. Sparrow: The WMO is one of our co-sponsors and we have been involved with the WMO High Mountain Activities. Several of our Core Projects (for example, GEWEX[34]and CliC[35]) have foci in the High Mountain regions. Some of our new activities, such as My Climate Risk, may also cover this.

73. **Can you suggest solution for recalibrating the IPCC uncertainty language to better convey its meaning in common usage?**

Mr. Ted Shepherd: We proposed a new lexicon here: https://doi.org/10.1007/s10584-020-02737-y

We should place more emphasis on the small-likelihood, high-impact possibilities. Storylines are a good way to do this.

74. **What kind of data is CORDEX modelling dependent on, such as satellite data, etc?**

Ms. Jacob: To validate our projections of the future we use all the models available from the satellite community. We use this independent data to compare the quality of our models against the observed data so that we ensure we can accurately simulate the past in order to project the future.

75. **Can indicators be established to track progress towards the Paris agreement?**

Mr. Sparrow: With regards to the question of climate indicators, these are mainly covered by GCOS (the Global Climate Observing System): https://gcos.wmo.int/en/global-climate-indicators The WCRP provides input.

Ms. Jacob: There is cooperation between the WCRP and the IPCC to define knowledge gaps and indices for making progress.

76. **How much time will it take to update CORDEX using CMIP6??**

Ms. Jacob: About one and a half years. The protocol is finished, we will now agree on settings and look at the strong and the medium-strong scenarios and variables. Some simulations will be ready by the end of 2021.

[34] See https://www.gewex.org/.
[35] See https://www.climate-cryosphere.org/.

77. **What are the big questions the WCRP strategic plan will enable us to answer that will help us enhance adaptation action?**

Mr. Sparrow: Defining new lighthouse activities in June 2021 will identify priority questions for the WCRP over the next 5–10 years. For example, what will be the impact of geo-engineering? How will weather extremes occur under a changing climate? How will reservoirs of heat, water and carbon change in the future? What is the interaction between climate and development trends, including relative to regional climate hotspots? How can we better understand climate sensitivity?

Ms. Jacob: Our information for adaptation will be better in the coming years as we will better understand the regional phenomena and how they change.

78. **How do we derive information from models and model archives produced by different centres? Should they be used together as an ensemble, or else how can it be determined which should be used?**

Ms. Jacob: There are different ways to easily access raw data for experts, and processed data such as indices for stakeholders.

Mr. Sparrow: The CORDEX website provides a portal to access that information directly.

79. **How practical is to work on the indicators of climate adaptation/ resilience. Has WASP worked on such indicators?**

Ms. Rosenzweig: It is challenging to create indicators for adaptation. Researchers must have a baseline of the impact of coastal flooding, for example, and monitor the effect of adaptation, a mangrove plantation for example, and compare the effect to an area without that adaptation. Getting this data is very challenging but absolutely necessary.

80. **Which aspects of economic recoveries from the pandemic are monitored by initiatives like WASP?**

Ms. Rosenzweig: There are two: health, and food security. Health in terms of the influence of the pandemic on vulnerability and the shared compound risk of COVID and climate.
Food security in terms of the disruption to food supply, such as labour within food processing plants as one example, in different contexts throughout the world.

81. **What are the implications of integrating climate-related damages in Integrated Assessment Models used to design emissions pathways compatible with limiting warming to 1.5 degrees C above pre-industrial levels?**

Mr. Riahi: Integrating damages across different sectors into different frameworks is an active field of research with a number of IAMs. Of particular note are the Navigate project, bringing together more than 20 international partners and eight IAM frameworks to integrate impacts and look at the distribution of those impacts. See *"Integrating impacts in mitigation pathway analysis reinforces need for ambitious climate action"* (paragraph 85) in the poster section.

Most integrated assessment scenarios in the literature look at the cost-effective approach to limit greenhouse gases to, for example, achieve the long-term objective of the Paris Agreement. Impacts are often not fully integrated, but as more information is known and the better the impact assessments become at different sectoral levels, we will see more pathways attempting to integrate as many impacts as possible.

82. **What efforts are there to produce IAMs that integrate issues such as response measures, economic feasibility, costs, social objectives, and national circumstances, and that are based on multi-objective optimisation to provide decision makers with a clear idea of trade-offs between shared socioeconomic pathways?**

Mr. Riahi: There has been multi-objective analysis in the literature, though most assessments are focused on understanding how mitigation might impact other objectives. There are frontier papers that explore how to reduce trade-offs with other objectives and maximise synergies between mitigation and a number of other SDGs.

Many models have started to integrate direct feedbacks between mitigation and food security and have integrated biodiversity in the mitigation assessment in ways that do not allow mitigation to lead to major adverse effects to other objectives.

Other IAMs include trade-offs between mitigation and energy access, for example where mitigation may lead to higher energy costs which can have negative implications to those excluded from basic energy services.

In the AR6 as much information has been synthesised as possible on different trade-offs and synergies that may result from mitigation action.

B. Poster Session

83. Ten posters were presented on Theme 1 to complement the information provided in the presentations. All posters can be viewed via the UNFCCC website for the thirteenth meeting of the research dialogue[36] with accompanying audio commentary, or individually via a hyperlink in each title below. Presenters are listed below while the full list of authors is listed on each poster.

84. **Advances in estimating and tracking the remaining carbon budget**

Joeri Rogelj (Imperial College London / IIASA)

Carbon budgets have been used over the past decade to inform emission reductions in line with limiting warming to internationally agreed temperature limits. This poster looks at some of the latest developments since the publication of the IPCC Special Report on Global Warming of 1.5°C that help us quantify, understand and track the size of the remaining carbon budget.

As part of the IPCC Special Report on Global Warming of 1.5°C, a consolidated framework was developed for estimating and tracking the remaining carbon budget (Rogelj et al 2019). The five components of this framework can now be individually assessed and tracked.

Recent advances have provided new insights in how much warming to expect per unit of CO2 emissions as well as the amount of warming projected to occur once global CO2 emissions have reached net zero levels, known as the zero CO2 emissions commitment. For the latter, latest research confirms that CO2-induced warming will be halted if global CO2 emissions are brought to zero.

However, it also indicates that this central zero estimate is surrounded by a range of the order of 10% of total warming. These advancements can be integrated in updated estimates of the remaining carbon budget.

Finally, recent publications once more clarify how value judgments play a role both in quantifying the remaining global carbon budget and particularly in translating this budget to the national or sub-national scale.

85. **Integrating impacts in mitigation pathway analysis reinforces need for ambitious climate action**

Franziska Piontek (PIK), Francesco Bosello (CMCC), Johannes Emmerling (CMCC), Celine Guivarch (CIRED), Elmar Kriegler (PIK), Nicolas Taconet (PIK), Kaj-Ivar van der Wijst (PBL)

Recent research has provided a deeper understanding of the impact of climate change on economic output and growth. These new impact estimates provide a fresh perspective of mitigation pathways.

Results indicate that aiming for the goals of the Paris agreement is cost-optimal and that including climate damages below the target can lead to more ambitious near-term action beyond what is suggested in cost-effective mitigation pathways serving as benchmark for the global stocktake.

Climate change will moreover exacerbate global inequalities, creating a need for compensatory and adaptive policies. This poster presents a selection of these results and explores further research needs.

86. **Balancing global sources and sinks under the Paris Agreement decreases overall feasibility concerns but requires faster mitigation early on**

Bas van Ruijven (IIASA), Keywan Riahi (IIASA), Elina Brutschin (IIASA), Silvia Pianta (CMCC)

A new scenario set based on fixed remaining carbon budgets until net zero CO2 emissions was developed to avoid overreliance on net negative CO2 emissions. While these scenarios avoid long-term feasibility

[36] See https://unfccc.int/event/thirteenth-meeting-of-the-research-dialogue.

issues, such as extremely high levels of negative emissions technologies later in the century, they do raise some short to medium term feasibility concerns.

To systematically explore feasibility concerns, we evaluate this ensemble of scenarios in a recently developed framework for a systematic feasibility assessment. This poster presents the conceptual frameworks behind the net zero budget logic, combined with a demonstration of insights with an interactive tool that allows stakeholders to gain a better understanding of the scenario.

The audience can systematically explore the feasibility concerns along geophysical, technological, economic, institutional and socio-cultural dimensions.

87. Understanding the impact of methane on the climate and human systems

Drew Shindell, A. R. Ravishankara, Johan C.I. Kuylenstierna, Eleni Michalopoulou, Lena Höglund-Isaksson, Yuqiang Zhang, Karl Seltzer, Muye Ru, Rithik Castelino, Greg Faluvegi, Vaishali Naik, Larry Horowitz, Jian He, Jean-Francois Lamarque, Kengo Sudo, William J. Collins, Chris Malley, Mathijs Harmsen, Krista Stark, Jared Junkin, Gray, Li, Alex Glick, Nathan Borgford-Parnell, UNEP, CCAC

The 2021 Global Methane Assessment by the Climate and Clean Air Coalition (CCAC) and the United Nations Environment Programme (UNEP) shows that human-caused methane emissions can be reduced by up to 45 per cent this decade. Such reductions would avoid nearly 0.3°C of global warming by 2045 and would be consistent with keeping the Paris Climate Agreement’s goal to limit global temperature rise to 1.5 degrees Celsius (1.5°C) within reach.

The Assessment also characterized the robustness of the climate response to methane, including the tropospheric ozone that is produced in response to methane emissions, highlighting the stronger response in the Northern Hemisphere driven by ozone.

The assessment integrated the climate and air pollution costs and benefits from methane mitigation. Because methane is a key ingredient in the formation of ground-level ozone, a powerful climate forcer and dangerous air pollutant, a 45 per cent reduction would prevent 260,000 premature deaths, 775,000 asthma-related hospital visits, 73 billion hours of lost labour from extreme heat, and 25 million tonnes of crop losses annually. When accounting for these environmental benefits roughly 85 per cent of the emission reduction measures have benefits that outweigh the net costs.

The assessment identified measures that specifically target methane that provide readily available solutions which can reduce methane emissions by 30 per cent by 2030. Roughly 60 per cent of these targeted measures are low cost and 50 per cent of those have negative costs, meaning companies make money from taking action, even without accounting for environmental benefits.

The greatest potential for negative costs is in the oil and gas industry where preventing leaks and capturing methane adds to revenue instead of releasing the gas into the atmosphere. There are also low and negative cost measures in the coal and waste sectors. Additional measures that do not specifically target methane, like a shift to renewable energy, residential and commercial energy efficiency, and a reduction in food loss and waste, can reduce methane emissions by a further 15 per cent by 2030 to meet the 45% goal that is consistent with 1.5°C.

88. Improved modelling of permafrost thaw strengthens case for more ambitious emission cuts to meet Paris targets

Pierre Friedlingstein, Sophie Hebden, Gustar Hugelius, Tatiana Ilyina, Ted Schuur, Merritt Turetsky, Future Earth

Emissions of greenhouse gases from permafrost could be larger than earlier projections because of abrupt thaw processes. The Arctic is responding quickly to climate change, with air temperatures warming three times as fast as the global average. Arctic permafrost is thawing in some High Arctic regions almost a century earlier than some climate models projected.

Abrupt thaw processes could, under moderate to high emissions scenarios, double the cumulative carbon emissions from permafrost thaw compared to gradual thaw alone by 2100 (this includes methane). The carbon emissions from permafrost regions could be even higher considering soil decomposition from root activity.

This may also apply to emissions scenarios consistent with 1.5°C or 2°C warming targets, which would impose tighter restrictions on remaining anthropogenic carbon emission budgets and impact climate negotiations.

89. **Findings from the Reduced Complexity Model Intercomparison Project**

Junichi Tsutsui, Central Research Institute of Electric Power Industry, Japan

The second phase of the Reduced Complexity Model Intercomparison Project has been conducted, comparing the probabilistic climate projections of nine participating models underpinning the climate assessment of mitigation scenarios for the IPCC AR6. The main focus is on the implementation and consistency of the given constraints controlling the ranges of specific Earth system quantities, such as forcing levels, land and ocean carbon uptake, climate sensitivity, and observed warming trends.

One of the nine models was developed under the Japanese climate model development program (TOUGOU) and has produced results that match the constraints well. Probabilistic projections obtained with this model show less warming than do those adjusted to the range of the state-of-the-art Earth system models, both of which are not necessarily consistent with a narrowed uncertainty range of climate sensitivity based on recent literature. Overall consistency must be improved using the upcoming AR6-assessed ranges.

90. **Climate Change Information for Risk Assessment and Decision Making**

Erika Hayami, Japan Meteorological Agency (JMA), Aya Takatsuki and Atsushi Minami, Ministry of Education, Culture, Sports, Science and Technology-Japan (MEXT)

Japan’s Act on Promotion of Global Warming Countermeasures (1998), its Climate Change Adaptation Act (2018) and associated national plans stipulated requirements or recommendations to promote and implement related mitigation and adaptation. The Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the Japan Meteorological Agency (JMA) published a report titled Climate Change in Japan in December 2020 to share basic information and expertise on climate change and promote impact assessment and consideration of related mitigation/adaptation in Japan.

The report outlines the current status of atmospheric greenhouse gases (GHGs) and observed/projected changes in climate variables in and around the country. Climate projections are generally based on the RCP2.6 scenario (corresponding to potential climatic conditions with achievement of the Paris Agreement’s 2°C target) and the RCP8.5 scenario. For optimal usability, specialists from the fields of physical science (meteorologists, climatologists and oceanographers) and climate impact assessment/science communication are involved in drafting and reviewing of the report.

The information and expertise shared have been used on various platforms, including presentations by other Ministries on climate change within their areas of responsibility and local-government plans for related mitigation and adaptation. Of particular note is incorporation of the information in the Assessment Report on Climate Change Impact, which is prescribed under the Climate Change Adaptation Act and published every five years or so under the responsibility of the Ministry of the Environment as a comprehensive assessment of climate change effects in Japan.

Other notable users include the Ports and Harbours Bureau of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), which recently began considering new harbour infrastructure technical standards for adaptation to potential future climate conditions in consideration of usage for 50 years or more.

91. **A framework for complex climate change risk assessment: How to increase clarity regarding the interactions that generate risk, including the role of adaptation and mitigation responses**

Nicholas P. Simpson and Christopher H. Trisos, University of Cape Town, South Africa

Real-world experience underscores the complexity of interactions among multiple drivers of climate change risk and of how multiple risks compound or cascade. However, a holistic framework for assessing such complex climate change risks has not yet been achieved. Clarity is needed regarding the interactions that generate risk, including the role of adaptation and mitigation responses.

This poster presents a new framework for assessing complex climate change risk that focus on interactions among the multiple drivers of risk, as well as among multiple risks. A significant innovation is recognizing that risks can arise both from potential impacts due to climate change and from responses to climate change.

This approach encourages thinking that traverses sectoral and regional boundaries and links physical and socio-economic drivers of risk. Advancing climate change risk assessment in these ways is essential for more informed decision making that reduces negative climate change impacts.

92. Characterization of the Climate System, from past to the future for risk assessment

Maxx Dilley, Amir Delju and Ilaria Galo, WMO

Past, present, and projected future climate information is necessary in order to understand how the climate affects a region or sector. Monitoring the past, present, and projected future status of climate enriches countries' abilities to track climate conditions in their national and local contexts and select effective actions under current and anticipated climate conditions.

An objective science-based approach draws on data, methods, and tools, that can be used to describe an overall picture of the trajectory of the characteristics of the climate system relevant for identifying potential climate action options. Data should be gathered for: historical observations that can be used to assess long-term trends, variability, and extremes; and projections generated from climate models used to estimate future changes of relevant climatic contributing factors.

For the past/present timeframe, Climpact offers the basis for identifying trends and variability at the local level. Climpact can calculate climate indices derived from site-specific daily temperature and precipitation data and proposed by WMO Expert Teams that are relevant for the health, agriculture, water and other climate-sensitive sectors. Climpact can also be used for calculating context-specific climate indicators and high-impact event indicators.

For the Future timeframe, the Coupled Model Intercomparison Project (CMIP) is designed to better understand future climate changes arising from natural, unforced variability or in response to external forcing. CMIP deploys Regional and Global Climate Models (RCMs and GCMs) designed for representing climate processes on a global and regional scales.

The Coordinated Regional Downscaling Experiment (CORDEX) deploys model ensembles from the Coupled Model Intercomparison Project Phase 5 (CMIP5) to calculate the climate indicators at a 0.5-degree (50 KM) resolution, producing outputs at a higher spatial resolution than those of CMIP.

The conclusions drawn from the use of these tools can support the identification of science-based climate actions and the design of climate services that respond to the local context, address potential vulnerabilities, and promote resilience to future climatic conditions. This also provides evidence for country-level contributions to the Paris Agreement Global Stocktake (GST) and the Paris Agreement transparency framework.

93. Climate Services for Adaptation: Case studies

Veronica Grasso, Nakiete Msemo, and Maxx Dilley, WMO GFCS

Weather and climate services are vital for sustainable development and climate change adaptation. The benefits of investment greatly outweigh the cost. Climate services investments overall have a cost benefit ratio of 1 to 10. The evidence suggests that the benefits of investing systematically in strengthening the operational global regional-national hydrometeorological system needed for climate services outweigh the costs by about 80 to one.

It is estimated that improved weather, climate, water observations and forecasting could lead to up to USD 30 billion per year in increased global productivity and up to USD 2 billion per year in reduced asset losses.

Case studies have been provided by WMO and the partners contributing to the State of Climate Services reports. They highlight how climate services contribute to improved outcomes in the agriculture sector and to reduce disaster risk.

Examples of outcomes achieved include findings from the 2019 and 2020 State of Climate Services reports, such as:

- In West Africa: 35% increase in crops yields reported and USD 45/ha savings achieved

- In China: Average per capita income of farmers increased by USD 326 per year, and crop production rose from 3.2 million tons to 4.2 million tons per year
- In the Caribbean: In the Dominican Republic, 3 000+ people sheltered before Irma hit. EWS strengthened
- In Bangladesh: Average asset loss in target areas dropped from US$ 78 to US$ 57 after being affected by floods
- In Cambodia: PRISM has been used to estimate the impacts of extreme weather to inform preparedness and reduce impacts from climate-related disasters
- In Mongolia: every US$ 1 spent had a return of US$ 7 in added benefits and avoided losses for rural herders
- In the Greater Horn of Africa: Climate- and drought-related products designed to reduce the impact of extreme climate events
- Across Africa: 720 000 tons of cereal saved from locust swarms across 10 countries, worth around US$ 220 million
- Downstream communities protected from glacial lake outburst floods
- In the EU: The European Forest Fire Information System has provided around € 390.5 million a year of estimated benefits in the EU
- In Australia: 200+ lives saved in 2014 heat wave.

III. Summary of plenary presentations and discussions and posters on Theme 2: Resilience for and by nature: Building knowledge and understanding to weave the protection and restoration of nature into decision making on mitigation and adaptation

148. Presenters for Theme 2 included Mr. Hans-Otto Pörtner, IPCC; Ms. Minna Epps, IUCN; Mr. Philippe Ciais, Institut Pierre-Simon Laplace (IPSL), France; Mr. Minhan Dai, Xiamen University, China; Ms. Jyotsna Puri, IFAD.

149. The recording of Day 2 of the 13th meeting of the research dialogue is available on-demand.

A. Presentations

1. Current and projected relationships between climate change and biodiversity and system risks

150. Mr. Hans-Otto Pörtner, IPCC, presented on Current and projected relationships between climate change and biodiversity and system risks, drawing on the three previous IPCC special reports[37], and particularly on the Special Report on the Ocean and Cryosphere in a Changing Climate[38] (SROCC).

Across the ocean and land, rising temperature trends are negatively impacting species richness and biodiversity and projected to continue. Due to the narrow temperature changes that higher plant and animal species are adapted to, depending on the degree of climate change conditions, performance (such as carbon storage) will be negatively impacted and some parts of the planet (the ocean and land in the tropics) may become intolerable for higher organisms.

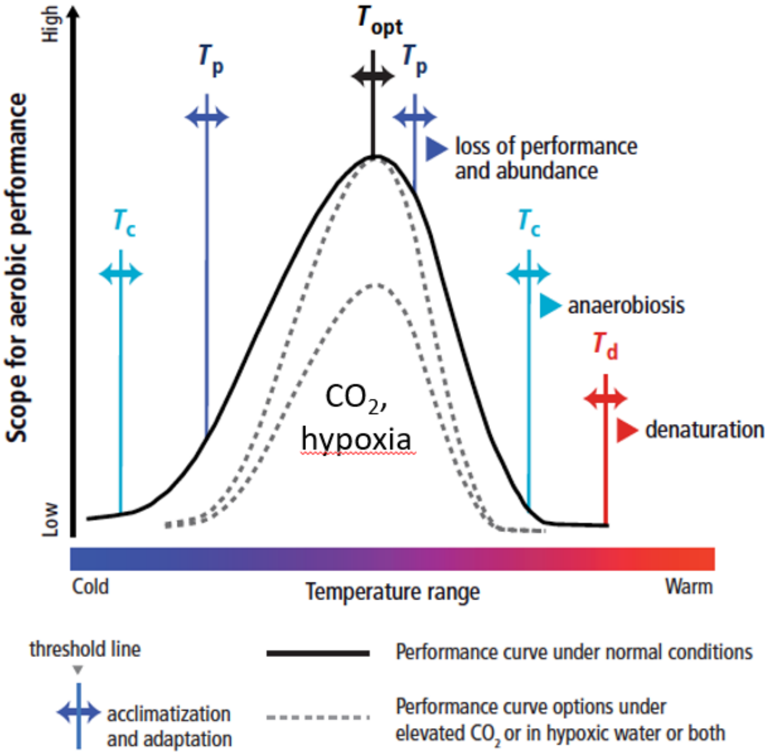
Ambitious and sustained emissions reductions are crucial for maintaining and strengthening the biosphere's capacity to support both mitigation and adaptation. This must be combined with land and ocean management for conservation, restoration, and sustainability to protect biodiversity, enable food security for humankind, and help to avoid future pandemics.

151. All life forms fit onto a temperature dependent performance curve reflecting their specialisation in a limited range of ambient temperatures. This is a dynamic curve that responds to other drivers and indicates

37 See https://www.ipcc.ch/reports/.
38 See https://www.ipcc.ch/srocc/.

performance in plants and animals and productivity in plants, Figure 11. Performance is constrained by temperature extremes. If a temperature falls below or exceeds the optimum, there is a drop in performance resulting in reduced growth and reduced ability to store carbon.

Figure 11
Thermal windows for animals: limits and acclimatisation

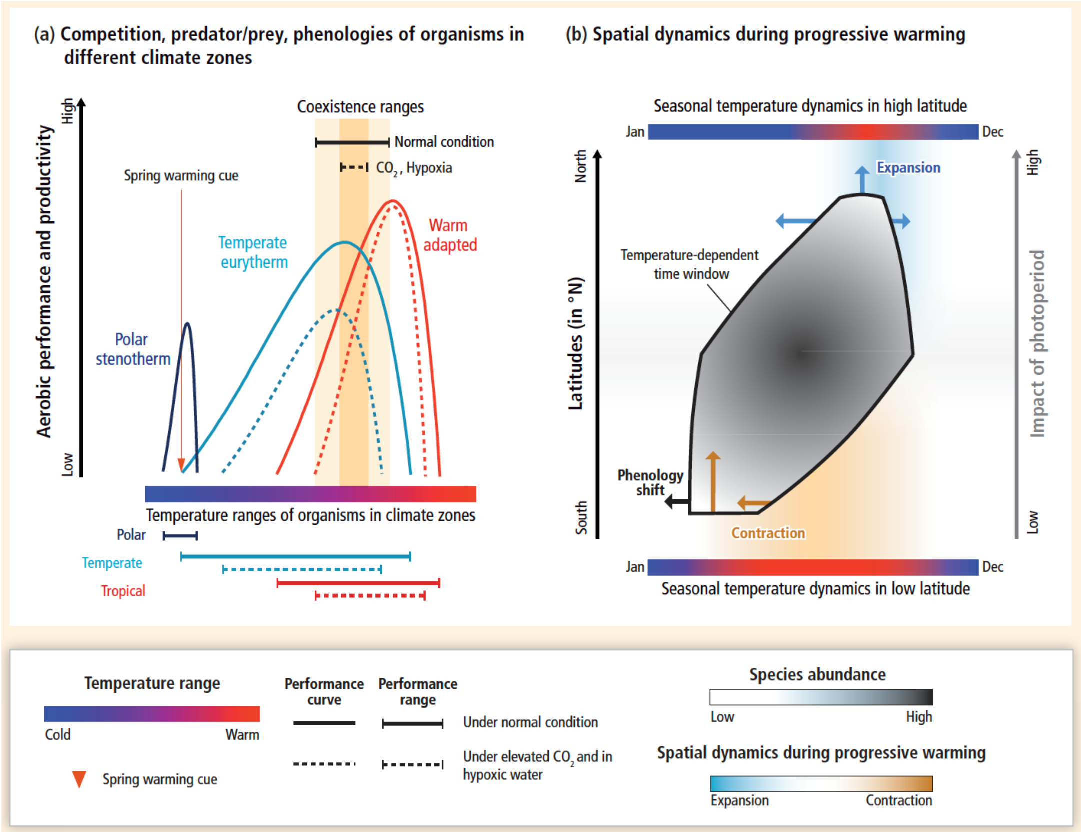


Thermal specialization of an organism explains the why, how, when, and where of climate sensitivity. The thermal tolerance range and performance levels of an organism are described by its performance curve (exemplified for an animal). Each performance (e.g., exercise, growth, reproduction) is maximal at its optimum temperature (Topt) and becomes progressively constrained during cooling or warming. Surpassing the first low- and high-temperature thresholds (Tp; p, pejus: getting worse) means going into time-limited tolerance. Once further cooling or warming surpasses the next low or high thresholds (Tc; c, critical), oxygen availability becomes insufficient and an anaerobic metabolism begins. Denaturation temperatures (Td) are even more extreme and characterized by the onset of damage to cells and proteins. Horizontal arrows indicate that Tp, Tc, and Td thresholds of an individual can shift, within limits, between summer and winter (seasonal acclimatization) or when the species adapts to a cooler or warmer climate over generations (evolutionary adaptation). Under elevated CO2 levels (ocean acidification) and in hypoxic waters performance levels can decrease and thermal windows narrow (dashed grey curves.
Source: Slide 2 of Mr. Pörtner's presentation; IPCC, Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. (2014) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.

152. This system is made more complex by the addition of more species and individuals within an ecosystem, each with different thermal windows. Thermal windows may depend, for example, on an individual's life stage and mobility, and are related to climate zones. In order for different species to live in the same area, their performance curves must overlap. This defines their coexistence range, which is also dependent on drivers such as CO_2 or hypoxia (low oxygen levels). This temperature specialisation range therefore not only defines how species interact in terms of their relative performance and competition, but also where they can live (on the land and in the ocean).

153. Figure 12 shows how species may move depending on the degree of warming, which causes a contraction of species range in the low latitudes and an expansion in the high latitudes. **Warming is already causing species to move from low latitudes to high latitudes, reducing biodiversity in the low latitudes in the ocean and on land and mirroring past evolutionary crises to some extent.**

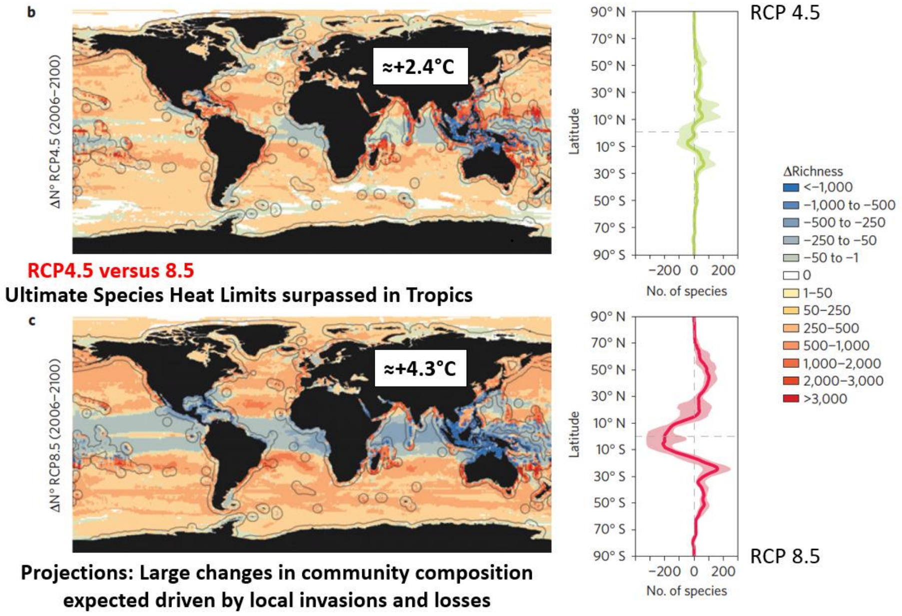
Figure 12
Performance and spatial dynamics of marine species under changing temperature, and oxygen and CO2 concentrations



Role of thermal tolerance and performance of organisms at ecosystem level. (a) Thermal tolerance ranges (Figure 6–5) differ between species across polar, temperate, and tropical climate zones, then overlap between coexisting species. Shifting temperatures and specific effects of additional drivers on the respective performance curves (dashed lines) change the fitness of coexisting species relative to each other as well as their temperature range of coexistence (after Pörtner and Farrell, 2008). Warming alters the timing of seasonal activities (e.g., elicited by spring warming cues) to earlier, or can benefit only one of two interacting species (e.g., in predator–prey dynamics or competition), causing shifts in predominance. (b) During climate warming a largely unchanged thermal range of a species causes it to follow its normal temperatures as it moves or is displaced, typically resulting in a poleward shift of the biogeographic range (exemplified for the Northern Hemisphere; modified after Beaugrand, 2009). The polygon delineates the distribution range in space and seasonal time; the level of grey denotes abundance. The Southern time window of tolerated temperatures shifts to earlier and contracts, while the Northern one dilates (indicated by arrows). Species display maximum productivity in low latitude spring, wide seasonal coverage in the centre, and a later productivity maximum in the North. The impact of photoperiod (length of daily exposure to light) increases with latitude (grey arrow). Water column characteristics or photoperiod may overrule temperature control in some organisms (e.g., diatoms), limiting northward displacement.
Source: Slide 3 of Mr. Pörtner's presentation; IPCC, Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. (2014) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.

154. **Increased ocean warming is leading to changes in biodiversity patterns across the ocean**, with serious impacts on species richness and distribution and the function of ecosystems. Projected changes in species range and distribution indicate that heat limits will be surpassed for many species in the tropics (Figure 13). **The tropical parts of the ocean would be cleared of higher life forms** that are more specialised on temperature than simpler organisms. This trend is being observed now, and mirrors to some extent what has happened in past evolutionary crises when the low latitudes were too hot for higher life forms on land and in the ocean.

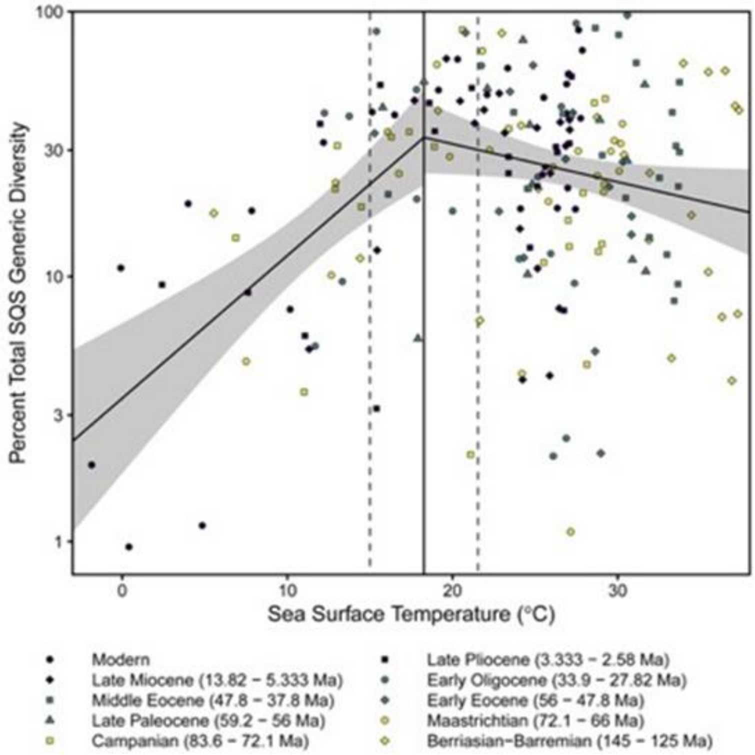
Figure 13
Implications for marine biodiversity of species' migration



Source: Slide 4 of Mr. Pörtner's presentation; Molinos, J, et al. Climate velocity and the future global redistribution of marine. Nature Climate Change. advance online publication. (2015) 10.1038/nclimate2769.

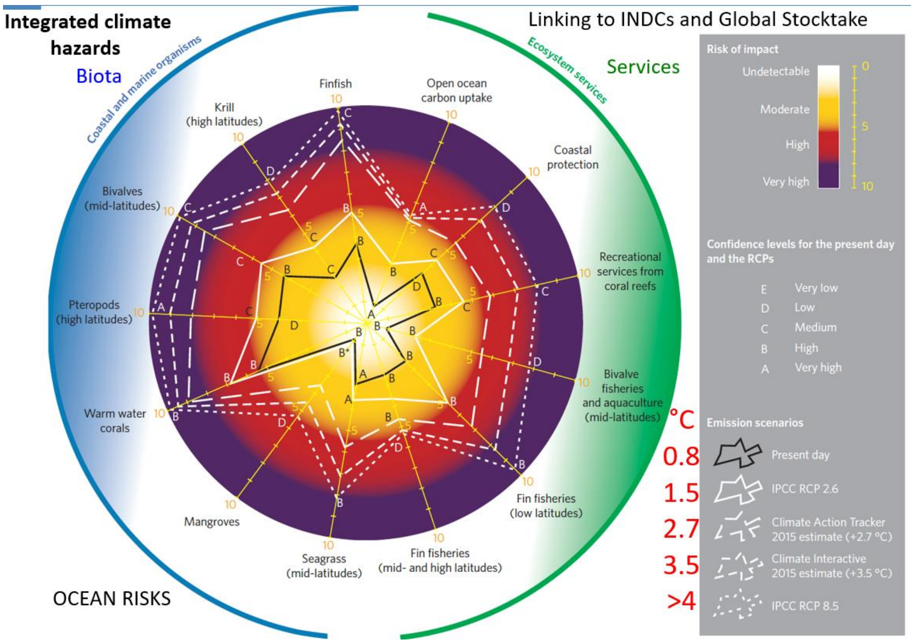
155. When present-day and paleo findings are combined with respect to the relationship between temperature and biodiversity, scientists can define a temperature optimum. **Beyond 20 degrees C, biodiversity tends to decline**, Figure 14. **Taken together, these data can factor into risk assessments**. Figure 15.

Figure 14
Present and paleo optimum temperatures for species' performance



Source: Slide 5 of Mr. Pörtner's presentation; Boag, TH, Gearty,W and Stockey RG, Metabolic tradeoffs control biodiversity gradients through geological time, Current Biology, 2021, ISSN 0960–9822, https://doi.org/10.1016/j.cub.2021.04.021.

Figure 15
Integrated climate hazards



The expected changes in the impacts on key marine and coastal organisms and ecosystem services by 2100 are shown, according to low (RCP2.6) and business-as-usual (RCP8.5) GHG emissions scenarios and to estimates derived from the aggregation of the 2015 INDCs by CI and the CAT (3.5 °C and 2.7 °C respectively. The figure also considers the impacts for the present day. Confidence levels in the level of the impacts per organism or service for the present day, RCP2.6 and RCP8.5 scenarios are from the IPCC AR5. Compared with the present day, the aggregated risks of impact in 2100 will probably be 1.4-, 2.2-, 2.5- and 2.7-fold higher under RCP2.6, CAT, CI and RCP8.5 scenarios, respectively.
Source: Slide 6 of Mr. Pörtner's presentation; Magnan, A, Colombier, M, Billé, R et al. Implications of the Paris agreement for the ocean. Nature Clim Change 6, 732–735 (2016). https://doi.org/10.1038/nclimate3038.

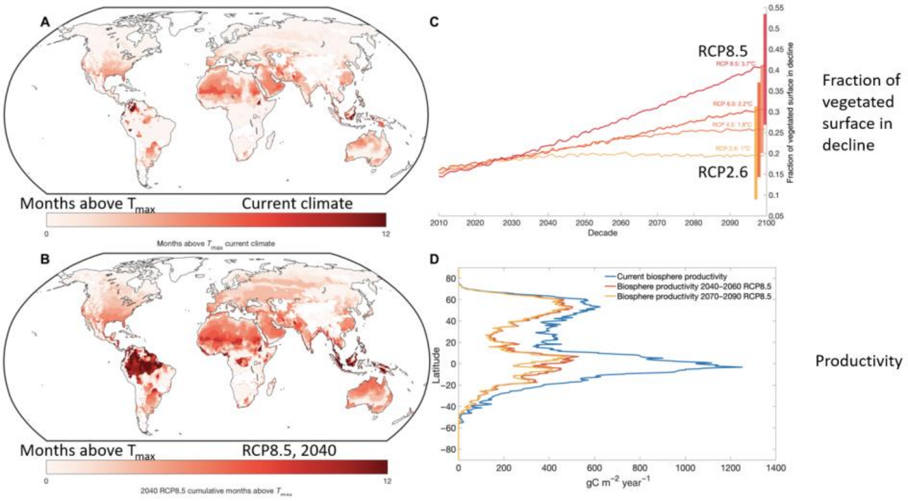
156. **At global temperatures of 1.5 degrees C, the warm water corals are already at high risk. At 2.7 degrees C, all systems move into the high-risk area - at this temperature, systems and species on land and in the ocean are either dying or at least losing performance**, for example, in carbon storage.

157. Plant biologists and physiologists have studied the temperature optimum performance of plant life on land in relation to their capacity for photosynthesis and the land carbon sink. Beyond 20 degrees C, the carbon sink declines due to the declining capacity for global photosynthesis in relation to the respiration of the ecosystem, which is driven by the warming trend. Projections using this data indicate when temperature tipping points would be exceeded (Figure 16).

158. **Some ecosystems with high carbon storage capacity, such as tropical forests, already exceed their temperature optimum performance for part of the year**, indicated by red shading in (Figure 16 A). Under business as usual scenarios, this trend strengthens depending on latitude (Figure 16 B and D). The fraction of surface vegetation affected by these systems increases with the degree of warming (Figure 16 C). Global warming is therefore constraining productivity of ecosystems and their mitigation capacity.

159. In African tropical forests, the carbon sinks and sources are in equilibrium until 2040, whereas the carbon sink of the Amazon rainforest is projected to continue to decline subject to warming, drought, and human activities. **The trend of carbon losses is cancelling the trend of carbon gains in these systems.**

Figure 16
Spatial patterns of temperature tipping points for the biosphere



Spatial patterns of temperature tipping points for the biosphere. (A) Current cumulative monthly dose of temperature above Tp max by biome (see Materials and Methods) based on 1950–2010 WorldClim data. (B) Cumulative temperature dose above Tp max under Representative Concentration Pathway 8.5 (RCP8.5) by 2040–2060 based on WorldClim data. (C) Cumulative fraction of terrestrial biosphere in exceedance of Tp max by RCP scenario based on Coupled Model Intercomparison Project Phase 5 (CMIP5) multimodel means monthly data. Vertical bars represent an integration of the uncertainty across CMIP5 ensemble member projections for changes in temperature, translated into a range of exceedance of Tp max for the vegetated surface. (D) Current mean gridded gross photosynthesis (2003–2013) along with reductions in biosphere productivity due to exceedance of Tmax for 2040–2060 (44% reduction) and 2070–2090 (49% reduction) based on Worldclim CMIP5 downscaled data.
Source: Slide 8 of Mr. Pörtner's presentation; Duffy, KA et al., How close are we to the temperature tipping point of the terrestrial biosphere? Science Advances, (2021). eaay1052.

160. Human and other mammalian life is also affected by these warming trends, based on geography. **Some places on the planet will become intolerable outdoors for humans and other mammals** (figure 17). This has implications for the future biogeographical distribution of mammals in these areas including livestock, and increasingly vulnerable groups such as aging populations and urban populations subject to the heat island affect.

161. **The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and the IPCC discussed the relationship between biodiversity and climate change in their first ever joint meeting in December 2020**.[39] They considered how biodiversity, climate, and human society are interconnected, and looked at solutions, options, and co-benefits of ambitious mitigation, nature-based solutions, and sustainable development.

162. The overarching finding of this meeting was that **ambitious emissions reduction are crucial for maintaining and strengthening the biosphere's capacity to support both mitigation and adaptation**.

163. The outline of the workshop report is as follows:

1) Section 1: Climate and biodiversity are inextricably connected with each other, and with human futures;

2) Section 2: Climate change affects/harms biodiversity conservation;

3) Section 3: Actions taken to mitigate climate change can have beneficial or harmful effects on biodiversity depending on policy;

4) Section 4: Biodiversity assists people and ecosystems to adapt to climate change;

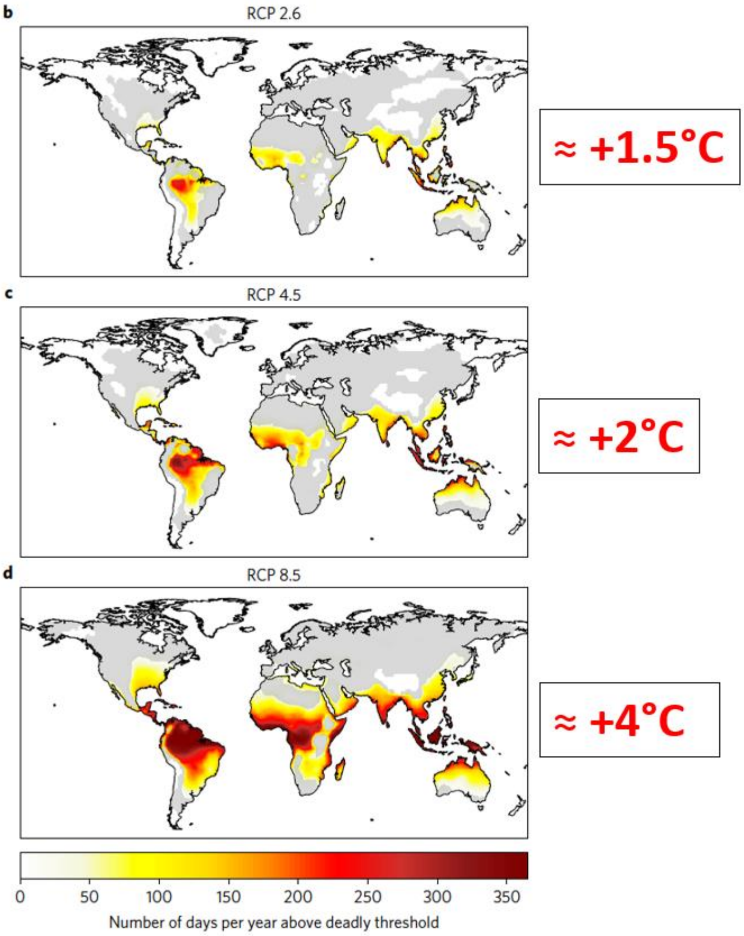
5) Section 5: Actions that halt, slow or reverse biodiversity loss can also help mitigate climate change;

6) Section 6: Treating climate, biodiversity and human society as coupled systems is key to successful outcomes;

7) Section 7: There are pathways of development that can successfully navigate through the multiple crises we face.

[39] See report available at https://ipbes.net/events/launch-ipbes-ipcc-co-sponsored-workshop-report-biodiversity-and-climate-change.

Figure 17
Human (Mammalian) geographical constraints due to warming



(b) Number of days per year exceeding the threshold of temperature and humidity beyond which climatic conditions become deadly between 2090 and 2100 under RCP 2.6, (c) RCP 4.5, (d) and RCP 8.5. Results are based on multimodel medians. Grey areas indicate locations with high uncertainty (that is, the multimodel standard deviation was larger than the projected mean; coefficient of variance >1). The expected lower number of deadly days at higher latitudes may help explain the large variability among Earth System Models in the projected number of deadly days at higher latitudes. The uncertainty presented in this figure should be interpreted with that caution in mind.
Source: Slide 10 of Mr. Pörtner's presentation; Mora, C, Dousset, B, Caldwell, I et al. Global risk of deadly heat. Nature Clim Change 7, 501–506 (2017). https://doi.org/10.1038/nclimate3322.

2. Nature-based Solutions to climate change – relevance, scope, and future directions

164. Ms. Minna Epps of the IUCN presented on Nature-based Solutions to climate change – relevance, scope, and future directions.

The need for more ambitious emission reduction is a priority but should be combined with protecting at least 30% of the land and ocean for conservation, restoration, and sustainability supported through nature-based solutions that synergise mitigation, adaptation and other ecosystem services. IUCN adopted the global standard for nature-based solutions in 2020.

165. The **IUCN defines nature-based solutions as actions to protect sustainably managed and restore natural or modified ecosystems that address societal challenges such as, climate change, food and water security, or natural disasters, effectively and adaptively, simultaneously providing human well-being and biodiversity benefits**.

166. Many NbS have built on the IUCN defined ecosystem approaches of the last 20 years on landscape restoration, ecosystem-based adaptation, or eco-disaster risk reduction. In 2009 the IUCN submitted a paper to the UNFCCC on NbS.[40] In 2016, the definition of nature-based solutions was adopted at the IUCN

[40] Available at https://www.iucn.org/sites/dev/files/import/downloads/iucn_position_paper_unfccc_cop_15.pdf.

conservation congress. It is the broadest and most adopted definition that exists within the environmental community.

167. In 2019 IUCN developed a draft global standard through two rounds of public consultations that led to a manifesto in relation to nature-based solutions that also integrates finance approaches.[41] The **IUCN adopted the global standard for nature-based solutions in 2020**. It is a way to provide quality assurance in implementing NbS and builds on eight criteria - societal challenges, designing at scale, biodiversity net-gain, economic viability, inclusive governance, balancing trade-offs, adaptive management, and sustainability and mainstreaming, which are measured by 28 different indicators. The standard is meant to be used as a facilitative standard, not a certification tool.

168. **There is growing recognition of the need to tackle the climate and biodiversity crises together and that nature-based solutions can be used as a bridge**. For example, land-based carbon removal, including forests, wetlands and soils, offer annual emissions reduction potential up to 12 GtCO2e[42].

169. Ms. Epps have an example of an IUCN community-based Mangrove project in the Philippines which restored a total area of 5,321 ha, including 1,888ha of no-take replenishment zones. The project also recovered 260,000 tonnes of fishing nets from the ocean and included regenerative seaweed farming that reduces coastal eutrophication and climate change-driven ocean acidification and deoxygenation. 148 families trained and 47 families were supported to set up regenerative seaweed farming practices.

170. The key findings of the IUCN and the University of Oxford report *Nature-based solutions within Naturally Determined Contributions*[43] were that:

1) **At least 66% of Paris Agreement signatories include NbS in their NDCs** in one form or another to achieve either mitigation or adaptation goals;

2) **More concrete, evidence-based targets for NbS are urgently needed.** Over 70% of NDCs are estimated to contain both references to efforts in the forest sector, but only 20% of these included quantifiable targets, and only 8% included targets that were expressed in CO2 emissions. Only approximately 17% of NDCs with current or planned actions involving NbS for adaptation (such as ecosystem-based adaptation) set quantifiable targets;

3) **NbS that synergise adaptation and mitigation are underused.** Only 17 countries aim to address adaptation and mitigation together.

171. There is an increased consideration of NbS in the current round of NDCs. Chile, for example, submitted an updated NDC in 2020 which explicitly incorporates NbS with specific targets, and references the IUCN NbS standard.

172. Ms. Epps concluded with identifying research needs for NbS moving forward:

1) NbS provide a framework that can link to different multilateral environmental agreements such as the UNFCCC, the CBD, and the UNCCD.

2) Needs remain at the policy level and in science in terms of research, and better data on carbon capacity and potential sources that will allow NDCs to include specific climate targets.

3) More data is also needed on the vulnerability of NbS, as they are also at risk from climate change. This also provides insights for adaptation plans and socio-economic resilience.

4) NbS need to be scaled up from smaller projects, and this experience must be used to steer finance and investment for nature-based solutions.

3. Potential synergies between mitigation and adaptation for the land sink and how to evaluate opportunities and trade-offs

173. Mr. Philippe Ciais, IPSL, presented on potential synergies between mitigation and adaptation for the land sink and how to evaluate opportunities and trade-offs.

The land carbon sink is highly variable with uncertainty around the estimates of land use emissions, especially at the global level. Coordinated planning is needed to reconcile the large differences in land

[41] See https://www.iucn.org/theme/nature-based-solutions/resources/iucn-global-standard-nbs.
[42] See the UNEP Emissions Gap Report 2017 at https://www.unep.org/resources/emissions-gap-report-2017.
[43] See https://portals.iucn.org/library/node/48525.

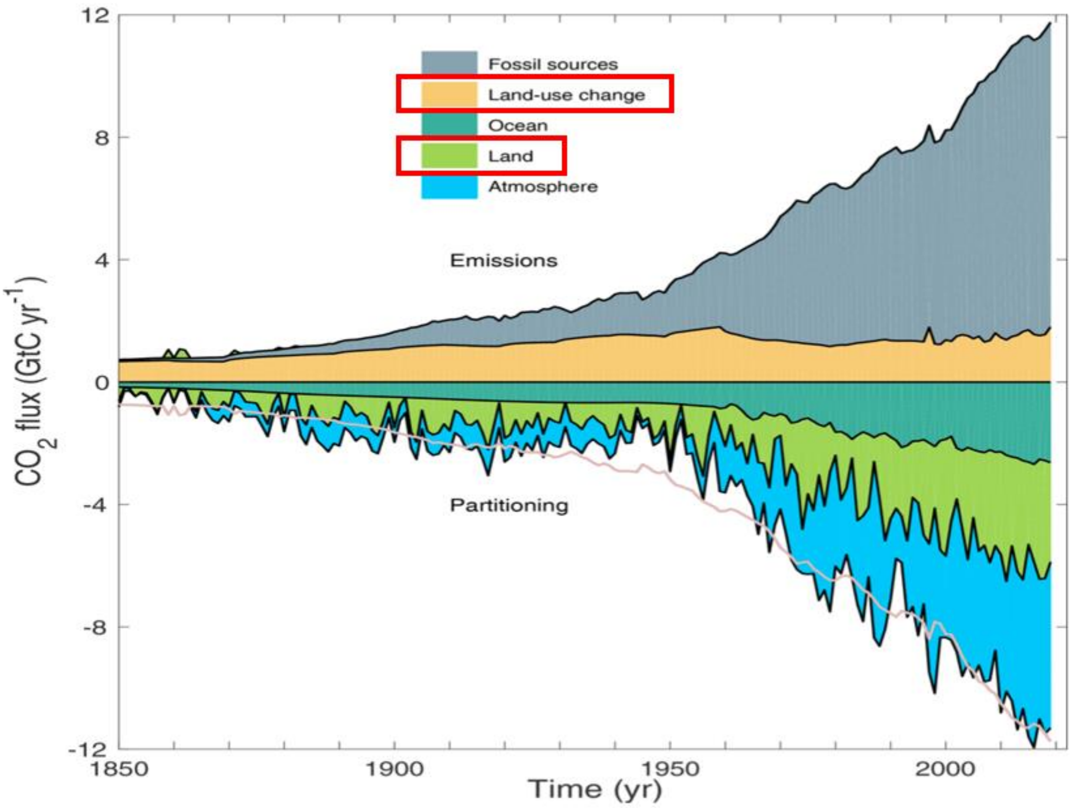
use CO2 flux between global models and national GHG Inventories to tailor the needed decision making at the local and sectoral level and address knowledge gaps.

Good guidance, well-considered trade-offs, consideration of compound impacts and the wider socio-ecological system must be part of the successful implementation of nature-based solutions, which can only be considered as a stop gap and do not lessen the urgency of reaching the mitigation goals of the Paris agreement.

174. The land carbon sink provides a large mitigation service. **Plants and soils have absorbed about one third of the CO_2 emitted by human activities.** However, the amount of carbon absorbed by the land sink is highly variable, responding to drought and hot conditions, especially in the tropics. Furthermore, **land is a source of carbon to the atmosphere in areas that are affected by land use and land use change** (Figure 18).

175. Global emissions from net land use change result from the imbalance of the gross source, mainly deforestation, and the gross sink, such as restored ecosystems. Global emissions from land degradation are also a growing concern. For example, in the Amazon, satellite observations reveal that the losses of carbon from degradation, induced directly by human activity or through climate degradation, exceed carbon losses from deforestation.

Figure 18
The highly variable land sink (green), and source (orange) relative to other sinks and sources



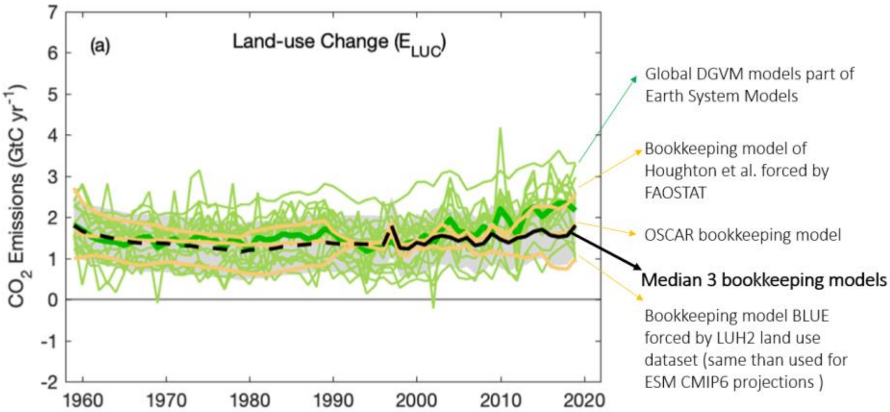
Source: Slide 3 of Mr. Ciais' presentation; Friedlingstein P et al., Global Carbon Budget 2020, Earth Syst. Sci. Data, 12, 3269–3340, 2020. https://doi.org/10.5194/essd-12-3269-2020.

176. **Despite progress in collecting long-term data sets, in particular from remote sensing, there is still uncertainty around the estimates of land use emissions, especially at the global level**. Large uncertainties and variability in biological systems exist including big emission spikes due to fires, pest attacks and drought.

177. There is a striking difference in the trend depending on the data set used to calculate net land use emissions, (Figure 19). The FAOSTAT data records a sharp increase of emissions over the past 10 years, whereas standard data sets used for future projection in CMIP6 produce a stabilisation or a negative trend of land use emissions.

Figure 19

Different estimations of the net land use change emissions from different models used in the annual update of the global carbon budget

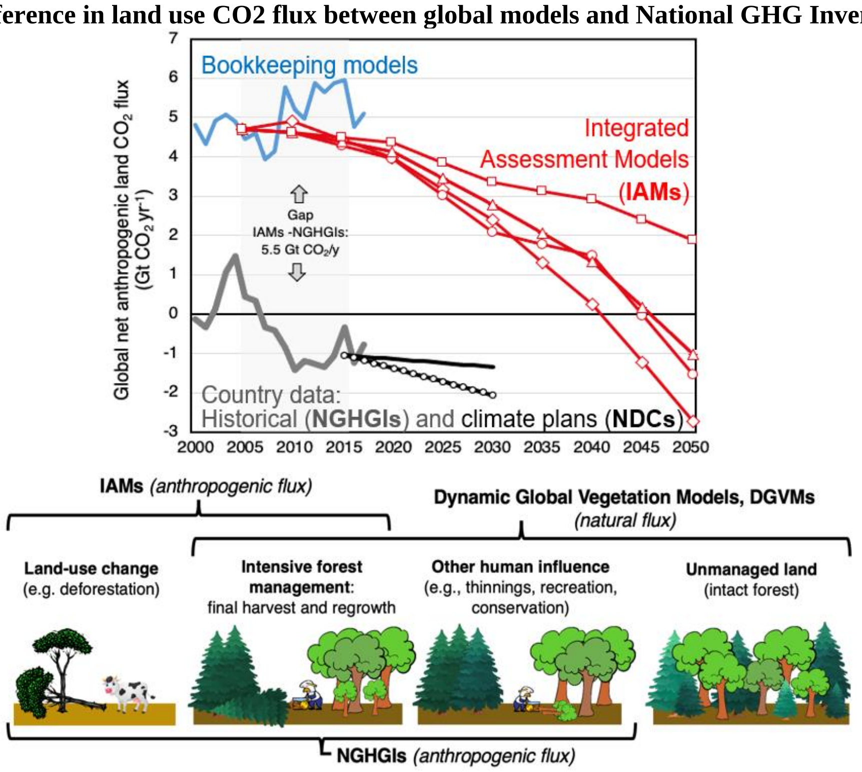


Modelled data on net carbon emissions from land use plotted together.
Source: Slide 6 of Mr. Ciais' presentation; Friedlingstein P et al., Global Carbon Budget 2020, Earth Syst. Sci. Data, 12, 3269–3340, 2020. https://doi.org/10.5194/essd-12-3269-2020.

178. There are different definitions of the parameters of land use, as highlighted by the poster "*Adjusting land mitigation pathways improves the assessment of global climate progress*" (see paragraph 234). **There are also large differences in land use CO2 flux between global models and national GHG inventories** (Figure 20). Whilst global models used by the research community consider 'managed' to apply only to forests subject to intensive harvest, national GHG inventories define managed forests more broadly consistent with IPCC guidelines. Global models also consider the natural response of land to human-induced environmental changes as natural while national GHG inventories consider it as anthropogenic. **Clearer definitions of the parameters need to be defined between the users of this data.**

Figure 20

Large difference in land use CO2 flux between global models and National GHG Inventories



Top: Differences in land use CO2 flux between global models and National GHG Inventories. Bottom: Differing labelling of land use and land use change.
Source: Slide 7 of Mr. Ciais' presentation; Slide 7 of Mr. Ciais' presentation; Grassi, G, Stehfest, E, Rogelj, J et al., Critical adjustment of land mitigation pathways for assessing countries' climate progress. Nat. Clim. Chang. 11, 425–434 (2021). https://doi.org/10.1038/s41558-021-01033-6; Based on Ogle, SM, Kurz, WA Land-based emissions. Nat. Clim. Chang. 11, 382–383 (2021). https://doi.org/10.1038/s41558-021-01040-7.

179. High quality atmospheric measurements over the last 60 years are available from observatories in the southern and northern hemisphere. These long-term data on the development of the global land sink in each hemisphere show that the **northern land sink has substantially increased**, especially since the 90s, and today absorbs about 2.4 billion tonnes of carbon – double the amount from 60 years ago. A mass balance calculation with the atmospheric CO2 growth rate shows that the rest of the global land sink has been increasing at a much slower rate or decreasing. This suggests that **the carbon balance is very close to zero in the tropics, with carbon sinks in forests being almost offset by emissions from land use change, including deforestation and degradation.**

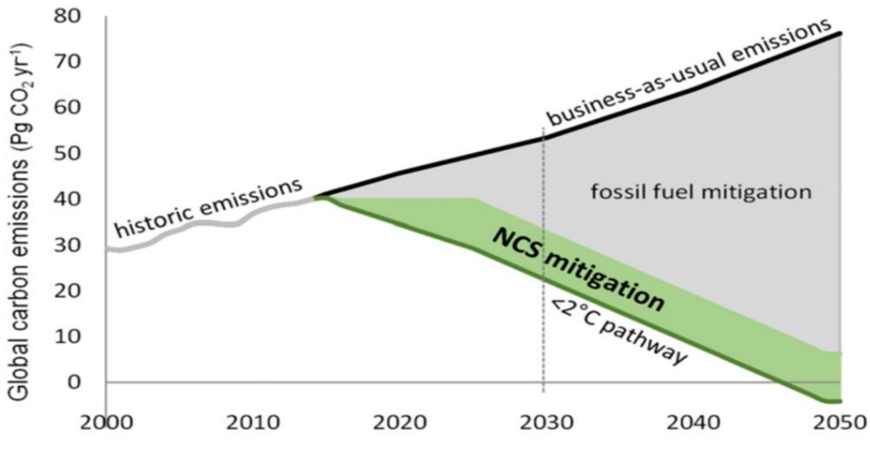
180. The latest generation of earth system models are now available alongside the CMIP6 data. **In all system models and all scenarios, the land sink decreases after some time**. In the most intensive warming scenario, this is due to negative climate impacts affecting the storage of carbon on the land weakening the carbon sink. In the most optimistic mitigation scenarios, this occurs due to a decrease in CO2 fertilisation decreasing productivity (and ocean outgassing). Both of **these scenarios result in the increased urgency for even greater mitigation as the future unfolds**.

181. The research community has considered the growth of atmospheric CO2 and the land and ocean CO2 sinks up to 2040, information that could be used for the Global Stocktake (GST). Earth system models can be nudged or initialized using observations and then run for the forthcoming years to tell the degree of predictability with which we can understand the natural carbon cycle.

182. The ocean carbon sink has relatively good predictability on a five-year timescale which allows scientists to project the average value of the ocean sink in the next decade. **The land sink is strongly influenced by climate variability such as El Nino events, which means that the predictability of the land sink is very limited with a lead time of three years. It is therefore difficult to predict the capacity of the land sink over the next decade. Thus, caution needs to be taken in interpreting global models at the local level.**

183. There are different concepts of nature-based solutions or natural climate solutions. **They have a large potential to assist with climate mitigation and could increase the remaining carbon budget by about one third and contribute to stabilising CO_2 emissions by 2050. However, NbS can only buy us time. To meet the goals of the Paris Agreement emissions must peak and decrease to zero as soon as possible** (Figure 21)**.**

Figure 21
Natural climate solutions can do part of the job but emissions need to peak and decrease to zero for meeting the Paris goals



Griscom et al. PNAS 2020.
Source: Slide 12 of Mr. Ciais' presentation; Griscom BW et al., Natural climate solutions, Proceedings of the National Academy of Sciences Oct 2017, 114 (44) 11645–11650 (2017). DOI: 10.1073/pnas.1710465114.

184. Importantly, when carbon is removed from the atmosphere and stored on land, the oceans will begin to outgas the carbon they have previously taken up in response to decreasing atmospheric concentrations. Approximately 3300 megatonnes of carbon may be stored in tropical land but this would only remove about half that amount of atmospheric CO2 however, as the ocean outgases CO2. **The amount of carbon which can be stored on land using natural processes is therefore not equal to the amount of carbon which is removed from the atmosphere.**

185. A synthesis paper recently published by Anderegg et al.[44] considering all current projects to protect and enhance carbon forest sinks found that these projects collectively removed about 80 megatonnes of CO2 per year, falling well short of the potential.

186. Nature-based solutions, include afforestation and forest restoration, improved grassland and agricultural practices, and wetland and peatland restoration. **Good guidance and well-considered trade-offs are important for the successful implementation of solutions**[45] including:

1) Protect existing forests first;
2) Natural regeneration will store more C & maintain diversity compared to plantations;
3) Tree planting is a means to achieve clearly specified goals and should be considered as part of a multidisciplinary decision-making process that thoroughly evaluates trade-offs and uncertainties;
4) Clear decision-making process required to plan, implement, maintain and monitor projects
    - In more arid ecosystems, extensive tree planting may increase risks of massive fires;
    - Some carbon farming projects have dispossessed local people from land in several developing countries;
5) Host of decisions must be made about implementation from local to regional, national and global scale;
6) New indexes to quantify carbon potentials & monitor carbon changes with a low latency
    - ESA CCI 100 m biomass maps;
    - Very high resolution Planet data (5m) made open for tropical regions by the Norwegian government for degradation;
    - Vegetation Optical depth for biomass change;
    - NASA GEDI global Lidar tree height products.

187. Decision makers at local level do not separate out mitigation and adaptation – the local context is important and **decision makers need to integrate adaptation/mitigation/nature protection through coordinated planning**. Scientists can support this through a portfolio of observations and data to support quantification of carbon sequestration potentials and monitoring carbon with a low latency and high accuracy.

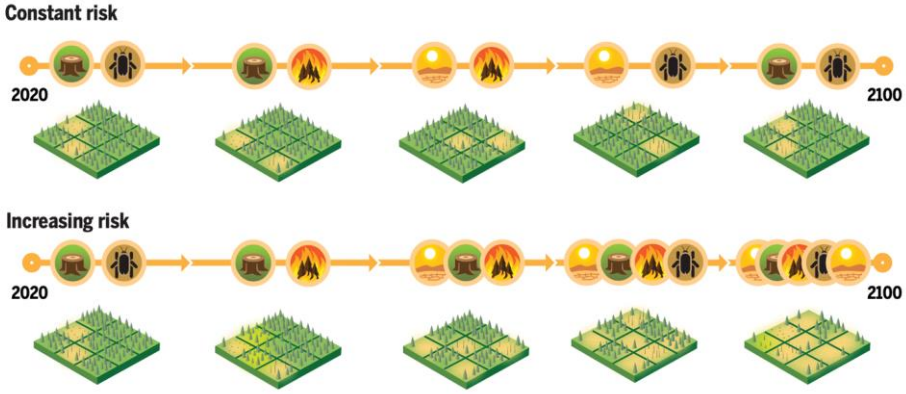
188. Mr. Ciais continued his presentation outlining the trade-offs between mitigation and adaptation. **Natural climate solutions may be produced and planned under the assumption that the climate is constant, while it is actually changing rapidly causing compound impacts**. Carbon storage over a century may be estimated with stationary disturbances such as drought, fires, insect attacks, and other activity considered.

189. However, as observed in the European drought of 2018 or insect attacks in North America in the previous decade, disturbances tend to compound each other and create relatively larger losses over time. All of these disturbances are triggered by climate factors and so the risk of them occurring and creating compound events will increase. This is important for science and mitigation trajectories, but also for financial planning (Figure 22).

[44] Anderegg, WRL et al., Climate-driven risks to the climate mitigation potential of forests, Science, 368, 6497, (2020) DOI: 10.1126/science.aaz7005.

[45] For example, see Brancalion, HSP, Guillemot, J, César, RG, et al., The cost of restoring carbon stocks in Brazil's Atlantic Forest, Land Degrad Dev 32 830–841 (2021). https://doi.org/10.1002/ldr.3764.

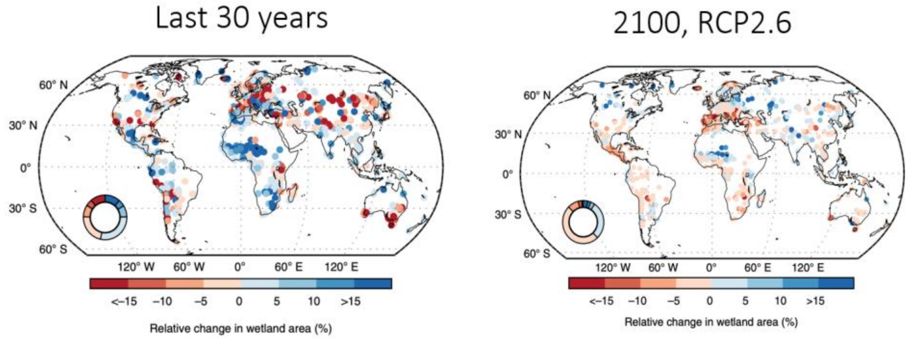
Figure 22
Non stationary climate & compound climate / anthropogenic disturbances must be accounted for in provisioning the risk for forest C offsets



Source: Slide 19 of Mr. Ciais' presentation; Anderreg et al. Science 2020.

190. The same principle applies to wetlands and peatlands. Restoring wetland and peatlands will increase the carbon storage capacity on land, but as the temperature warms the productivity of land will decrease and the water table will lower in wet areas. This will decrease methane emissions, but it will increase organic carbon decomposition and CO2 emissions. These carbon losses of CO2 from wetlands can overwhelm the reduction of methane emissions. This is an important effect as most mid-latitude wetlands are expected to shrink from the climate induced decrease of the water table, Figure 23.

Figure 23
Most mid-latitudes wetlands are expected to shrink from climate-induced decrease of the water table



Source: Slide 21 of Mr. Ciais' presentation; Xi, Y, Peng, S, Ciais, P et al., Future impacts of climate change on inland Ramsar wetlands, Nature Climate Change 11, 45–51 (2021). https://doi.org/10.1038/s41558-020-00942-2.

191. Mr. Ciais concluded by emphasising that:

1) People have different concepts of nature-based climate solutions.

2) There are large uncertainties and variability in biological systems (including via emission spikes during fires/pest attacks/drought). A singular event can negate all the carbon that has been sequestered during previous years.

3) Caution is required when interpreting the results of global models for national or sectoral planning. Adaptation, mitigation, and / or nature protection must be integrated through coordinated planning from the local to the regional and global level.

4) Trade-offs between adaptation and mitigation mean that the resilience of land systems must be increased.

5) Mitigation cannot be separated from adaptation when planning at the local level. The conversation around science must be applicable to the local context.

6) People cannot be decoupled from ecosystems. Socio-ecological ecosystems must be restored. Without this, managing ecosystems for mitigation and increasing local income, or adaptation benefits will not work.

7) A strong and deep science-based sectoral dialogue is required to make progress on these issues.

4. Potential synergies between mitigation and adaptation for the ocean carbon sink and how to evaluate opportunities and trade-offs

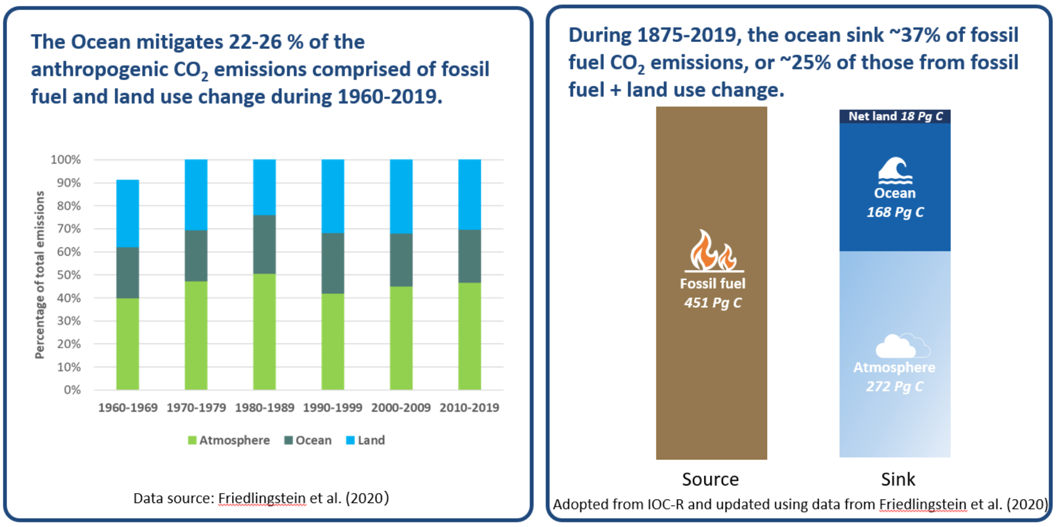
192. Mr. Minhan Dai, Xiamen University, presented on potential synergies between mitigation and adaptation for ocean carbon sink and how to evaluate opportunities and trade-offs.

The ocean carbon sink has been essential in mitigating climate change although urgent emissions reductions are needed to limit further deleterious changes in the ocean. The precise role of the ocean as a future carbon sink remains uncertain and more research is needed to better understand the ocean carbon cycle.

The ocean provides a space for strengthening mitigation and adaptation action. All marine Carbon Dioxide Removal (CDR) techniques have limitations and trade-offs and require additional research and development to better understand some of the options available, and their policy implications. However, nature-based mitigation and adaptation action can be synergised while also positively impacting the ocean carbon sink. The coastal zone is a vital area of focus for increased research and decision making.

193. The ocean carbon sink annually mitigated 22–26% of the anthropogenic CO2 emissions comprised of fossil fuel burning and land use change during 1960–2019. **The ocean sink contains 90% of the carbon in the carbon cycle**. In the pre-industrial era, the ocean was a net source of carbon to the atmosphere. Now it is a substantial net carbon sink of around 1.9 Pg of carbon per year. On long timescales, the land carbon sink is equivalent to land use change, leaving the ocean as the primary carbon sink of the last 200 years (Figure 24).

Figure 24
The ocean as a carbon sink over different time periods



Source: Slide 7 of Mr. Dai's presentation; Intergovernmental Oceanographic Commission UNESCO, Integrated ocean carbon research: a summary of ocean carbon research, and vision of coordinated ocean carbon research and observations for the next decade, IOC/2021/TS/158 (2021); Friedlingstein P et al., Global Carbon Budget 2020, Earth Syst. Sci. Data, 12, 3269–3340, 2020. https://doi.org/10.5194/essd-12-3269-2020.

194. Mr. Dai highlighted that **the coastal zone is a vital area of focus for research and decision making**. Coastal zones have been and will be the main population growth area in the world (70% of mega-cities, ~50% GDP), especially in China (55% of mega-cities, ~60% GDP). They link the atmosphere, lithosphere, biosphere, and hydrosphere and is a site of complex interactions between these spheres and hosts abundant natural resources for the ecological environment. They are subject to intense human activity but are also an extremely important region with a comparatively small surface area:

1) **7% of the global ocean**
2) **The main reservoir of biodiversity and ecosystem diversity: species abundance ~97%**
3) **Marine primary productivity ~25%, and fish catches ~86%**
4) **Carbon sink ~21%, organic matter ~80%; blue carbon ~50%**

5) **~30% of global crude oil production.**

195. **The land-ocean interaction at the coasts is affected by land-based pollutants, such as fertilizers, which strongly affect the local carbon storage systems and the natural ecosystems causing chain reactions in the carbon and oxygen cycles in coastal zones worldwide**. For example, in the Changjiang estuary, the hypoxic area reached 20,000 km^2 in 2016 and has become one of the largest seasonal hypoxic zones in the world due to fertilizer consumption in the river watershed. Similar examples of such hypoxic conditions exist in East Asia in the Pearl river estuary, Fujian, and in Malaysia and Thailand.

196. With progressive emission reductions and CDR, the atmospheric CO_2 concentration will decline. Changes in coastal-ocean physics and biology as well as changes in riverine input and sediment interactions will modify the distribution of carbon and alkalinity. A potential future outcome is that enhanced anthropogenic activities and precipitation will increase carbon export from land to the coastal ocean. Another possibility is a decline in the input of nutrients from land after the use of fertilizers peaks. Given these possibilities, it is uncertain how ocean carbon will evolve relative to atmospheric CO_2 changes and inputs from land.

197. For decision makers, the emerging issues related to the ocean carbon sink that are of paramount importance for our environment and society can be categorized as

1) Understanding whether the ocean will continue as a sink for human-produced CO2 and its climate change mitigation capacity, such as in regard to climate-carbon coupled systems & zero-emission strategies & actions;

2) The vulnerability of ocean ecosystems to increasing CO2 levels;

3) Adaptation options and needs to changing ocean conditions.

198. Research directions identified by the IOC-R in its report *Integrated Ocean Carbon Research: A Summary of Ocean Carbon Knowledge and a Vision for Coordinated Ocean Carbon Research and Observations for the Next Decade*[46] include:

1) Will the ocean uptake of anthropogenic CO2 continue as primarily an abiotic process?

2) What is the role of biology in the ocean carbon cycle, and how is it changing?

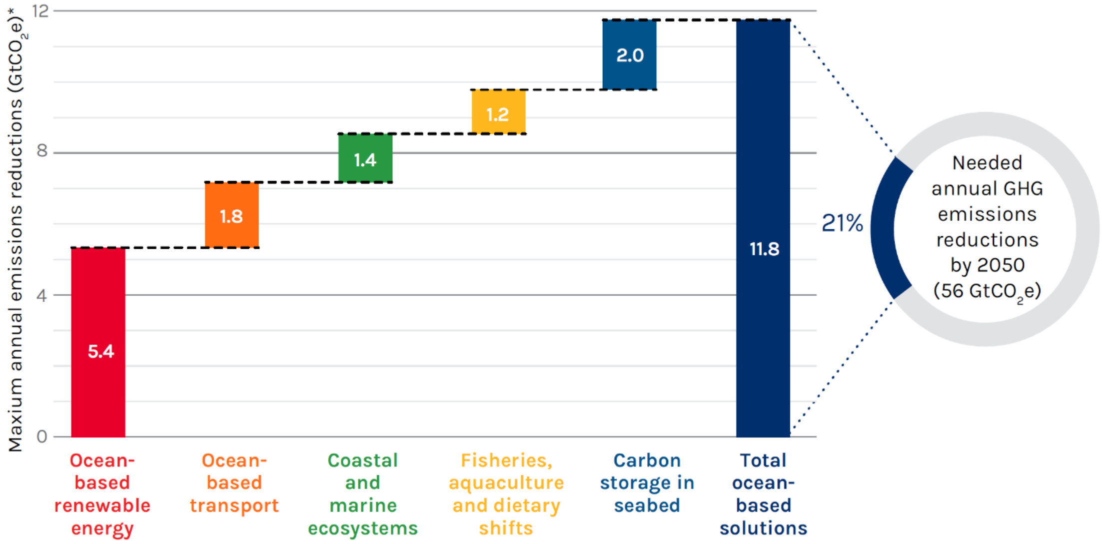
3) What are the exchanges of carbon between the land-ocean-ice continuum and how are they evolving over time?

4) How are humans altering the ocean carbon cycle and resulting feedbacks, including possible purposeful CDR from the atmosphere?

199. Urgent and deep emissions reductions are vital to protect the ocean from further climate change impacts. However, the ocean is also a space where mitigation can take place. Mr. Dai outlined some of the ocean-based mitigation options. The High-Level Panel for a Sustainable Ocean Economy identified that **ocean-based mitigation options could reduce global GHG emissions by about 4 billion tonnes of CO2 equivalent per year in 2030 and by over 11 billion tonnes per year in 2050, reducing the emissions gap by up to 21% on a 1.5°C pathway, and by around 25% on a 2°C pathway** (Figure 25).

[46] Available at https://unesdoc.unesco.org/ark:/48223/pf0000376708.

Figure 25
Ocean-based mitigation options associated with annual mitigation potential in 2050



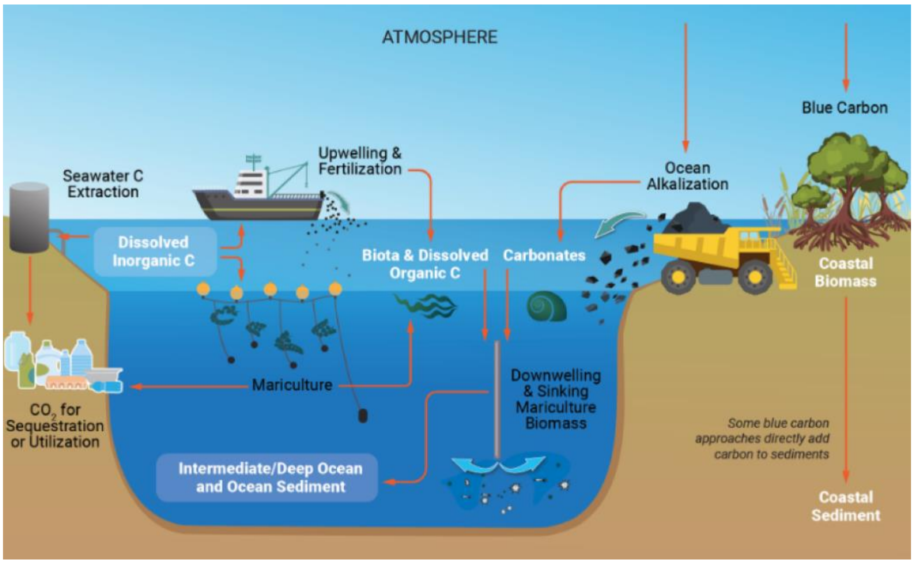
Source: Slide 16 of Mr. Dai's presentation; Hoegh-Guldberg O, et al. The Ocean as a Solution to Climate Change: Five Opportunities for Action. Report. Washington, DC: World Resources Institute (2021). Available online at http://www.oceanpanel.org/climate.

200. Ocean-based carbon dioxide removal (CDR) techniques can be identified in two broad categories – biological and chemical (Figure 26):

1) Biological pathways include: coastal ecosystem restoration; enhanced microalgae cultivation to boost surface ocean nutrients through fertilization or upwelling; increased cultivation and harvesting of marine-based plants; downwelling of seawater as a means of sequestering CO2 dissolved in upper ocean waters;

2) Chemical pathways include ocean alkalinisation and electrochemical extraction of CO_2 from seawater. Artificial ocean alkalinisation, for example, can reduce the effects of ocean acidification and increase CO2 uptake.

Figure 26
Marine Carbon Dioxide Removal



Source: Slide 15 of Mr. Dai's presentation; Energy Future Initiative, 2020.

201. Earth system models show that after peak emissions are reached, atmospheric CO_2 will begin to decline. This will lead to a weakening of the ocean and land sink as projected under RCP 2.6. To maintain atmospheric CO2 and temperature at low levels, not only does anthropogenic CO2 in the atmosphere need

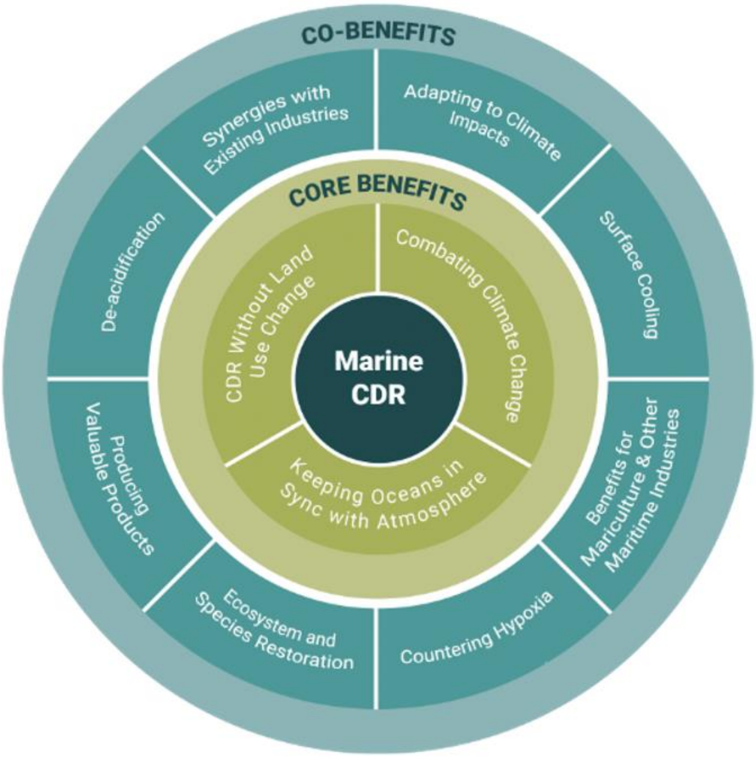
to be continuously removed by CDR, but anthropogenic CO2 stored in the ocean and land needs to be removed when it outgasses to the atmosphere. This must be considered when designing future pathways.

202. All marine CDR measures have limitations and trade-offs. **Marine CDR requires additional research and development to better understand some of the options available and their policy implications.** This was also highlighted at the twelfth meeting of the research dialogue by Mr. Chris Vivian speaking on the work of GESAMP Working Group 41.[47] Mr. Dai highlighted a number of potential co-benefits for marine CDR (figure 27).

203. **Research and development policy needs** include:

- Defining the RD&D portfolio of specific biological and nonbiological CDR pathways for technology development, optimization and scalability, including anticipating new and emerging pathways;
- Improving the methods for monitoring, quantifying, and verifying CDR benefits, ecosystem effects, and lifecycle impacts;
- Developing predictive modelling and planning tools for siting and operations;
- Creating markets for co-products from ocean CDR pathways and integration into carbon markets;
- Enhancing public engagement and support;
- Creating enabling national and international governance frameworks.

Figure 27
Potential Co-benefits of Marine CDR



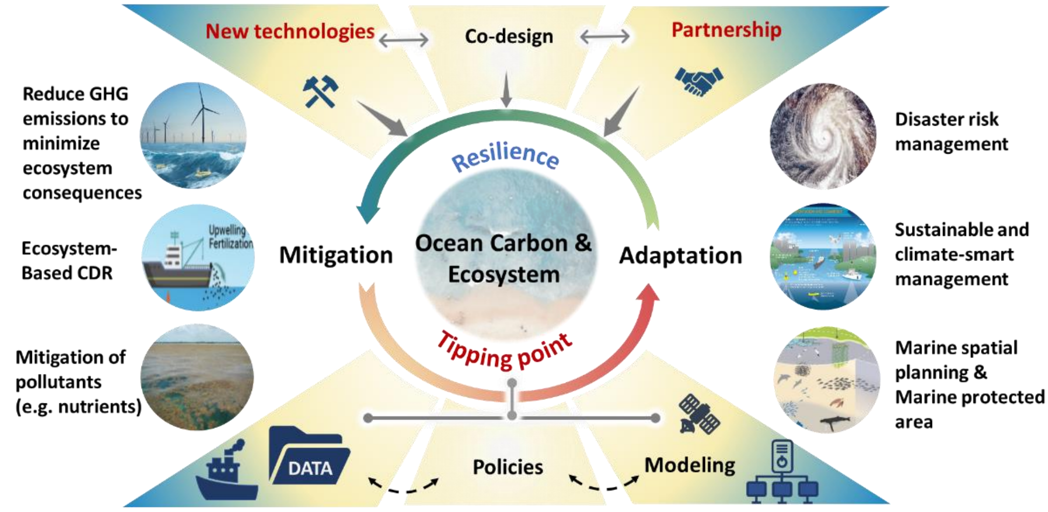
Source: Slide 18 of Mr. Dai's presentation; Energy Future Initiative, 2020.

204. Mr. Dai emphasized the **importance of ecosystem-based approaches to combatting climate change but that they must be considered comprehensively including with respect to their effect on ecosystems, their synergies with other land and ocean systems, and the impact on the ocean carbon sink.** For example, mangroves planted in Siangshan Wetland, north western Taiwan since 1997 resulted in negative impacts on the local ecosystem, including the loss of the benthic organisms and habitats for birds, sediment accumulation and flooding, and increased mosquito populations. A mangrove removal project was subsequently launched in 2015. Thus, integrated ecosystem-based governance for nature-based solutions is important.

47 See http://www.gesamp.org/work/groups/41.

205. **Ecosystem-based mitigation and adaptation action can be synergised while also positively impacting the ocean carbon sink.** Mitigation action includes reducing GHG emissions to minimise ecosystem consequences, using ecosystem-based CDR to advance climate action and benefit ecosystems, and minimising pollution to enhance the natural capacity of ecosystems to store carbon. Adaptation approaches such as disaster risk management, sustainable and climate-smart management, and implementing marine spatial planning and protected areas rely heavily on data, modelling, policies and mitigation action that affect when tipping points occur. Successful adaptation increases climate resilience through technological innovation, partnerships, and codesign of solutions (figure 28).

Figure 28
Synergies & Ecosystem-Based Mitigation and Adaptation for the Ocean Carbon Sink



Source: Slide 23 of Mr. Dai's presentation.

206. Mr. Dai concluded with several key points:

- **The ocean has been the only sustained carbon sink for the last 200 years. However, the future trend of ocean carbon sink is subject to large uncertainty, especially under net-zero and in the land-ocean-atmosphere coupled system.**
- **CO2 and climate changes have caused negative consequences to ocean ecosystems.**
- **Marine CDR is crucial for both mitigation and sustaining the ocean carbon sink, as well as possibly maintaining ocean health under zero-emission scenarios.**
- **Ocean-based solutions provide great opportunities for both mitigation and adaption and should be considered in Nationally Determined Contributions and UNFCCC deliberations.**
- **Ecosystem-based approaches should be enforced in both mitigation and adaption and thus, the UN Decade on Ocean Science for Sustainable Development and the UN Decade on Ecosystem Restoration could be organised in a more coherent way.**

5. Going beyond what works in climate: Science and data for decision making and being future-fit

207. Ms. Jyotsna Puri of IFAD presented on current and future needs for decision making to build resilience based on science - going beyond what works in climate: science and data for decision-making and being future-fit.

Uptake of resilience measures requires wider engagement with "non-traditional actors" to help create a paradigm shift towards greater resilience and greater uptake of resilience measures that can be measured, tested and scaled. Evidence or anomalies that can encourage change must be built into adaptation to become a force by themselves and must be better researched.

208. Ms. Puri discussed how definitions of **resilience can mean different things to different people**. IFAD works with smallholder farmers in rural spaces and focuses on building both production and consumption value chains. In this work it is extremely important to understand how resilience and adaptation are perceived on the ground. IFAD has found that one of the critical challenges in adaptation and resilience building amongst smallholder producers and farmers has been the low uptake of

interventions. **The relatively small amount of work completed on engaging with local and indigenous communities on resilience has prevented many non-traditional actors contributing in this space**.

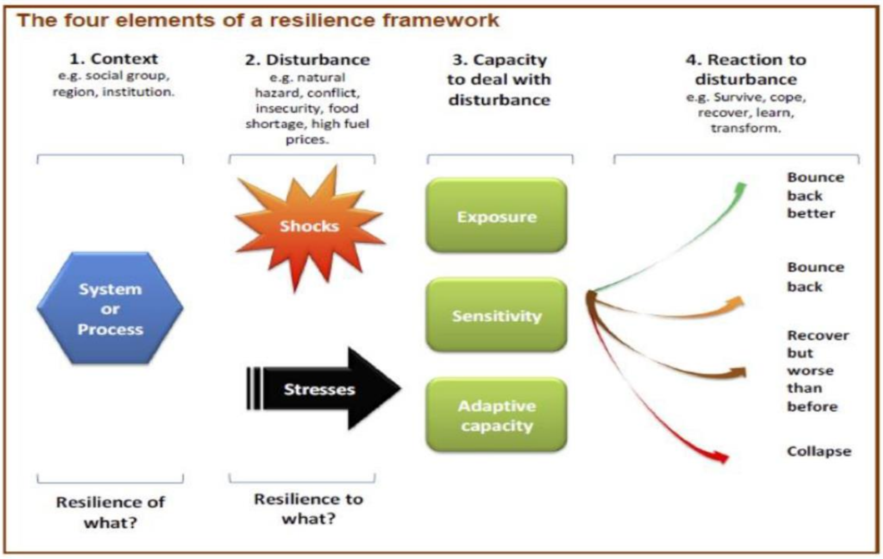
209. Globally, one third of food is produced by smallholder farmers using less than two hectares of land each. It is therefore important to understand how adaptation interventions can be made more attractive to these farmers. Ms. Puri defined resilience in this context as the ability to cope with changes and shocks, to recover, learn, adapt, and transform. She highlighted that **engaging with the language around adaptation and resilience can make adaptation interventions more attractive to non-traditional actors, such as smallholder farmers, and assist them to engage more in the process.**

210. Evidence reviews, meta-analyses, and behavioural science papers have been published to consider and parse the overall concept of adaptation, and understanding the exposures, sensitivities and adaptive capacities involved in defining concepts. There are three steps to use data to inform decision-making:

1. Know what you know (and what you do not)
2. Set up measurement systems and test
3. Scale (and test again)

211. **To create a paradigm shift towards greater resilience and greater uptake of resilience measures, evidence or anomalies that can encourage change must be built into adaptation to become a force by themselves.** A resilience framework can help support these shifts (figure 29).

Figure 29
Resilience framework

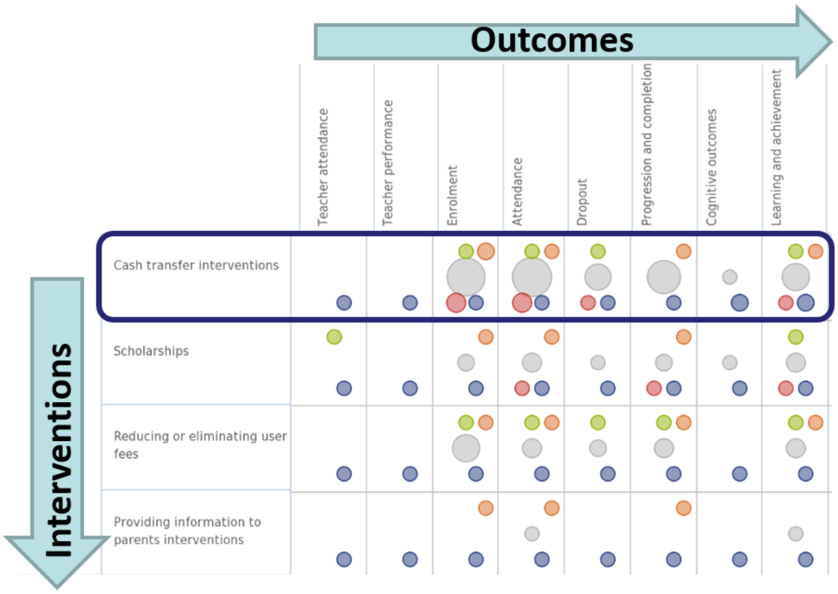


Source: Slide 4 of Ms. Puri's presentation; DFID KPI4-methodology, 2014.

Know what you know

212. Ms. Puri described how mapping evidence and evidence gaps can support decision making through using a matrix to understand the overall theory of change in a system (Figure 30).

Figure 30
An example of an evidence gap map used to support evidence-informed policy making



Evidence linking interventions or actions is shown on the left. Targeted outcomes are shown on at top.
Source: Slide 7 of Ms. Puri's presentation.

213. Evidence gap maps help to identify high quality evidence as well as the target population, interventions, comparators, outcomes, and what methodologies have been used. It can also clarify the rigour used to collect evidence and the biases within it.

214. The state of the evidence base regarding the ability of adaptive interventions to help people in low- and middle-income countries adapt to the impacts of climate change was assessed by IFAD for 486 studies in the past 15 years. The definitions of parameters for this gap map were:

1) Population - Human individuals, groups, communities, institutions, systems and economic sectors (water, transport, infrastructure, agriculture, forestry, etc...) in low to middle income countries;

2) Intervention - Aim to adjust, reduce, stop or make use of the benefits of an impact from a direct change in climate or a climatic hazard;

3) Comparator - No adaptation intervention, different levels of intervention or comparison of different interventions;

4) Outcome - Human adaptation to climate change, variability, extremes or other natural hazards that could be linked to climate.

215. The research showed that agricultural insurance is one example of the resilience or adaptation related interventions that are challenging for small-holder farmers to adopt. Even given fair terms and presented as an option to mitigate risk, adoption rates for this adaptation option are 8% to 25% when not tied to other incentives. Uptake of other interventions have been similarly low, even with strong scientific proof. This is a known issue in the field of development, but is also becoming increasingly important within the climate space as we transition to low-carbon, climate resilient pathways.

216. Although an overall assessment of the evidence found that it was of low quality. There were some examples of uptake with high evidence such as those within the 'Forestry, Fishing and Agriculture' Sector, where evidence for the effect of nature-based, and technological options on economic benefits is high, and there is high evidence for the effects of informational or educational interventions on uptake.

217. Despite substantial resources and attention being devoted to institutional systems, there is very little evidence of what does or does not work to transform institutional systems and why for different sectors.

Set up measurement systems and test

218. For adaptation interventions, it is important to develop the understanding of how interventions should be delivered on the ground, develop the ability to translate science into behaviour, and design systems to be able to deliver on those interventions. Understanding the 'how' of these programmes is

more important than the 'what'. **We may be at a stage where we know what works, but not how, thus making implementation and behavioural science vital at this stage of the process.**

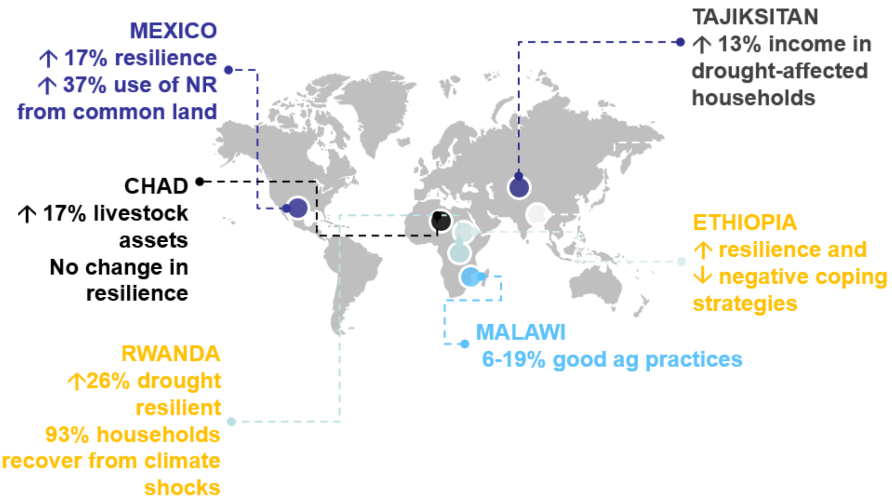
219. High quality Impact Assessment Measurement methods using counterfactuals at the cluster, district, and household levels were used to enhance understanding of what improves types of resilience, such as of households or livestock, and resilience in response to climate hazards and shocks. Figure 31 shows the outcomes of different interventions in different countries to support resilient agriculture. **It is important to note where interventions are unsuccessful, not only those that are**, such as in these studies in Ethiopia.

Scale and test again

220. At the scaling up phase, an intervention is well-tested and known to work to build resilience and understand how this can also help communities graduate from ultra-poverty. From IFAD interventions in different pilot areas - Ethiopia, Ghana, Honduras, India, Pakistan, and Peru – they have shown **that resilience interventions which combine foci on decision-making, the role of women, mental health, income and revenues, finance, access to assets, food security, and training can affect a graduation from ultra-poverty**. Using packets of interventions, rather than single interventions, is key to achieving this. Data on costs and benefits is often neglected in policy discussions, but is a vital factor to be integrated into the policy mix. What works in pilots does not always work at scale.

221. Ms. Puri concluded by recapping the three steps to inform decision making (see paragraph 210). She stated that **it is important to remember that we may know less than we think about what works, especially in terms of 'how' an intervention works and what can affect behaviours in terms of uptake and perception. This is an important direction for research.**

Figure 31
Zooming into impact assessments



Examples of the outcomes of interventions in selected countries.
Source: Slide 25 of Ms. Puri's presentation.

Discussion

222. **Can you provide clarification and expand on the risks of relying too much on nature-based solutions as an option to reduce emissions, given that NbS become increasingly limited with on-going warming and sea-level rise?**

Mr. Hans-Otto Pörtner: The vulnerability of natural systems to climate change is a guiding principle, but my personal view is that there cannot be too much reliance on nature-based solutions if ambitious emissions reductions happen at the same time, and if these reductions are not compromised by waiting for nature to 'do the job for us'.

We are seeing that the capacity of natural systems to store carbon is already being affected and declining. If we want to maintain that service, we have to strengthen those systems, but that takes time. The resilience and capacity of these systems must be improved, and we must help them adapt to the climate change that we are allowing to happen.

The fraction of blue carbon is small in relation to current emissions, which emphasises the importance of emission reductions to be able to exploit the capacity of nature-based solutions, but the capacity of ocean sediments to store carbon seems to have been heavily underestimated and requires more research.

Ms. Minna Epps: Nature based solutions cannot be relied upon to the point that they may exclude emissions reductions, and we must stick to the emission reduction targets. On the other hand, this is also linked to the vulnerability of nature, its resilience, and its capacity to adapt. Nature must be protected and restored to ensure a buffer when implementing nature-based solutions.

223. **Can you give a few examples of cutting-edge scientific questions requiring a synergy between the climate and biodiversity scientific communities?**

Ms. Minna Epps: Protect and restoring nature is one example of this. It is possible. In coral reefs for example there are climate resilient species.

Overfishing is another example. To ensure fishing is sustainable and resilient we require more precautionary approaches. Protecting nature will also protect carbon storage on the seafloor, even if it is not included in UNFCCC accounting.

Mr. Pörtner: Some of the most important research is related to implementation. When we talk about strengthening the carbon storage capacity of ecosystems, we must acknowledge that climate change is happening to some degree. We must ask which system will be most resilient in a certain place.

224. **What can we do to make forests more resilient to climate change?**

Mr. Pörtner: We may need to consider new species to integrate into forests to make them more resilient. We must also ask how much percent area a system needs to still be functional. The percentage numbers required for the Amazon rainforest to function, for example, are much higher than what is currently proposed. This allows the Amazon to set up its own climate and maintain the water cycle, which prevents it from reaching its tipping point and becoming a dry forest with a much lower carbon storage capacity.

225. **How can we best apply the term ‘nature-based solutions’? For example, where 66% of mitigation options is NbS, do all of these solutions fit the criteria of the definition?**

Ms. Epps: ‘Nature based solutions’ does not necessarily mean solutions specific to climate change or to biodiversity. It is a holistic approach. When a standard is defined it is important to know what the ‘best-practice’ looks like. The eight criteria I outlined can be applied differently, but the IUCN’s definition is intended to be facilitative.

These self-assessments were developed with our members from indigenous peoples’ organisations and so are inclusive and have benefits for the local community, but they also consider economic viability.

An assessment may not score high on all criteria or indicators, but it can be used to move forward using the scientific guidance and the technical capacity of IUCN.

226. **Can you comment on the economic and sustainability aspects of CDR, including beyond its technical potential?**

Mr. Philippe Ciais: The potential was estimated using available land, so as not to harm existing forest cover, and were estimated for two different scenarios of carbon price. The lowest carbon price was 100USD per ton, which is aligned to a Paris trajectory. The potentials have been calculated given both area and growth rate per climate type and per type of ecosystem.

227. **What are the principles and technologies involved in the use of CDR for extracting carbon from the ocean, and what sustainability aspects are associated with this?**

Mr. Minhan Dai: CDR has some overlap with nature-based solutions, and we have to improve our methods of monitoring, quantifying and verifying the benefit of CDR and any impact on ecosystems.

In terms of techniques to develop CDR, there are essentially three categories. – biological, chemical (as mentioned above see paragraph 200) as well as a third category of currently unknown techniques for CDR.

An important message both Philippe and I pointed out is that under a low emission scenario, the carbon dioxide in the ocean could be degassed into the atmosphere. Because of this, CDR will have to be implemented permanently to some extent.

228. **Are indigenous peoples’ traditional knowledge being included when considering how to preserve natural resources, protect ecosystems, and maintain carbon stocks?**

Mr. Ciais: In the Amazon countries for example there is more carbon, and more carbon sequestration, in areas under indigenous stewardship compared to other areas. It is a very important point that natural climate solutions can only be implemented with the help of local people and, in particular, local indigenous communities.

229. **With regard to indications that boreal forest sinks are already weakening, the uncertainty of future land sinks, and the inconsistency between the use of land sinks in integrated assessment models and UNFCCC accounting, can you explain this inconsistency in terms of the mitigation efforts required to meet the 1.5 degree C goal?**

Mr. Ciais: When there is a climate shock such as a large fire or a drought you see a decrease in the storage capacity of the land sink. Globally however, we see variability but no global sign of the saturation of the land sink. We do however think that the intensity of the land sink is slowing down in intact tropical forests.

The land use numbers produced by the IPCC only account for land [unknown] after being converted. Countries' reports account for established forest which are subject to management but also to indirect effects. We need to speak the same language, but it is possible to identify the indirect effect of the role of planted forest and add it to the flux for recently converted land. It is important not to call a flux 'land-use' if these terms mean different things. *See "Adjusting land mitigation pathways improves the assessment of global climate progress", paragraph 234, in the poster section.*

230. **Is the ongoing cost of maintaining protected primary forests and planted forests reflected in the models used by Philippe?**

Mr. Ciais: We must not only consider the cost of additionality or sequestration but also the cost of maintaining carbon stocks. The best [unknown] is to leave the forests where they are and to manage them so that they can maintain their carbon stocks or increase them. This cost must be compared with the extra cost of increasing replantation or forest restoration programmes.

It is important to restore degraded forest systems, but most important to have a system where things are aligned – both preserving existing forests and restoring degraded systems.

231. **Are there risk management strategies from other fields that you have incorporated into solutions?**

Ms. Jyotsna Puri: We are learning that risk is the other side of uncertainty. We need to use Bayesian techniques[48] to update our priors[49] and use that in decision making. One insight emerging from uncertainty science is that there are unknown unknowns. When science takes us into spaces where we can calculate probabilities, we can handle unknown unknowns by incorporating priors.

In terms of unknown unknowns, there are two important things in this context that are both options on the ground. Building redundancy into systems gives us a way to adapt, recover, and sustain ourselves. We are advocating for that as we build systems and work with institutional actors in this space.

Probably even more important is modularity – the idea that you can decouple different action points from each other but still enable each one to take action. Glacier melt in India has led to the loss of many lives, but far more could have been lost if communities had not been empowered in a modular way to undertake action to react and respond immediately. That is a key strategy to think about in the context of uncertainty that has not yet been recognised.

232. **What are the similarities between resilience to climate change based on livestock and land between the Lake Chad region and elsewhere?**

Ms. Puri: The responses and results that I am presenting are very specific to the areas we are intervening in. There are separate impact assessment studies going on in other areas. lands like the Savannah but I would have to know more about the areas you are talking about.

In term of the Sahel, we are also working on the great green wall for example, and there is a group of impact assessments being produced that will help us to understand the resilience of these systems.

[48] Statistical probability incorporating the concept of expectation based on personal knowledge and beliefs.

[49] Statistical expressions of personal belief before other data or evidence is accounted for.

B. Poster Session

233. Ten posters were presented on Theme 2: Resilience for and by nature: Building knowledge and understanding to weave the protection and restoration of nature into decision making on mitigation and adaptation. They can be viewed on the UNFCCC website for the thirteenth meeting of the research dialogue[50] or individually via a hyperlink in each title below.

234. **Adjusting land mitigation pathways improves the assessment of global climate progress**

Giacomo Grassi, Joint Research Centre (JRC), European Commission, Ispra, Italy; Joeri Rogelj, Grantham Institute for Climate Change and the Environment, Imperial College, London, United Kingdom; Elke Stehfest, PBL Netherlands Environmental Assessment Agency, The Hague, Netherlands; and Detlef van Vuuren, Alessandro Cescatti, Jo House, Gert-Jan Nabuurs, Simone Rossi, Ramdane Alkama, Raúl Abad Viñas, Katherine Calvin, Guido Ceccherini, Sandro Federici, Shinichiro Fujimori, Mykola Gusti, Tomoko Hasegawa, Petr Havlik, Florian Humpenöder, Anu Korosuo, Lucia Perugini, Francesco N. Tubiello, Alexander Popp, Joint Research Centre of the European Commission

Collective climate progress under the Paris Agreement will be assessed by the Global Stocktake in the light of the best available science. To this aim, collective country GHG historical data and targets are expected to be compared with emissions pathways by Integrated Assessment Models (IAMs). Currently, however, a mismatch of ~5.5 GtCO2/year exists between the global land-use fluxes estimated with IAMs and from countries' GHG inventories. This may hamper an accurate assessment of collective climate progress.

The main reason for this large gap in estimates is the different approach by global models and countries to estimate the 'anthropogenic' CO2 removals by forest. Country GHG inventories (following IPCC guidelines) consider a broader managed forest area than global models, and on this area they consider some 'anthropogenic' fluxes seen in the global models as 'natural'. Both approaches are valid in their own specific context, yet both have limitations. What counts most is the transparency and comparability of these estimates, across countries and with global models.

This study implements a method that enables comparison between the two different approaches by reallocating part of the forest CO2 removals considered 'natural' by the global models to the 'anthropogenic' component. This solution does not change the models' original decarbonization pathways, but recalibrates them to ensure greater comparability with countries' GHG reporting. This improves the understanding of how the remaining allowable economy-wide cumulative net emissions (i.e. the 'remaining GHG budget') for a well-below 2oC target correspond to the collective country targets, and thus helps a more accurate assessment of collective progress towards the Paris Agreement.

235. **Land-based mitigation potentials within the agenda for sustainable development**

Stefan Frank, Mykola Gusti, Petr Havlík, Pekka Lauri, Fulvio DiFulvio, Nicklas Forsell, Tomoko Hasegawa, Amanda Palazzo, and Hugo Valin, IIASA

Even though enormous expectations for greenhouse gas mitigation in the land use sector exist, at the same time worries about potential implications for sustainable development have been raised as many Sustainable Development Goals (SDGs) are closely tied to developments in the sector.

This poster assesses the implications of achieving selected key SDG indicators for Zero Hunger, Clean Water and Sanitation, Responsible Consumption and Production, and Life on Land on the land-based climate change mitigation potential.

Protecting highly biodiverse ecosystems has profound impacts on biomass potentials (-30% at >12 US dollar per gigajoule) while other SDGs mainly affect greenhouse gas abatement potentials. Achieving SDGs delivers synergies with greenhouse gas abatement and may even in the absence of additional mitigation policies allow to realize up to 25% of the expected greenhouse gas abatement from land use required to stay on track with the 1.5 °C target until 2050. Future land use mitigation policies should consider and take advantage of these synergies across SDGs.

[50] See https://unfccc.int/event/thirteenth-meeting-of-the-research-dialogue.

236. **State and future of boreal forest natural climate solutions**

Julia Pongratz, Ludwig-Maximilians University of Munich (LMU); Anders Ahlström, Lund University (LU); Ana Bastos, Max Planck Institute for Biogeochemistry, Jena; Lars Bergström, Stockholm University; Wendy Broadgate, Future Earth (FE); Phillippe Ciais, LSCE – Institute Pierre Simon Laplace; Giacomo Grassi, Joint Research Center, European Commission, Ispra; Anders Lindroth, LU; Wolfgang Obermeier, LMU; Mike Norton, European Academies' Science Advisory Council; Erik Pihl, FE; Timo Pukkala, University of Eastern Finland; Anders Wijkman, The Royal Swedish Academy of Sciences

Boreal forests have been a strong and growing carbon sink throughout the 20th century but some regions now show early signs of weakening. A greening trend may be turning into "browning". Disruptions from drought, fires and insects can be more intense and frequent under climate change and other environmental stress factors. These constitute the largest uncertainty for the future health of the boreal forests and their role as carbon sinks.

While boreal forests cool Earth by absorbing carbon, they also have a strong warming effect by decreasing Earth's albedo and causing more of the Sun's radiation to be absorbed. On the local scale, forests cause mixing of air layers due to their "roughness" which gives a warming effect.

Many values of forests, such as biodiversity, cleaning of air and water, and recreation are often not factored in fully and these services may be lost when decisions on forestry are taken on purely market-based values. A multidimensional assessment of forests' values is key to sustainable management.

Forestry products can play a role through substitution of fossil-based products and this needs to be factored in when assessing the potentials for nature-based solutions. The climate benefits of forestry products vary widely, however, depending on how they are produced and what they substitute.

237. **Enhancing Climate Mitigation and Adaptation Co-Benefits with NOAA's Blue Carbon Inventory Project**

Alec Shub and Lisa Vaughan, NOAA; and Stephen Crooks, Silvestrum Climate Associates

Coastal wetlands, such as mangroves, salt marshes, and seagrasses, play a significant role in carbon storage and sequestration around the world, providing some of the highest density stores of carbon in the biosphere. This ability to continuously sequester carbon through photosynthesis and the capacity of these wetlands to provide long-term storage is known as "coastal blue carbon."

Reporting comprehensive inventories of greenhouse gas sources and sinks is an important step for tracking progress towards meeting the Paris Climate Agreement. In 2013, the Intergovernmental Panel on Climate Change released technical guidance on including wetlands in national greenhouse gas inventories (NGGI). Yet, given the technical challenges involved, to date only a handful of countries have incorporated blue carbon into their NGGI.

Supported by the U.S. Department of State and conducted in partnership with EPA and other USG agencies, the newly launched NOAA Blue Carbon Inventory (BCI) Project will support countries in their inclusion of coastal wetlands in their NGGI, with the goal of translating enhanced monitoring and reporting of emissions from wetlands into improved mitigation and resilience outcomes.

Through initial stakeholder engagement, NOAA will identify potential partner countries and organizations, and begin refining specific project plans by identifying key needs and opportunities. The project will advance bilateral and/or multilateral technical collaboration to analyze data and build tools to include coastal wetland information in greenhouse gas inventories. Targeted research may address broader regional and global knowledge gaps critical to improving greenhouse gas inventories. Collaboration could include regional workshops and trainings, webinars, peer-to-peer engagement, mentoring, and learning by doing.

The NOAA BCI Project is intended to foster the development of emissions mitigation, coastal resource management, and resilience strategies that reflect the value of coastal ecosystems in carbon storage and sequestration. A strong network of healthy wetlands can protect coastal communities from storms, waves, erosion and flooding; protect biodiversity; and provide ecosystem services that support livelihoods, culture, food security, water quality, recreation, and tourism.

238. **Outcomes of nature-based solutions for biodiversity & ecosystem health**

Isabel Key, Megan Macgillivray, Alexandre Chausson, Beth Turner, Nathalie Seddon, Nature-based Solutions Initiative, University of Oxford

The sustained flow of societal benefits from nature-based solutions (NbS) is underpinned by healthy, functioning ecosystems. By definition, NbS should bring benefits for nature by enhancing ecosystem health, and increasing biodiversity where appropriate. However, the empirical evidence for this statement is dispersed and the quality of evidence unknown.

Terrestrial, marine and freshwater NbS have measurable benefits for ecosystem health and biodiversity. On average, NbS lead to local increases in species richness. However, evidence quality was sometimes weak; the biodiversity and ecosystem health outcomes of an intervention were often measured with only one metric, and effects on functional and genetic diversity were under-reported.

Results highlight a need for more comprehensive assessment of NbS projects, using a broader suite of metrics for biodiversity and ecosystem health. An improved understanding of these outcomes will enable NbS to be designed and adaptively managed to help reach biodiversity conservation targets whilst also addressing other global challenges.

239. **Building knowledge to weave the protection and restoration of coastal Blue Carbon ecosystems into decision making on mitigation and adaptation to climate change**

Elisabetta Bonotto and Kirsten Isensee, IOC-UNESCO

Coastal Blue Carbon ecosystems, such as mangroves, tidal marshes, and seagrasses, play a significant role in carbon sequestration and long-term carbon storage around the world, providing some of the highest density stores of carbon in the biosphere.

Reporting comprehensive inventories of greenhouse gas sources and sinks is an important step for tracking progress towards meeting the Paris Climate Agreement. In 2013, the Intergovernmental Panel on Climate Change released technical guidance on including wetlands in national greenhouse gas inventories (NGGI). Yet, given the technical challenges involved, to date only a handful of countries have started this endeavour.

The Blue Carbon Initiative and the International Partnership for Blue Carbon provide platforms to connect, share and collaborate to build solutions, take actions and benefit from the experience and expertise of the global community, supporting scientists and countries to increase ambition directed towards the inclusion of coastal Blue Carbon ecosystems in decision-making on mitigation and adaptation to climate change.

240. **Vida Manglar: Scientific and traditional mangrove knowledge in practice**

Paula Cristina Sierra-Correa, Invemar; María Claudia Diazgranados, Conservation International; Anny Paola Zamora, Invemar; Rafael Hernando Espinosa, Corporación Valles del Sinú y el San Jorge; Dalila Caicedo, Fundación Omacha

Vida Manglar is a science and community-based initiative. It is the first REDD+ project at the global level on mangroves, which seeks the certification of actions related to the reduction of 939,296 tCO_2e for 30 years and the conservation of intact wetlands of about 7645.7 ha of mangrove forests initially.

The project objective is to achieve the reduction of Greenhouse Gas (GHG) emissions through the identification, prioritization, and implementation of actions to ensure the proper management of mangroves in the area, promoting sustainable development (SDGs 5, 8, 11, 13, 14, 15) through economic and alternative initiatives, strengthening local governance, and contributing to the protection of high community conservation and biodiversity values.

Vida Manglar integrates the community with scientific knowledge and climate action, ensuring local sustainable practices. Executed in Golfo de Morrosquillo, Colombian Caribbean coast by local communities, Ministry of Environment of Colombia, CVS, CARSUCRE, INVEMAR, Fundación Omacha, and Conservation International Colombia, joining efforts to integrate the commitments of the National Development Plan 2018–2022, which established in the "Caribbean Pact" the goal of developing 6 new blue carbon initiatives throughout the Colombian Caribbean. Also private and public alliance with apple and other potential companies that acquire the bonds in the voluntary carbon market currently up for auction.

241. **The use of environmental services information by social forestry communities and forest management units to support improved forest management in Aceh, Indonesia**

Jay H. Samek, Global Observatory for Ecosystem Services, Department of Forestry, Michigan State University; Ashabul Anhar, Forestry Study Program, Faculty of Agriculture, University of Syiah Kuala; Siti Maimunah, Forestry Faculty, STIPER Agricultural Institute Yogyakarta

Devolution of forest management in Indonesia has meant the proliferation of Forest Management Units (KPH, Kesatuan Pengelolaan Hutan) for watershed scale sustainable forest management as well as forest areas under community management in the Indonesian Ministry of Environment and Forestry's (MOEF) Social Forestry program.

KPH units and social forest areas under community management are required to develop forest management plans that include actions specific to several environmental services including carbon storage and sequestration and biodiversity protection. However, challenges exist for both KPH staff and community members in accurately collecting and reporting information specific to forest carbon, biodiversity, and the various forest provisioning and cultural environmental services.

This APN-funded project focuses on training KPH staff and social forestry community members in Aceh province, Indonesia, to use Excel-based ecosystem services tools for measuring and reporting forest carbon, tree biodiversity, provisioning and cultural resources, and forest integrity and health. These tools support the inclusion of environmental services in KPH and Social Forestry village management plans.

The project contributes to mainstreaming nature-based solutions into climate change mitigation and adaptation in the following three ways:

1. Providing tools that enable the measuring, monitoring, and reporting of forest carbon, tree biodiversity and other environmental services by local people and local government agency staff;
2. Supporting the integration of environmental services data and information in forest management plans;
3. Reinforcing the importance of environmental services such as carbon storage and sequestration and biodiversity conservation and protection in valuing forest resources.

The project focuses on co-creating expertise through action-research that first recognizes local people are the experts of their forest domains. Including ways for them to understand important ecological aspects in more academic or scientific terms does not diminish or replace their knowledge but adds to it.

242. **Local perception as scientific evidence for managing blue carbon ecosystems for climate mitigation and adaptation**

Ryo Kohsaka, Nagoya University, Japan; Jay Mar D. Quevedo and Kevin Muhamad Lukman, Tohoku University, Japan; Yuta Uchiyama, Nagoya University, Japan

The blue carbon ecosystems (BCEs), the collective term for mangrove forests, seagrass meadows, and salt marshes, are gaining salience in the international arena because of their vital role in regulating the global climate through carbon sequestration process while delivering other essential diverse services (e.g., food provision and coastal protection) that enhance people's well-being.

Despite the benefits they provide, there has been a global decline resulting from natural and anthropogenic threats. When degraded or destroyed, their essential services are reduced or lost in the process, thus, there has been an increase of research investigations from different fields of the scientific community to further identify the drivers of such decline and to improve the existing understanding and management of BCEs.

Among these BCE-related studies, social and policy science assessments are still limited globally, despite being an essential part of the research and practice of BCE management relative to the natural science-related assessments. Our work highlights this gap in BCE management by conducting a perception analysis of BCEs in the Coral Triangle Region (CTR), specifically in the countries of the Philippines and Indonesia, where BCEs are among the main resource that many communities depend on, yet, are continually pressured.

Local communities have a critical role in supporting collective responses for the sustainable management of BCEs and engaging them facilitates their role in the multi-governance of ecosystems' management.[51] [52] Thus, enhancing and/or strengthening their capacities for BCE management is essential towards sustainability which in turn maximizes the delivery of benefits such as climate mitigation and adaptation.

To capacitate the local stakeholders for BCE management, it is vital to understand first how they perceive the BCEs particularly their awareness and utilization of ecosystem services. The key results of our investigations include that locals from Busuanga Island, Philippines are relatively high awareness of the ecosystem services of mangroves and seagrasses. In contrast, the awareness of respondents from Karimunjawa Island, Indonesia depends on the type of benefits.[53]

Perceptions gathered in this work also revealed the potential of BCEs for Nature-based Solutions (NbS) strategies specifically in disaster risk reduction.[54] [55] Involving key policy-makers at the local level will ensure the integration of NbS into resiliency building and decision making.[56] [57] Understanding locals' perceptions and socio-ecological characteristics can serve as a guideline to enhance local community awareness and capacity.[58]

This information can be used for the application of bottom-up 'citizen science' approaches for the BCE management which is necessary to address specific local issues and to promote sustainability and community resiliency as well as apt climate mitigation and adaptation practices in the CTR.

243. **Overview and perspectives of Nature-based Solutions in climate and biodiversity governance**

Nan Zeng and Li Huo, The Nature Conservancy (TNC); Qihui Gao, Yuanyuan Qin, and Xiang Gao, National Center for Climate Change Strategy and International Cooperation (NCSC)

This poster provides an overview of how nature-based solutions (NbS) as a critical concept is developed, further probing into perspectives of viewing its emergence in the climate and biodiversity governance at both the global and national level.

At the global level, this study examines the framing of NbS in 185 Nationally Determined Contributions (NDCs) by distinguishing mitigation- and adaptation-related NbS proposed in NDCs and mining their latent correlations.

Many countries have already incorporated NbS-related elements in their NDCs, yet these elements are still very scattered. There are rich connotations and diverse scopes of NbS for climate governance given

51 Kohsaka R, Developing biodiversity indicators for cities: applying the DPSIR model to Nagoya and integrating social and ecological aspects, Ecological Research 25(5): 025–936, (2010). DOI:10.1007/s11284-010-0746-7.

52 Uchiyama Y, Kohsaka R, Application of the City Biodiversity Index to populated cities in Japan: Influence of the social and ecological characteristics on indicator-based management. Ecological Indicators 106, 105420, (2019). https://doi.org/10.1016/j.ecolind.2019.05.051.

53 Quevedo JMD, Uchiyama Y, Lukman KM, Kohsaka R, How blue carbon ecosystems are perceived by local communities in the Coral Triangle: Comparative and empirical examinations in the Philippines and Indonesia, Sustainability 13(1): 127 (2021). https://doi.org/10.3390/su13010127.

54 Quevedo JMD, Uchiyama Y, Kohsaka R, Local perceptions of blue carbon ecosystems infrastructures in Panay Island, Philippines, Coastal Engineering Journal, (2021). https://doi.org/10.1080/21664250.2021.1888558.

55 Quevedo JMD, Uchiyama Y, Kohsaka R, Perceptions of local communities on mangrove forests, their services and management: implications for Eco-DRR and blue carbon management for Eastern Samar, Philippines, Journal of Forest Research 25(1): 1–11 (2020). https://doi.org/10.1080/13416979.2019.1696441.

56 Quevedo JMD, Uchiyama Y, Kohsaka R, A blue carbon ecosystems qualitative assessment applying the DPSIR framework: Local perspective of global benefits and contributions, Marine Policy 128: 104462 (2021). https://doi.org/10.1016/j.marpol.2021.104462.

57 Lukman KM, Quevedo JMD, Kakinuma K, Uchiyama Y, Kohsaka R, Indonesia Provincial Spatial Plans on mangroves in era of decentralization: Application of content analysis to 27 provinces and "blue carbon" as overlooked components, Journal of Forest Research 24(6): 341–348 (2019). https://doi.org/10.1080/13416979.2019.1679328.

58 Lukman KM, Uchiyama Y, Quevedo JMD, Kohsaka R, Local awareness as an instrument for management and conservation of seagrass ecosystem: Case of Berau Regency, Indonesia, Ocean & Coastal Management 203, 105451 (2021). DOI:10.1016/j.ocecoaman.2020.105451.

different national circumstances, and there also exist disparity of concerns about NbS between developed and developing countries.

To gain national-level perspectives, how NbS is compatible with China's practices of ecological civilisation is conducted as a case study. Four key challenges for mainstreaming NbS in the climate and biodiversity governance are identified:

1. Definiteness (whether NbS shall be limited to policies and actions conducive to safeguarding and enhancing ecosystems);
2. Additionality (whether NbS could deliver added values compared to available practices);
3. Balance (whether NbS could strike the de facto balance between natural and human demands);
4. Crossover (whether NbS could overcome barriers of unclear jurisdiction).

Further institutional arrangements and phase-in policy implementation are thus called for effectively framing NbS into the governance system.