Impacts, Adaptation, and Vulnerability (IPCC WG2)

6.S891/12.S992/6.S893: AI for Climate Action

Spring 2026

Speaker: Sara Beery

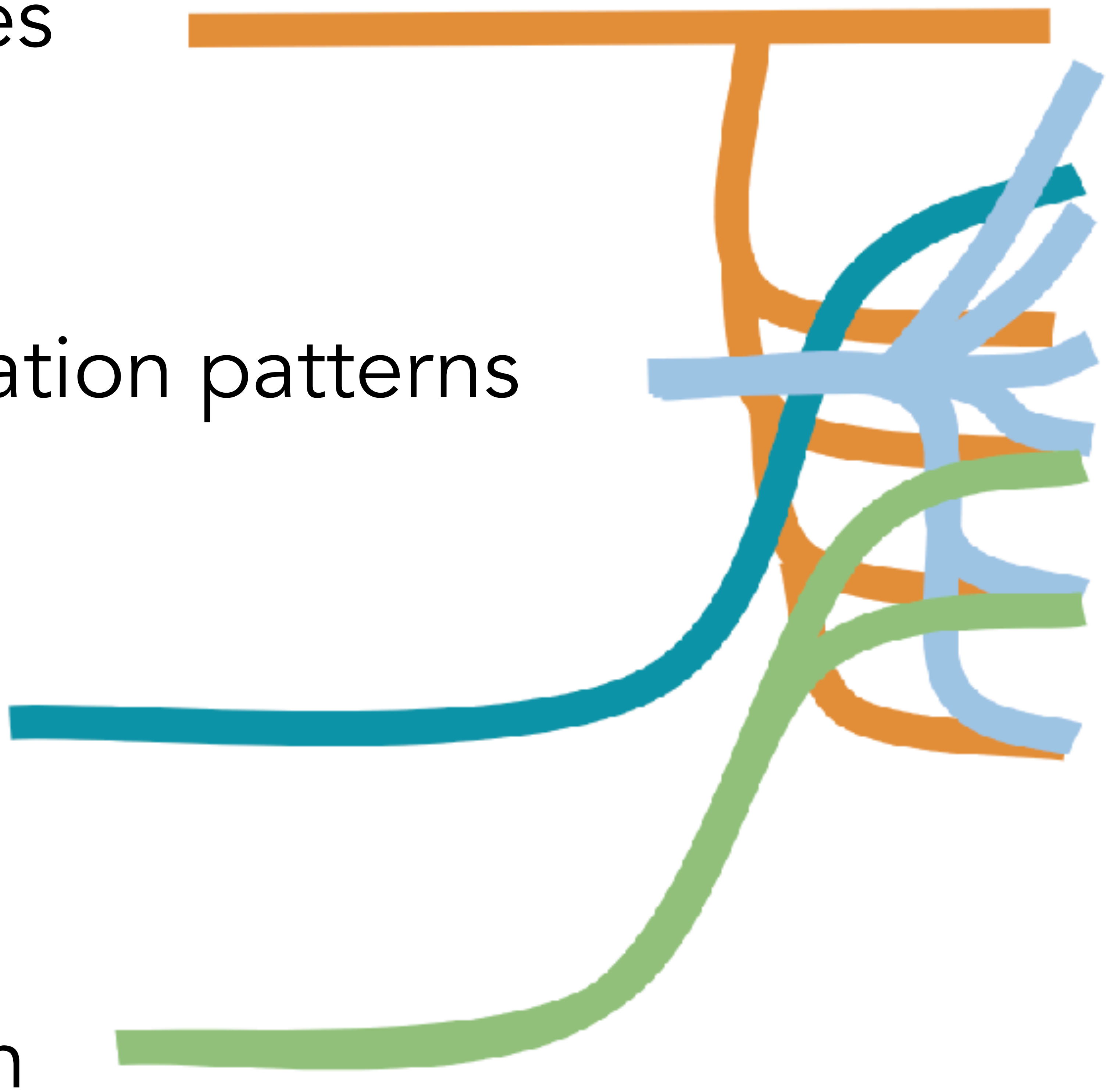
Climate change adaptation

Adaptation: Responding to the effects of a changing climate

Climate impacts and downstream effects

Climate impacts

- Rising temperatures
- Changing precipitation patterns
- Rising sea levels
- Ocean acidification



Downstream effects

- Droughts and heatwaves
- More intense storms & flooding
- More frequent wildfires
- Loss of ecosystem services
- Biodiversity loss
- Spread of disease vectors & pests

Figure adapted from Kris Sankaran

Climate change adaptation

Adaptation: Responding to the effects of a changing climate

1. Measuring and predicting risks
    - **Risk**: Impact x probability

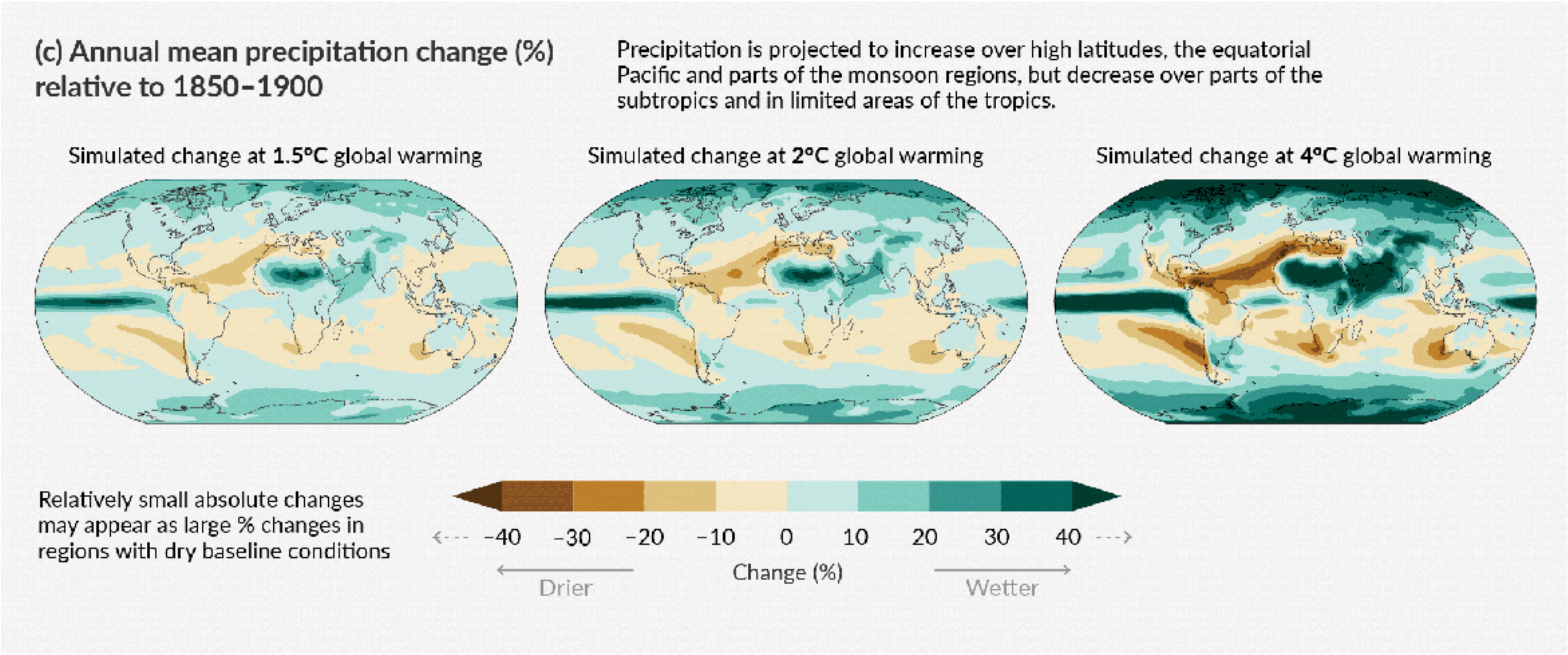


Figure source: IPCC AR6 Summary for Policymakers (2021)

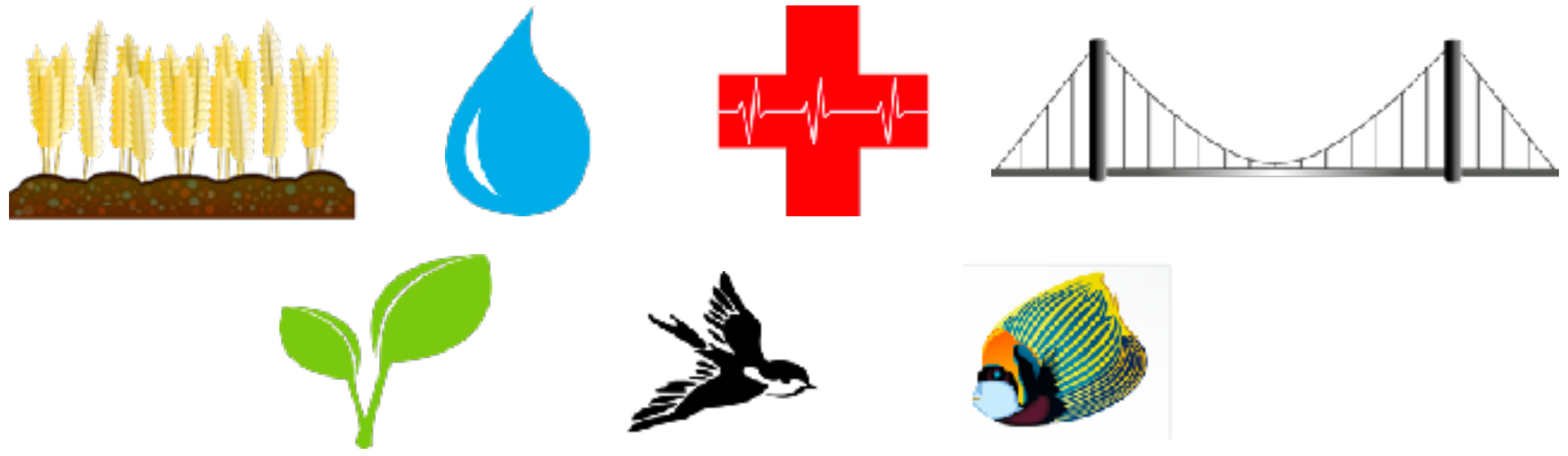
Climate change adaptation

Adaptation: Responding to the effects of a changing climate

1. Measuring and predicting risks
   - **Risk**: Impact x probability

2. Strengthening adaptive capacity
   - **Robustness:** Withstanding a range of outcomes with no/minimal impact
   - **Resilience:** Recovering quickly after impact

Human & ecological systems



Connections with UN SDGs

Figure source (bottom): United Nations

Approaches to addressing climate change

Axes of action

- **Climate science:** Understanding and predicting climate change
- **Mitigation:** Reducing or preventing greenhouse gas emissions
- **Adaptation:** Responding to the effects of a changing climate

Important frameworks

- **Co-benefits:** Explicitly considering linkages between climate action and other UN Sustainable Development Goals (SDGs)
- **Climate justice:** An equity-centered approach to climate change

From climate risk to climate resilient development: climate, ecosystems (including biodiversity) and human society as coupled systems

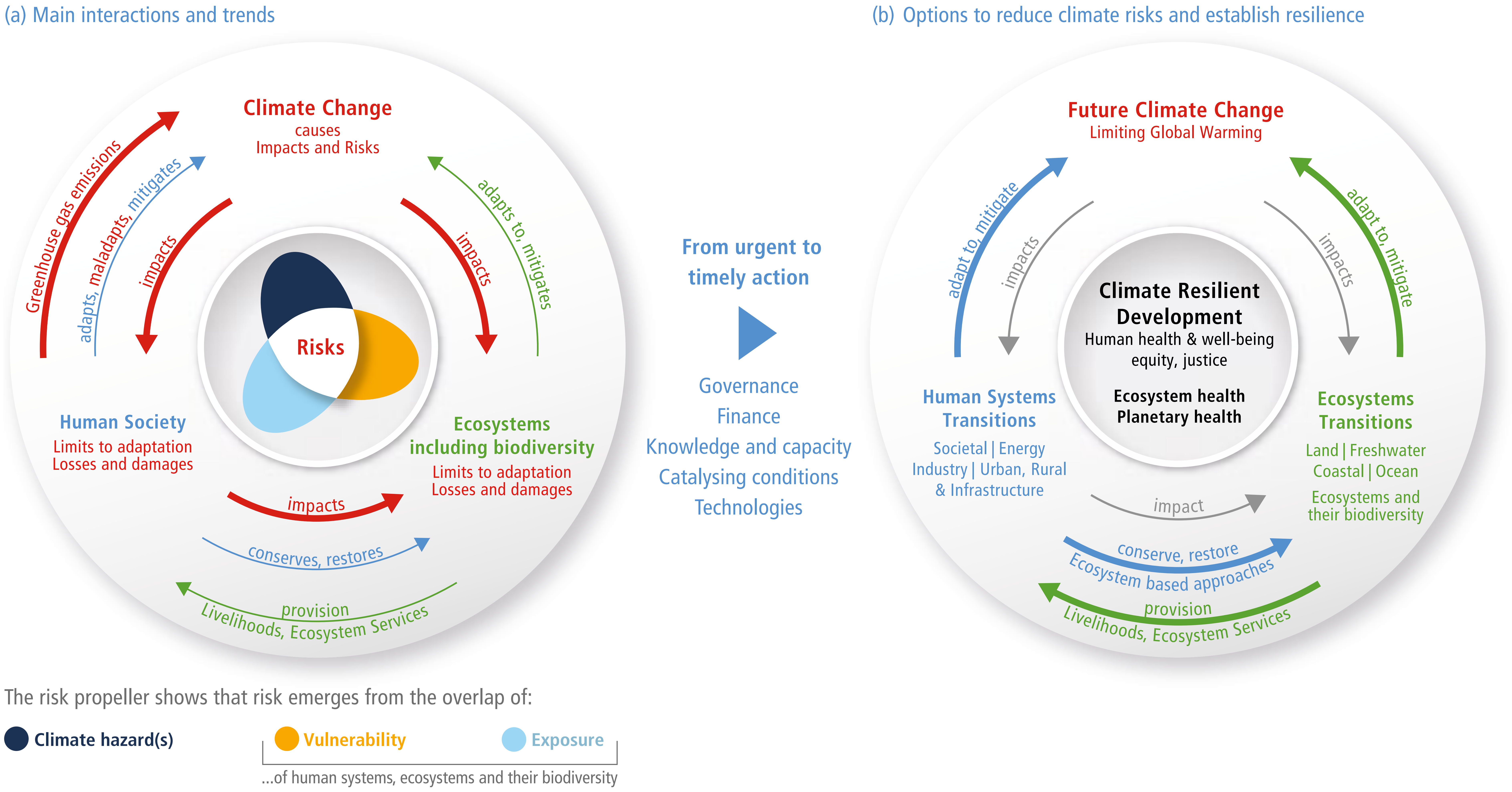


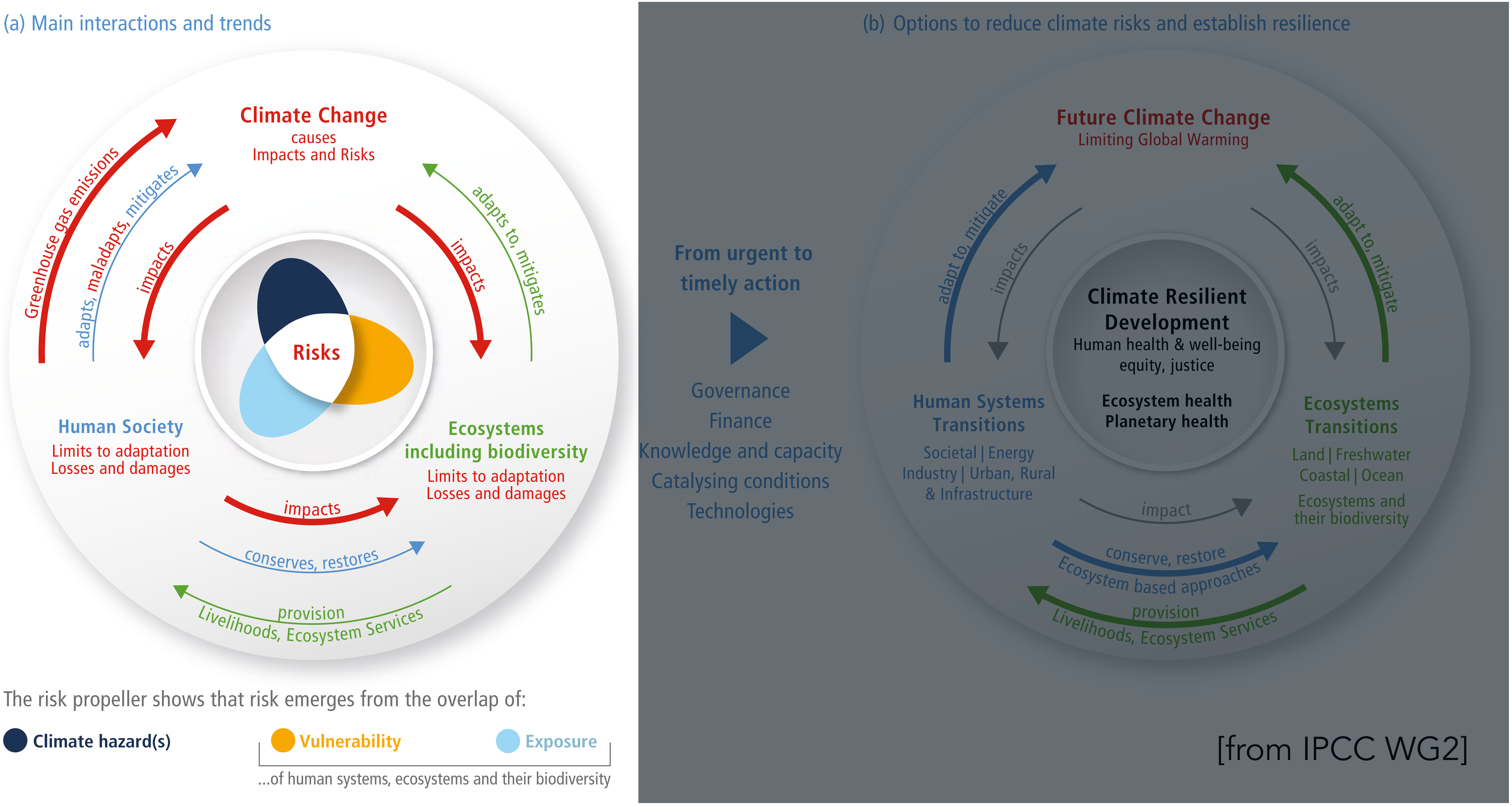
Figure SPM.1 | This report has a strong focus on the interactions among the coupled systems climate, ecosystems (including their biodiversity) and human society. These interactions are the basis of emerging risks from climate change, ecosystem degradation and biodiversity loss and, at the same time, offer opportunities for the future.

(a) Human society causes climate change. Climate change, through hazards, exposure and vulnerability generates impacts and risks that can surpass limits to adaptation and result in losses and damages. Human society can adapt to, maladapt and mitigate climate change, ecosystems can adapt and mitigate within limits. Ecosystems and their biodiversity provision livelihoods and ecosystem services. Human society impacts ecosystems and can restore and conserve them.

(b) Meeting the objectives of climate resilient development thereby supporting human, ecosystem and planetary health, as well as human well-being, requires society and ecosystems to move over (transition) to a more resilient state. The recognition of climate risks can strengthen adaptation and mitigation actions and transitions that reduce risks. Taking action is enabled by governance, finance, knowledge and capacity building, technology and catalysing conditions. Transformation entails system transitions strengthening the resilience of ecosystems and society (Section D). In a) arrow colours represent principle human society interactions **(blue)**, ecosystem (including biodiversity) interactions **(green)** and the impacts of climate change and human activities, including losses and damages, under continued climate change **(red)**. In b) arrow colours represent human system interactions **(blue)**, ecosystem (including biodiversity) interactions **(green)** and reduced impacts from climate change and human activities **(grey)**. {1.2, Figure 1.2, Figure TS. 2}

[from IPCC WG2]

From climate risk to climate resilient development: climate, ecosystems (including biodiversity) and human society as coupled systems



Outline

Climate risks: hazards, exposure, and vulnerability

How can we adapt to reduce the impact of these risks?

How can adaptation strategies go wrong?

Where does AI fit in?

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Climate risks

Hazard	Exposure	Vulnerability

Coastal Flooding

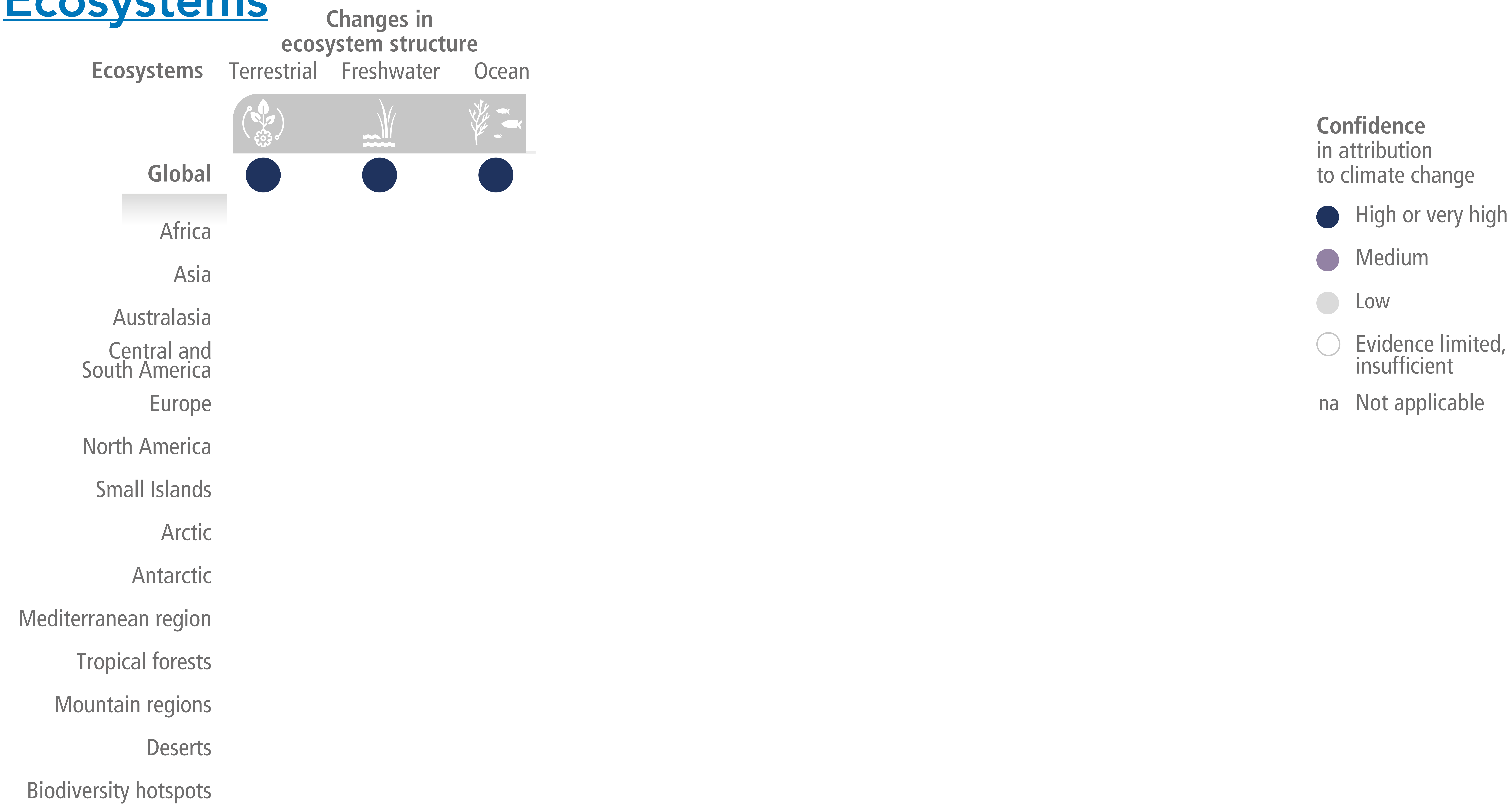
Sea Level Rise	Populations in low-elevation coastal zones	Lack of early warning systems

Observed climate impacts:

What is happening now?

Ecosystem	Human system	
• ~50% of Species ranges shifted poleward • **Irreversible changes:** extinctions, permafrost thaw	• **Food and Water:** ~50% of humans see seasonal water scarcity • **Health:** Heat-related mortality	• **Infrastructure:** Damages due to extreme weather • **Humanitarian:** Increasing climate refugees

Ecosystems



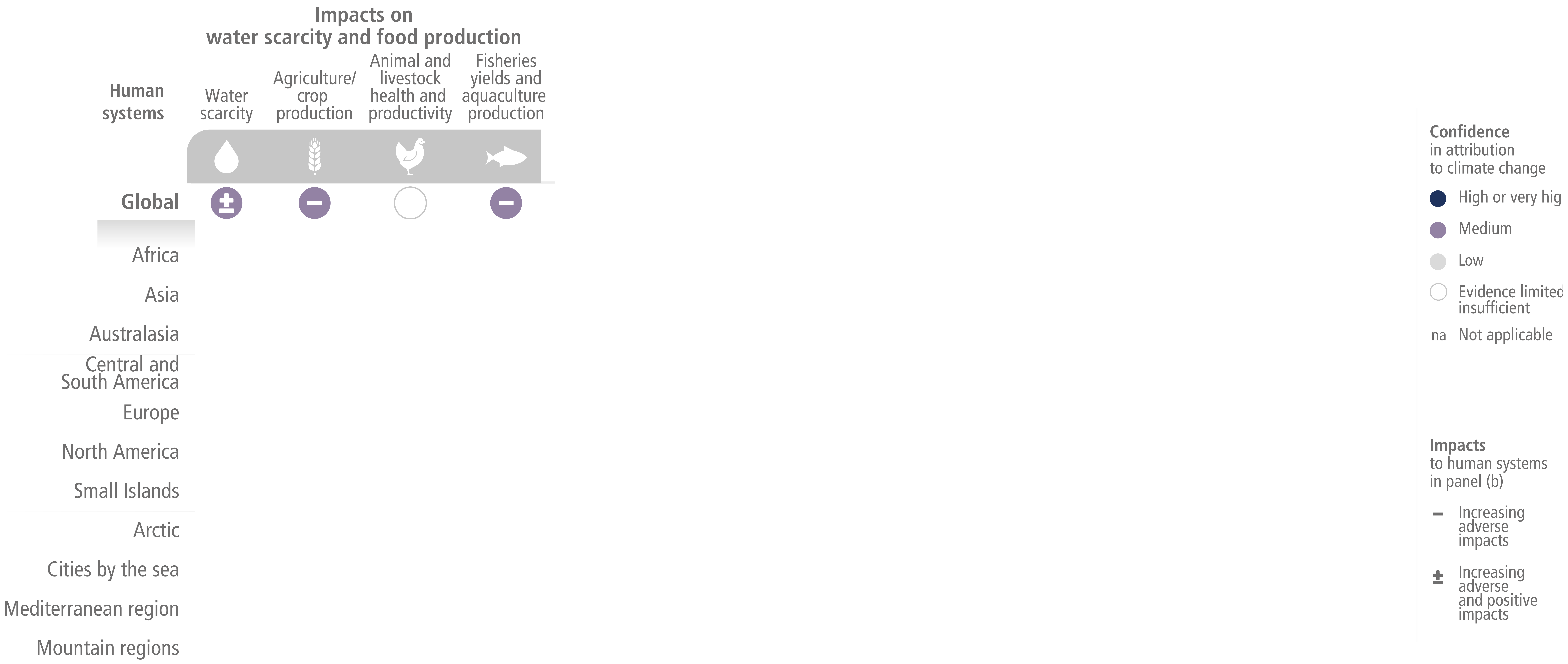
[from IPCC WG2]

Zombie forests

Forests that are "undead": their ecosystem niche no longer supports natural recruitment of key species

https://www.nytimes.com/interactive/2023/03/06/climate/california-zombie-forests.html

Human society



[from IPCC WG2]

Exposure: Who is most vulnerable?

Exposure: Who is most vulnerable?

- **Geographic hotspots:** West/Central/East Africa, South Asia, Central/South America, Small Island States, Arctic

Exposure: Who is most vulnerable?

- **Geographic hotspots**
- **Socioeconomic factors:** Poverty, weak governance, limited basic services, marginalization

Exposure: Who is most vulnerable?

- **Geographic hotspots**
- **Socioeconomic factors**
- **Intersectional vulnerabilities:** Gender, ethnicity, income, indigenous status, disability

Exposure: Who is most vulnerable?

- **Geographic hotspots**
- **Socioeconomic factors**
- **Intersectional vulnerabilities**
- **Impact: Mortality disparity** (15x in highly vulnerable regions)

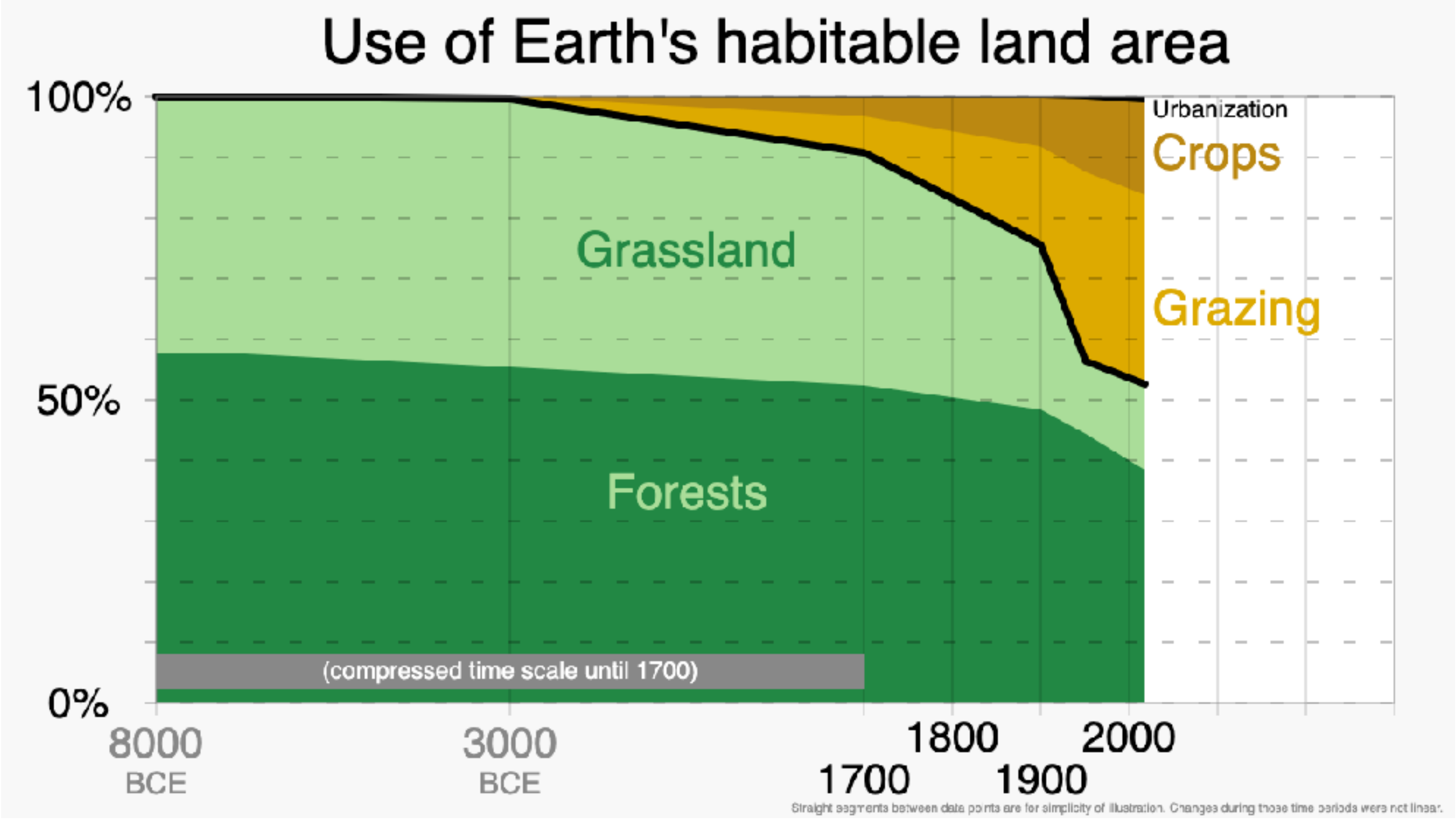
Key Vulnerability drivers

- Unsustainable resource consumption
- Ecosystem degradation and biodiversity loss
- Historical inequities and colonialism patterns
- Rapid urbanization
- Climate-sensitive livelihoods (smallholder farming, fishing, pastoralism)

Humans and Ecosystems are Interdependent

Humans and Ecosystems are Interdependent

E.g. significant change in global land use



NOAA (2016)

Projected risks

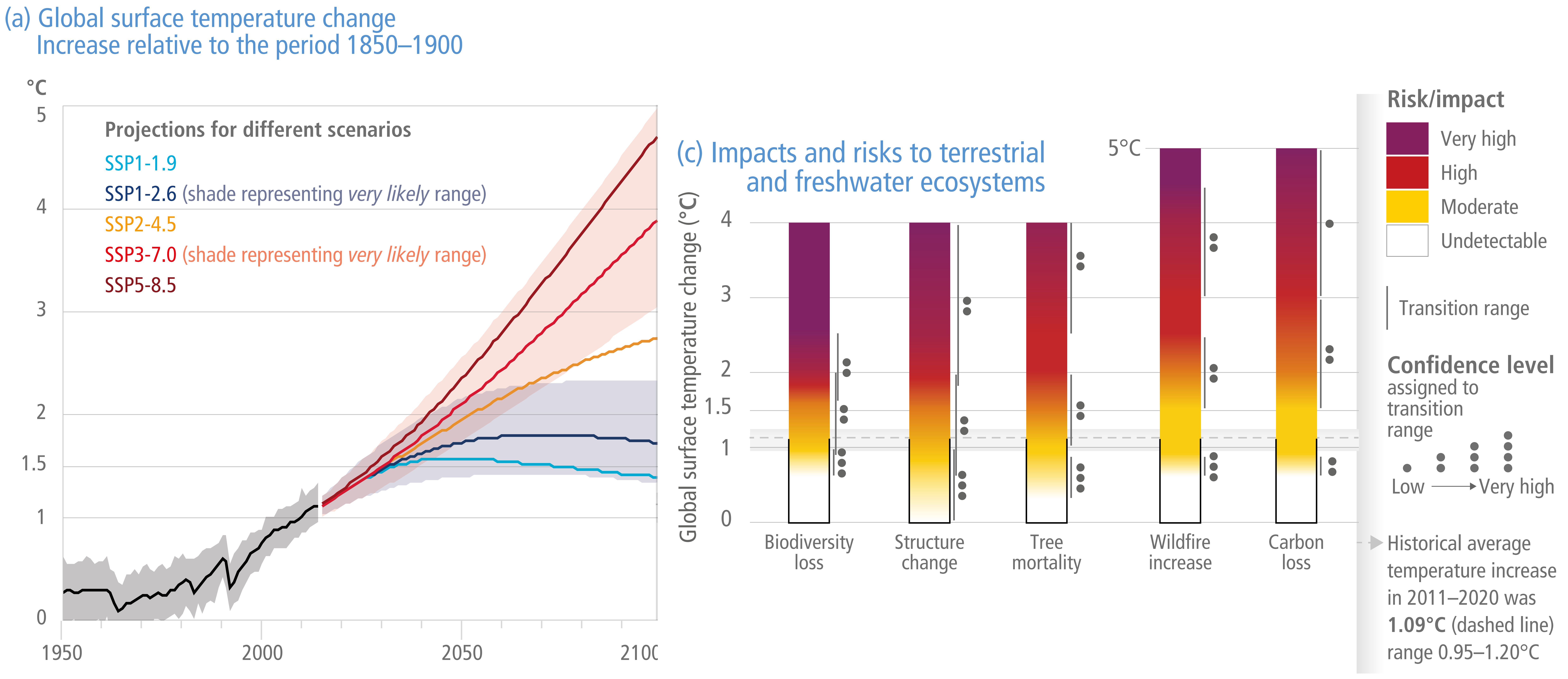
Near-term (<2040)	Long-term (>2040)

- **Global warming likely >1.5°C**
- **Biodiversity & ecostem loss**
- **Sea level rise**

- **Exponential risk magnitudes**
  - Risk escalates across sectors with every additional 0.5°C

Projected risks

Warming Level	Biodiversity Risk	Food Security	Water Stress



[from IPCC WG2]

Hazards are not independent

- Concurrent heat + drought → crop losses, tree mortality
- Sea level rise + storm surge + heavy rainfall → compounded flooding
- Heat + food production losses + labor productivity losses → malnutrition risk

Let's discuss

Compound risks: How would you design an AI system to track cascading failures across energy → water → food systems rather than predicting each independently?

Outline

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How can we adapt to reduce the impact of these risks?

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Adaptation strategies

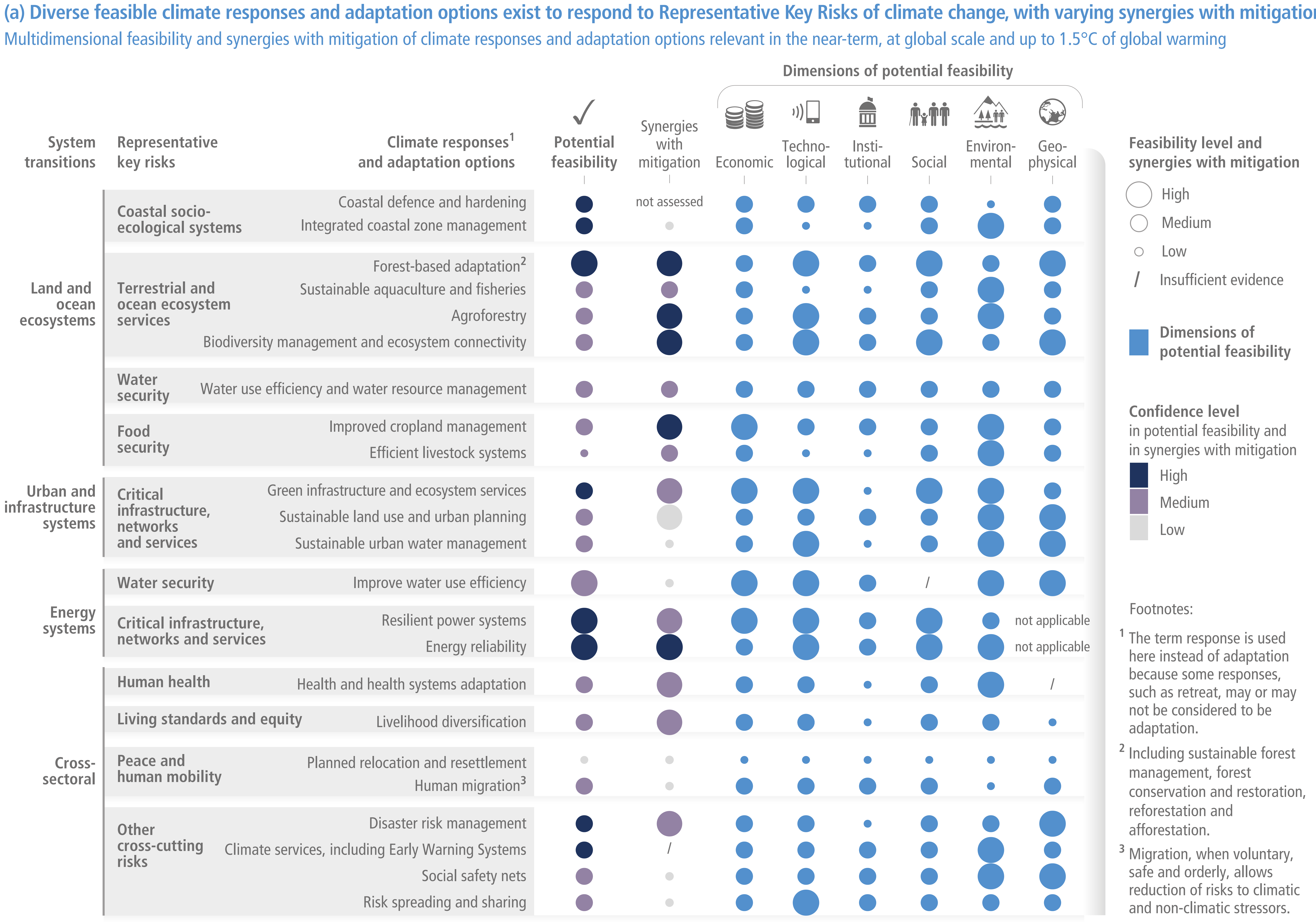

Figure SPM.4 | (a) Climate responses and adaptation options, organized by System Transitions and Representative Key Risks (RKRs), are assessed for their multidimensional feasibility at global scale, in the near term and up to 1.5°C global warming. As literature above 1.5°C is limited, feasibility at higher levels of warming may change, which is currently not possible to assess robustly. Climate responses and adaptation options at global scale are drawn from a set of options assessed in AR6 that have robust evidence across the feasibility dimensions. This figure shows the six feasibility dimensions (economic, technological, institutional, social, environmental and geophysical) that are used to calculate the potential feasibility of climate responses and adaptation options, along with their synergies with mitigation. For potential feasibility and feasibility dimensions, the figure shows high, medium, or low feasibility. Synergies with mitigation are identified as high, medium, and low. Insufficient evidence is denoted by a dash. {CCB FEASIB, Table SMCCB FEASIB.1.1, SR1.5 4.SM.4.3}

[from IPCC WG2]

Footnotes:

[1] The term response is used here instead of adaptation because some responses, such as retreat, may or may not be considered to be adaptation.

[2] Including sustainable forest management, forest conservation and restoration,

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2 Including sustainable forest management, forest conservation and restoration,

Sector	Best Options	Feasibility	Limits
Water	On-farm management, storage, wetland restoration	High (near-term)	Effectiveness declining above 1.5°C; groundwater depletion risk
Food	Agroforestry, crop diversification, urban agriculture	Medium-High	By 2°C, soft limits in tropical staple crops
Forests	Conservation, sustainable management, restoration with Indigenous cooperation	High	Must include Indigenous knowledge; hard limits above 1.5°C
Coastal	Integrated protection + accommodation + planned relocation (combined > single approach)	Medium	Hard limits if sea level rise >2-3m; cultural loss inevitable
Urban	Green infrastructure, integrated planning, nature-based solutions	High for wealthy cities; Low for informal settlements	Limited finance for most vulnerable urban residents
Energy	Renewable diversification, smart grids, demand management	High	Resilience increases with decentralization

Where are we at?

- 170+ countries now include adaptation in climate policy
- Water management adaptation is most common (dams, irrigation, early warning systems)
- Co-benefits occurring: agricultural productivity gains, improved health, biodiversity protection

Adaptation Co-benefits

(b) Climate responses and adaptation options have benefits for ecosystems, ethnic groups, gender equity, low-income groups and the Sustainable Development Goals

Relations of sectors and groups at risk (as observed) and the SDGs (relevant in the near-term, at global scale and up to 1.5°C of global warming) with climate responses and adaptation options

Footnotes: [1] The term response is used here instead of adaptation because some responses, such as retreat, may or may not be considered to be adaptation. [2] Including sustainable forest management, forest conservation and restoration, reforestation and afforestation. [3] Migration, when voluntary, safe and orderly, allows reduction of risks to climatic and non-climatic stressors. [4] The Sustainable Development Goals (SDGs) are integrated and indivisible, and efforts to achieve any goal in isolation may trigger synergies or trade-offs with other SDGs. [5] Relevant in the near-term, at global scale and up to 1.5°C of global warming.

[from IPCC WG2]

Observed relation with sectors and groups at risk
Relation with Sustainable Development Goals[4, 5]
System transitions
Climate responses[1] and adaptation options
Ecosystems and their services
Ethnic groups
Gender equity
Low-income groups
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Land and ocean ecosystems
Coastal defence and hardening
Integrated coastal zone management
Forest-based adaptation[2]
not assessed
Sustainable aquaculture and fisheries
Agroforestry
not assessed
Biodiversity management and ecosystem connectivity
Water use efficiency and water resource management
Improved cropland management
Efficient livestock systems
not assessed
Urban and infrastructure systems
Green infrastructure and ecosystem services
Sustainable land use and urban planning
Sustainable urban water management
not assessed
Energy systems
Improve water use efficiency
Resilient power systems
not assessed
Energy reliability
not assessed
Health and health systems adaptation
Livelihood diversification
Cross-
Planned relocation and resettlement
Types of relation
+ With benefits
− With dis-benefits
• Not clear or mixed
/ Insufficient evidence
Confidence level in type of relation with sectors and groups at risk
High
Medium
Low
Related Sustainable Develop
1: No Poverty
2: Zero Hunger
3: Good Health and Well-bei
4: Quality Education
5: Gender Equality
6: Clean Water and Sanitatio
7: Affordable and Clean Ener
8: Decent Work and Econom
9: Industry, Innovation and I
10: Reducing Inequality

System transitions	Climate responses[1] and adaptation options	Ecosystems and their services	Ethnic groups	Gender equity	Low-income groups	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		Observed relation with sectors and groups at risk				Relation with Sustainable Development Goals[4, 5]																
Land and ocean ecosystems	Coastal defence and hardening	– (Medium)	/	– (Medium)	– (Low)			+						+	–	•		■	•	•		
	Integrated coastal zone management	• (Low)	/	• (Medium)	/	+		+	+	+			+			+		■	+	+	+	+
	Forest-based adaptation[2]	not assessed				+	•	+		+	+	+	+	+	+	+	+	■		+		
	Sustainable aquaculture and fisheries	+ (High)	+ (Low)	+ (Medium)	+ (High)	+	+	+		+	+		+	+	+	+	+	■	+	+		
	Agroforestry	not assessed				+	+	+		+	+	+	+		+	+	+	■		+		+
	Biodiversity management and ecosystem connectivity	+ (High)	/	/	– (Low)			+			+					+	+	■		+		
	Water use efficiency and water resource management	+ (Medium)	• (Medium)	• (Medium)	• (Medium)			+		•	+	•			•	+	+	■		+	•	
	Improved cropland management	+ (High)	+ (Low)	+ (Medium)	+ (High)	+	+	+		+	+	+	+	+	•		+	■		+	+	+
	Efficient livestock systems	not assessed				+	+	+		•			+	+			+	■		+		
Urban and infrastructure systems	Green infrastructure and ecosystem services	+ (High)	/	+ (Low)	+ (Medium)			+			+		+	+	+	+	+	■				
	Sustainable land use and urban planning	+ (Medium)	• (Medium)	• (Medium)	• (Medium)			+			+		+	+	+	+		■				
	Sustainable urban water management	not assessed						+			+		+	+	+	+		■				
Energy systems	Improve water use efficiency	+ (Medium)	/	• (Medium)	• (Low)	+	+	+	+	+	+	+			+			■		+		
	Resilient power systems	not assessed				+	+	+	+	+	+	+			+			■				
	Energy reliability	not assessed				+	+	+	+	+	+	+			+			■				
Cross-	Health and health systems adaptation	• (Medium)	• (Medium)	+ (Medium)	+ (Medium)	+	+	+	+	+	+	+	+		+	+	+	■	+	+	+	+
	Livelihood diversification	+ (Low)	/	• (Low)	• (Low)	+	+	+	+	•	•	•	•	•	–	–	•	■		•		
	Planned relocation and resettlement	+ (Medium)	• (Low)	• (Medium)	• (Medium)													■			•	

Types of relation

- \+ With benefits
- – With dis-benefits
- • Not clear or mixed
- / Insufficient evidence

Confidence level in type of relation with sectors and groups at risk

- High
- Medium
- Low

Related Sustainable Develop

1: No Poverty
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Critical Adaptation Gaps

- **Scale mismatch**: Most adaptation is fragmented, small-scale, reactive to current impacts
- **Finance crisis**: Global tracked adaptation finance is ~$25-50B/year but needs are 5-10x higher
- **Inequality**: Wealthiest regions receiving disproportionate adaptation finance; poorest most underfunded
- **Speed gap**: Long implementation times vs. rapidly accelerating climate change

What facilitates adaptation?

- Political commitment
- Institutional frameworks
- Knowledge and Capacity
- Finance
- Monitoring and evaluation
- Inclusive governance

Successful river basin management requires:

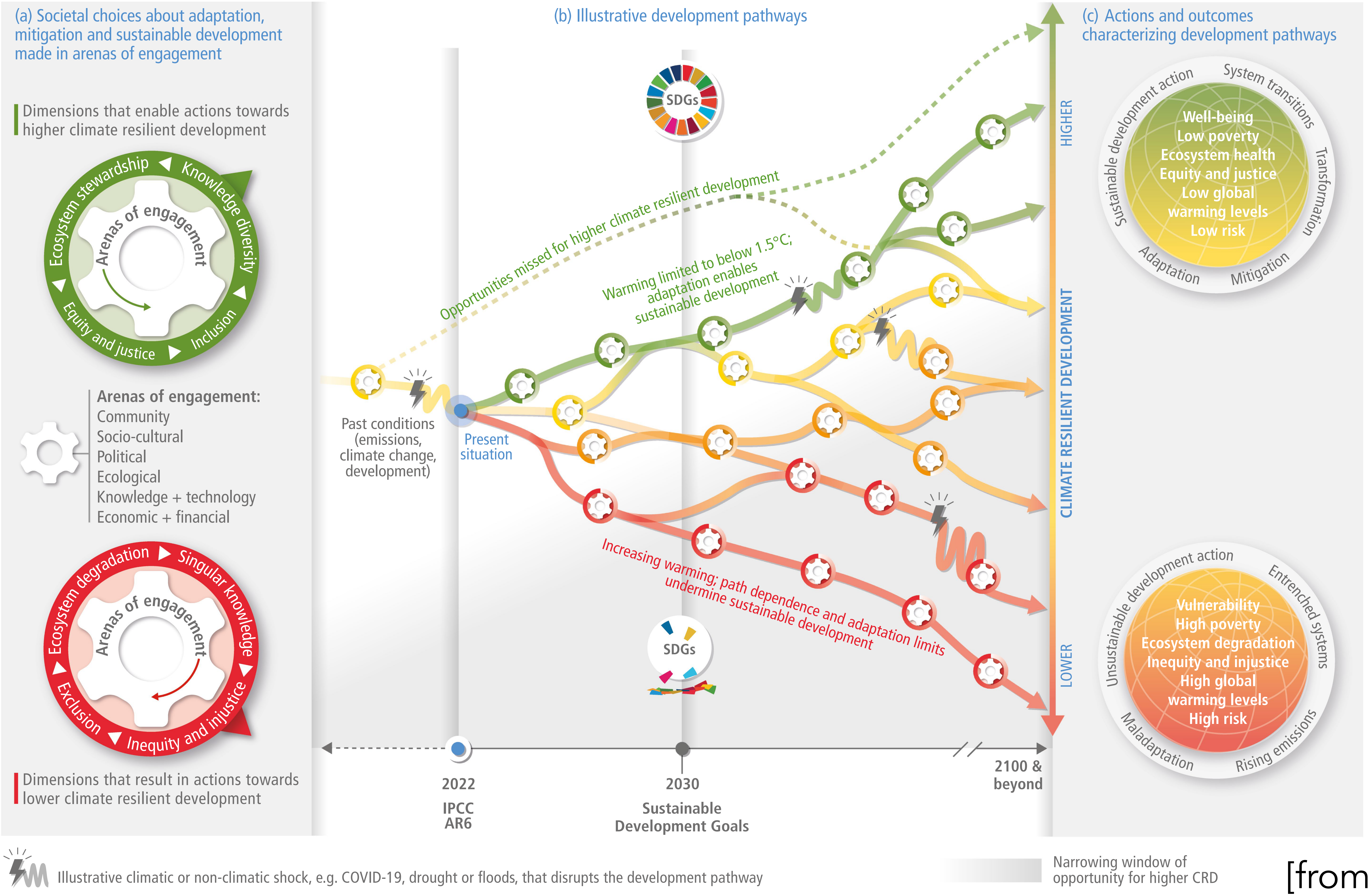
- Upstream-downstream coordination (governance)
- Water use data (knowledge)
- Finance for infrastructure + inclusive decision-making (farmer participation)
- Monitoring of outcomes

Climate resilient development

A framework to integrate mitigation and adaptation for sustainable development

- **Energy**: Renewable, decentralized, resilient systems
- **Land**: Sustainable use, forest conservation/restoration, biodiversity protection
- **Ocean/Coastal**: Ecosystem restoration, sustainable fisheries, marine protection
- **Urban/Rural**: Integrated planning, equitable infrastructure, climate-informed design
- **Industry & Society**: Circular economy, just transitions, equity-centered development

There is a rapidly narrowing window of opportunity to enable climate resilient development



[from IPCC WG2]

Case study: CRD in East Africa

1. Reduce drought risk through water harvesting (adaptation) + improved irrigation efficiency
2. Transition away from fossil fuels + support renewable energy (mitigation)
3. Restore pastoral livelihoods + guarantee land rights for pastoralists (development + equity)
4. Protect 30% of ecosystems for biodiversity + carbon storage

30x30

[from IUCN]

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Maladaption

- **Short-term focus**: Isolated sector actions without long-term consideration
- **Lock-ins**: Inflexible infrastructure creating future vulnerability (e.g., seawalls)
- **Ecosystem harm**: Fire suppression in fire-adapted ecosystems, hard flood defenses
- **Inequality amplification**: Actions harming marginalized groups; reinforcing disparities

Trillion trees and the complexity of carbon sequestration

In 2019, a *Science* paper estimates there is space outside of urban and agricultural areas on Earth to plant 1 trillion more trees, resulting in additional capture of 205 Gigatons of carbon.

Stop Planting Trees, Says Guy Who Inspired World to Plant a Trillion Trees

Ecologist Thomas Crowther's research inspired countless tree-planting campaigns, greenwashing, and attacks from scientists. Now he's back with a new plan for nature restoration.

https://www.wired.com/story/stop-planting-trees-thomas-crowther/

Solar geoengineering

"Cool the planet" by increasing the Earth's albedo (reflectivity)

- E.g., Release stratospheric aerosols to increase reflectance for a few years

Viewed as last resort: Uncertainty, moral hazard, termination shock, governance

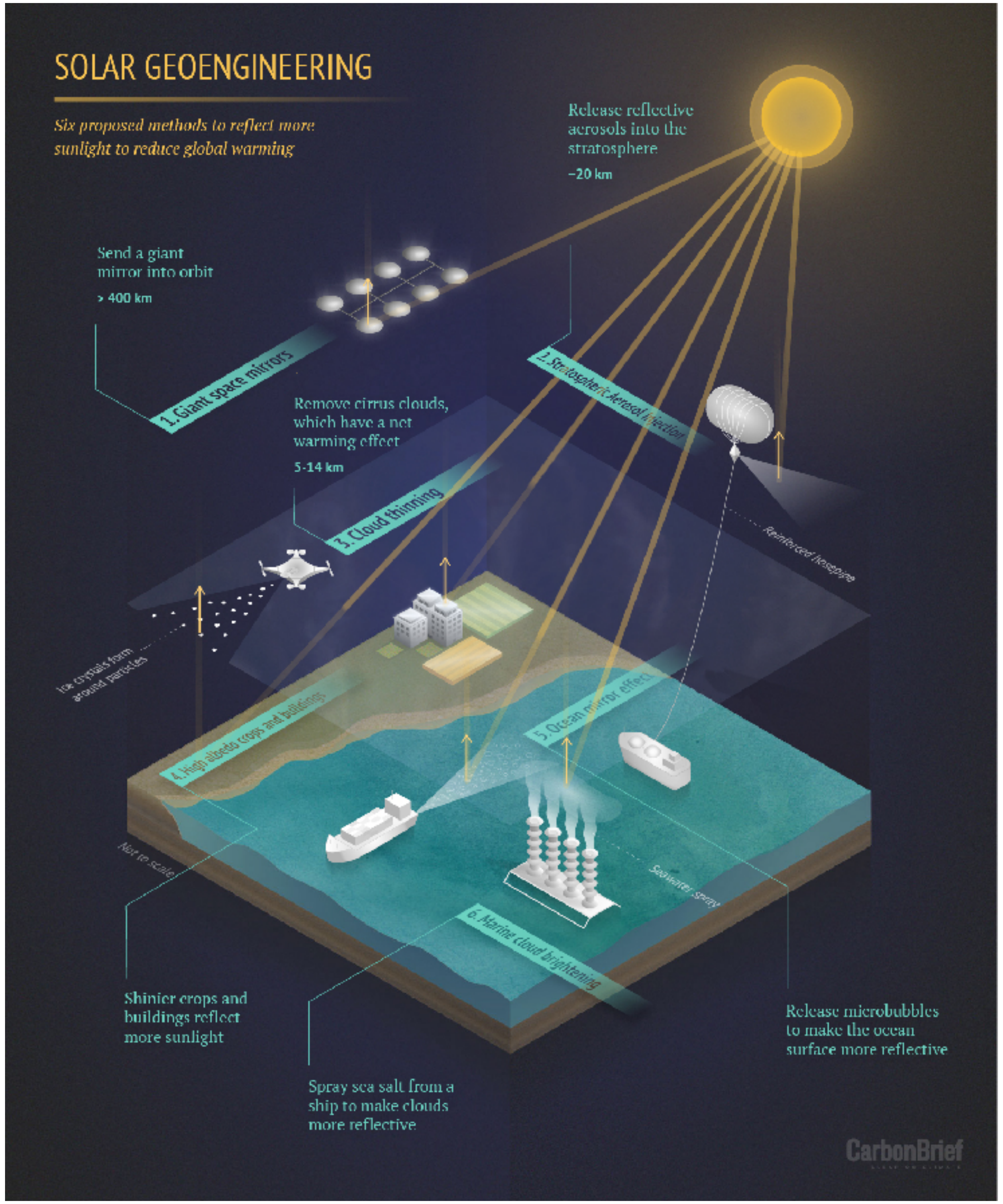

Figure source: CarbonBrief.org

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- **Early warning systems**: Real-time hazard detection for floods, heat waves, wildfires
- **Climate services**: Downscaled climate projections informing agricultural/water decisions
- **Adaptive decision support**: Tools accounting for uncertainty and multi-sectoral trade-offs
- **Monitoring adaptation**: Remote sensing + ML for tracking ecosystem restoration, coastal protection effectiveness

Where could AI hurt?

- **Data inequality**: AI models trained on data-rich regions; perform poorly for vulnerable regions with least data
- **Maladaptation risk**: AI optimizing for short-term outcomes (e.g., maximum yield) without long-term impacts (soil depletion)
- **Equity risk**: AI-driven decisions can embed/amplify existing inequities if not carefully designed
- **Limits recognition**: AI must know when hard limits are reached; not all problems are solvable

Recap

- Impacts are accelerating
- Vulnerability is unequal, and the most vulnerable are often the least responsible
- Adaptation is necessary but insufficient
- Decade-scale decisions determine century-scale outcomes
- System transitions necessary
- Equity is essential for CRD
- AI has potential to help and to hurt