TSSM

Technical Summary Supplementary Material

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Table of Contents

SMTS.1 Figure TS.3/SPM.2 Observed Impacts of Climate Change: Methodology and Line of Sight to Chapters and Papers

Figure TS.3/SPM.2 displays a synthesis of observed regional and global impacts of climate change on ecosystems (TS.3a/SPM.2a) and human systems (TS.3b/SPM.2b). Regional assessments are primarily based on the expert assessments in the regional chapters (Chapters 9–15) and cross-chapter papers (CCPs 1–7). The global assessment is provided by the ecosystem sectoral chapters (Chapters 2 and 3) and observed impacts on human systems by Chapters 4–8 and CCP2. In Figure TS.3/SPM.2 confidence is provided in attribution of the observed impacts to climate change as defined in AR5 Chapter 18 and Cross-Chapter Box (CCB) ATTRIB in WGII AR6 Chapter 1.

Panel a – ecosystems

Observed impacts on 'changes in ecosystem structure', on 'species range shifts' and on 'changes in timing (phenology)' were assessed separately for terrestrial, freshwater and ocean ecosystems. Here, the observation of an impact (i.e. whether detected or not) and the confidence with which the observation can be attributed to climate change are shown. In panel (a), global assessments often focus on large studies, multi-species, meta-analyses and large reviews. For that reason they can reach higher confidence than regional studies, which often use smaller studies that have limited data in order to provide regional examples. References to the underlying evidences in chapters and cross-chapter papers are provided in Table SMTS.1.

Panel b – human systems

Observed impacts have been assessed within the three overarching categories 'water scarcity and food production' (including water scarcity, agriculture/crop production, animal and livestock health and productivity and fisheries yields and aquaculture production), 'health and well-being' (including infectious diseases, heat, malnutrition and other diseases, mental health as well as displacement) and 'cities, settlements and infrastructure' (including inland flooding and associated damages, flood/storm induced damages in coastal areas, damages to infrastructure and damages to key economic sectors). Here, not only confidence levels are shown but also the direction of observed impacts, i.e. whether increasing adverse impacts or adverse and positive impacts have been observed within a region. In panel (b) the global assessment is the overall global outcome. Exclusively positive impacts have not been observed in any of the categories. References to the underlying evidences in chapter and cross-chapter papers are provided in Table SMTS.2.

An additional, more detailed synthetic assessment of observed impacts is provided in WGII AR6 Chapter 16, Figure 16.2 (see also SM16.7, Table SM16.7.2). Figure 16.2 is both more precise (splitting attribution) and more generic (including weather sensitivity and climate attribution, whereas Figure TS.3/SPM.2 just focuses on impact attribution). It separates the identification of weather sensitivity (observed influence of fluctuations in the climate-related systems on natural, human or managed systems) (also listed in Table SM16.7.3) from impact attribution (observed impact of long-term changes in the climate-related system on natural, human or managed systems) (also listed in Table SM16.7.2) and climate attribution (observed impacts of anthropogenic climate forcing on climate-related systems, generally provided by WGI) (also listed in Table SM16.7.1). Figure TS.3/SPM.2 focuses on impact attribution, sometimes also based on a combination of weather sensitivity and climate attribution. Some thematic and regional chapters include additional attribution assessments sometimes without this specific separation; this additional information is also reflected in Figure TS.3/SPM.2.

SMTS.1.1 Panel (a): Ecosystems

Table SMTS.1 | Chapter and cross-chapter paper (CCP) sections, boxes, tables and figures supporting the assessment of observed impacts shown in Figure TS.3 and Figure SPM.2, panel (a): Ecosystems. n.a.: not applicable. - : no line of sight because not applicable, not assessed or evidence limited/insufficient

	ECOSYSTEMS								
	Terrestrial			Freshwater			Ocean		
	Changes in ecosystem structure	Species range shifts	Changes in timing	Changes in ecosystem structure	Species range shifts	Changes in timing	Changes in ecosystem structure	Species range shifts	Changes in timing
Global	*High confidence*	*Very high confidence*	*Very high confidence*	*High confidence*	*Very high confidence*	*Very high confidence*	*High confidence*	*High confidence*	*High confidence*
	2.4.3.1– 2.4.3.9, Box 2.1, Figure Box 2.1.1, Table 2.5	2.4.2, Table 2.2, Table SM2.1	2.4.2, Table 2.2, Table 2.S. 1	2.4.2.2, 2.4.2.3, 2.4.2.7	2.4.2.3, 2.4.2.7	2.4.2.2, 2.4.2.3, 2.4.2.7	3.4.2.1–3.4.2.3, 3.4.2.5, 3.4.3.3, Box 3.2	3.4.2.3–3.4.2.5, 3.4.2.8, 3.4.2.10, 3.4.3.4, Box 3.2	3.4.2.6, 3.4.2.8, 3.4.3.2, Box 3.2, Table 3.19
Africa	*High confidence*	*High confidence*	Evidence limited/ insufficient	*High confidence*	Evidence limited/ insufficient	*Low confidence*	*High confidence*	*High confidence*	*Low confidence*
	Figure 9.17	9.6.1	–	9.6.1	–	9.6.1	9.6.1	9.6.1	9.6.1
Asia	*High confidence*	*Low confidence*	*Low confidence*	*Medium confidence*	*Medium confidence*	*Low confidence*	*High confidence*	Evidence limited/ insufficient	*Medium confidence*
	2.4.3.2.1, Box 2.1, Table Box 2.1, Table 2.S. 5	10.4.2.1	10.4.2.1	2.4.2.3.1, 10.4.2	2.4.2.1, 2.4.2.7.2, 10.4.2.1.2	2.4.2.1, Table 2.2	10.4.3	–	10.4.3
Australasia	*High confidence*	*High confidence*	*High confidence*	Evidence limited/ insufficient	Evidence limited/ insufficient	Evidence limited/ insufficient	*High confidence*	*High confidence*	*Low confidence*
	11.3.1.1, Table 11.2	11.3.1.1, Table 11.2	11.3.1.1, Table 11.2	–	–	–	Table 11.6	Table 11.6	11.3.4.4
Central and South America	*High confidence*	*Very high confidence*	Evidence limited/ insufficient	*High confidence*	*High confidence*	Evidence limited/ insufficient	*High confidence*	*High confidence*	*Low confidence*
	12.3.3.4, 12.3.4.2, 12.3.4.4, 12.3.7.2	12.3.1.4, 12.3.2.3, 12.3.2.4, 12.3.4.2, 12.3.6.2, 12.3.7.2, 12.3.8.4	–	12.3.2.4, 12.3.4.4, 12.3.5.2, 12.4	2.4.2.7.1 (Case Study 2: chytrid)	–	12.3, 12.5.2, Figure 12.8, Figure 12.9, Table SM12.3	Table SM12.3	Table SM12.3
Europe	*High confidence*	*High confidence*	*High confidence*	*High confidence*	*High confidence*	*High confidence*	*High confidence*	*High confidence*	*High confidence*
	13.3.1, 13.4.1, Figure 13.9	13.3, Figure 13.9	13.3, Figure 13.9	13.3, Figure 13.9	13.3, Figure 13.9	13.3, Figure 13.9	13.4.1, Figure 13.12	Figure 13.12	Table 13.12
North America	*Very high confidence*	*Very high confidence*	*Very high confidence*	*Very high confidence*	*Very high confidence*	*High confidence*	*High confidence*	*High confidence*	*High confidence*
	14.5.1	14.5.1	14.5.1	14.5.1	14.5.1	2.4.2.4	14.5.2	14.5.2	14.5.2
Small islands	*High confidence*	*High confidence*	*High confidence*	*High confidence*	*High confidence*	Evidence limited/ insufficient	*High confidence*	*High confidence*	*Medium confidence*
	15.3.3.3, CCP1.2.2	15.3.3.3, CCP1.2.2	15.3.3.3, CCP1.2.2	15.3.3.2	2.4.2.2	–	3.4.2.1, 15.3.3.1, 15.3.4.4	3.4.2, 3.4.3, 15.3.4.4, 15.3.4.8, 15.4	3.2.2.3, 3.4.2, 3.4.3
Biodiversity hotspots	*High confidence*	*High confidence*	*High confidence*	Evidence limited/ insufficient	Evidence limited/ insufficient	Evidence limited/ insufficient	*High confidence*	*High confidence*	Not assessed
	CCP1.2.2.1	CCP1.2.2.1	CCP1.2.2.1	–	–	–	CCP1.2.4.1	CCP1.2.4.1	–

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	ECOSYSTEMS								
	Terrestrial			Freshwater			Ocean		
	Changes in ecosystem structure	Species range shifts	Changes in timing	Changes in ecosystem structure	Species range shifts	Changes in timing	Changes in ecosystem structure	Species range shifts	Changes in timing
Deserts	*High confidence*	*High confidence*	Evidence limited/ insufficient	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Table SM2.1	2.4.2.5	–	–	–	–	–	–	–
Mediterra-nean region	*High confidence*	*High confidence*	*High confidence*	Evidence limited/ insufficient	*Medium confidence*	Evidence limited/ insufficient	*High confidence*	*High confidence*	*Medium confidence*
	Table SMCCP4.1	Table SMCCP4.1	13.3.1.1	–	13.3.1.1	–	Table SMCCP4.1	13.4.1.1, Table SMCCP4.1	3.4.2, CCP4.1.4
Mountain regions	*High confidence*	*High confidence*	*High confidence*	*Medium confidence*	*Medium confidence*	*Low confidence*	n.a.	n.a.	n.a.
	CCP5.2.1, Figure CCP5.4, SMCCP5.2.2, Table SMCCP5.7, SROCC 2.3.3.1	CCP5.2.1, Figure CCP5.4, SMCCP5.2.2, Table SMCCP5.7, SROCC 2.3.3.1	CCP5.2.3, CCP5.3.1, CCP5.3.2.3	2.4.2.1, SROCC 2.3.3.2	2.4.2.1, SROCC 2.3.3.2	CCP5.2.1, CCP5.2.7	–	–	–
Arctic	*High confidence*	*High confidence*	*High confidence*	*Medium confidence*	*High confidence*	*Medium confidence*	*High confidence*	*High confidence*	*High confidence*
	2.4.3.5, 2.4.3.9, Box 2.1, Table Box 2.1, Table 2.S. 5, Table CCP6.2	CCP6.2.2, Table CCP6.2	2.4.2.1, 2.4.2.7, 2.4.3.9, Table 2.2;	2.4.4.1	2.4.2.7.2	CCP6.2, Table CCP.6.2	CCP6.2.1.1, CCP6.2.1.4, Table CCP6.2	CCP6.2.1.1, CCP6.2.1.2, Table CCP6.2	CCP6.2.1.1, CCP6.2.1.2, Table CCP6.2
Antarctic	*Medium confidence*	*Medium confidence*	*Medium confidence*	Evidence limited/ insufficient	Evidence limited/ insufficient	Evidence limited/ insufficient	*Medium confidence*	*Medium confidence*	*Evidence limited/ insufficient*
	CCP6.2.2, Table CCP6.2	CCP6.2.2, Table CCP6.2	Table 2.2a	–	–	–	CCP6.2.2, Table CCP6.2	CCP6.2.2.1, Table CCP6.2	–
Tropical forests	*High confidence*	*Medium confidence*	Evidence limited/ insufficient	Evidence limited/ insufficient	Evidence limited/ insufficient	Evidence limited/ insufficient	n.a.	n.a.	n.a.
	CCP7.3, CCP7.5.1	CCP7.3.4, Table CCP7.3	–	–	–	–	–	–	–

SMTS.1.2 Panel (b): Human Systems

Table SMTS.2 | Chapter and cross-chapter paper (CCP) sections, boxes, tables and figures supporting the assessment of observed impacts shown in Figure TS.3 and Figure SPM.2, panel (b): Human Systems. n.a.: not applicable . - : no line of sight because not applicable, not assessed or evidence limited/insufficient

	HUMAN SYSTEMS											
	Water scarcity and food production				Health and well-being				Cities, settlements and infrastructure			
	Water scarcity	**Agriculture/ crop production**	**Animal and livestock health and productivity**	**Fisheries yields and aquaculture production**	**Infectious diseases**	**Heat, malnutrition and other**	**Mental health**	**Displacement**	**Inland flooding and associated damages**	**Flood/storm induced damages in coastal areas**	**Damages to infrastructure**	**Damages to key economic sectors**
	(e.g., water availability in general, groundwater, water quality, demand for water, drought in cities)	(global assessment for agricultural production is based on the impacts on global aggregated production)	(e.g., heat stress, diseases, productivity, mortality)	(includes marine and freshwater fisheries/ production)	(e.g., water-borne and vector-borne diseases)	(e.g., human heat-related morbidity and mortality, labour productivity, harm from wildfire, nutritional deficiencies)	(includes impacts from extreme weather events, cumulative events, and vicarious or anticipatory events)	(refers to evidence of displacement attributable to climate and weather extremes)	(e.g., river overflows, heavy rain, glacier outbursts, urban flooding)	(includes damages due to, e.g., cyclones, sea level rise, storm surges)	(observed impacts related to an attributable mean or extreme climate hazard or directly attributed)	(includes standard classifications and sectors of importance to regions)
Global	Adverse and positive impacts, *medium confidence*	Adverse impacts, *medium confidence*	Evidence limited/ insufficient	Adverse impacts, *medium confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *medium confidence*
	4.2.5–4.2.7, 4.3.1–4.3.3, Box 4.1, Table SM4.3, Figure TS FOOD–WATER	5.2.1, 5.4.1	–	5.8.1, SROCC SPM A.5.4	2.4.2.7, 4.3.3, 7.2.2, Box 7.3, Table 7.1, CCB ILLNESS	7.2.3–7.2.5, Table 7.1, 8.2.1, 8.3.2, 8.3.4, Box 8.6	3.5.6, Figure 3.23, 4.3.3, 4.3.8, 7.2.5, 7.2.5.2, Table Box 7.2.1	6.2.3.3, 7.2.6, 8.2.1.3, CCB MIGRATE	4.2.4, Table SM4.3, CCP2.2, SMCCP2.1	6.2, CCP2.2, SMCCP2.1	6.2.5, 6.2.6, Box 6.2	6.2, CCP2.2, SMCCP2.1
Africa	Adverse impacts, *medium confidence*	Adverse impacts, *high confidence*	Adverse impacts, *low confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *limited evidence*	Adverse impacts, *high confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *high confidence*
	Table SM4.3, 9.5.2, 9.5.6, 9.7.1, Box 9.4	9.2, 9.8.1, 9.8.2	9.8.1, 9.8.2	9.1.2, 9.2, 9.6.1.3, 9.8.5.1	2.4.2.7, 9.10.2, Figure 9.32, CCB ILLNESS	7.2.4, 9.10.1, 9.10.2, Figure 9.34	9.10.2.6.1	9.9.2, Box 9.8, Table Box 9.8.1	9.7.1, 9.9.1.1, 9.9.2	9.9.2, Figure 9.27	9.9.2, Box 9.5, Table 9.7	9.11.1, Figure 9.37

	HUMAN SYSTEMS											
	Water scarcity and food production				Health and well-being				Cities, settlements and infrastructure			
	Water scarcity	Agriculture/ crop production	Animal and livestock health and productivity	Fisheries yields and aquaculture production	Infectious diseases	Heat, malnutrition and other	Mental health	Displacement	Inland flooding and associated damages	Flood/storm induced damages in coastal areas	Damages to infrastructure	Damages to key economic sectors
Asia	Adverse and positive impacts, *medium confidence*	Adverse and positive impacts, *high confidence*	Adverse impacts, *low confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *low confidence*	Adverse impacts, *high confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *medium confidence*
	10.4.4, Table SM4.3	10.4.5, 5.4.1	10.4.5.2.3	10.4.3.2, 10.4.5.2	2.4.2.7, 10.4.4.3, 10.4.7, CCB ILLNESS	10.4.7	10.4.6.3.2, 10.4.7.1	Box 10.2	10.4.4.3, Figure 10.2	Figure 10.2	10.4.6.3	Box 10.7
Austral-asia	Adverse and positive impacts, *low confidence*	Adverse impacts, *high confidence*	Adverse and positive impacts, *medium confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *low confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *medium confidence*	Not assessed	Adverse impacts, *low confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*
	11.3.3.1, 11.3.11, Table SM16.B.2	11.3.4.1, Table SM16.B.2	11.3.4.2	11.3.4.4	11.3.6.1, Table SM16.B.2	7.2.5, Table 7.4, 11.3.5.1, 11.3.6.1, 11.3.11, 11.4, Table 11.10, Table SM16.2	11.3.6.2, Table 11.10	–	Box 11.4, Box 11.6, Table SM16.B.2	11.3.5.1, Table Box 11.6.1	11.3.5.1, 11.5.1, Table SM16.B.2	11.3.5.2, 11.5.1, 11.5.2.1, Box 11.6
Central and South Amer-ica	Adverse and positive impacts, *low confidence*	Adverse impacts, *medium confidence*	Adverse and positive impacts, *medium confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *medium confidence*	Not assessed	Adverse impacts, *medium confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *low confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *medium confidence*
	Table SM4.3, 12.3.1.4, 12.3.2.4, 12.3.3.4, 12.3.5.4, 12.3.6.4, 12.3.7.4, 12.3.8.4, 12.5.3.1, Figure 12.9, Figure 12.10, Table 12.3	12.3.1.4, 12.3.2.4, 12.3.3.4, 12.3.4.4, 12.3.5.4, 12.3.6.4, 12.3.7.4, 12.5.4.1, Figure 12.9, Table 12.4	12.3.1.4, 12.3.3.4, 12.3.4.4, 12.3.5.4, 12.3.6.4, Figure 12.9	12.3.2.2, 12.3.3.4, 12.3.5.4, 12.3.7.4, Figure 12.9, Figure 12.10	12.3.2.4, 12.3.3.4, 12.3.5.4 12.3.6.4, 12.7.2.6, Figure 12.9, Figure 12.10, Table 12.1	12.3.1.3, 12.3.8.4, 12.5.7.1, Figure 12.9, Figure 12.10, Table 12.2, Table 12.5, Table 12.6	–	12.3.1.4, 12.3.2.4, 12.3.3.4, 12.3.5.4, 12.5.8.4	12.3.2.4, 12.3.3.4, 12.3.4.4	Figure 12.9	12.3.3.4, 12.3.1.4, 12.3.7.4	12.3.1.4, 12.3.3.4, 12.3.4.4, 12.3.6.3, 12.3.6.4, 12.10, Figure 12.9, Table SM12.3

	HUMAN SYSTEMS											
	Water scarcity and food production				**Health and well-being**				**Cities, settlements and infrastructure**			
	Water scarcity	**Agriculture/ crop production**	**Animal and livestock health and productivity**	**Fisheries yields and aquaculture production**	**Infectious diseases**	**Heat, malnutrition and other**	**Mental health**	**Displacement**	**Inland flooding and associated damages**	**Flood/storm induced damages in coastal areas**	**Damages to infrastructure**	**Damages to key economic sectors**
Europe	Adverse and positive impacts, *medium confidence*	Adverse and positive impacts, *high confidence*	Adverse impacts, *medium confidence*	Adverse and positive impacts, *medium confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *high confidence*	Adverse impacts, *low confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *low confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *medium confidence*
	13.2.1, 13.10.1, 13.10.2.3, Figure 13.29, Table SM4.3	13.5.1.1, 13.10.1, 13.10.2.2, Figure 13.29	13.5.1.2	13.5.1.3	2.4.2.7, 13.7.1.3, 13.10.1, 13.10.2.1, Figure 13.24, Figure 13.29, CCB ILLNESS	13.7.1.1, 13.7.1.4–13.7.1.7, 13.10.1	13.7.1.7, CCP6.2.6	13.8.1.2	13.2.1.2	13.2.1.1, Figure 13.12	13.10.1, 13.10.2.4, Figure 13.29, Table SM13.8.1	13.2.1.2, 13.6.1.1, 13.10.1, Figure 13.2, Figure 13.29
North Amer-ica	Adverse and positive impacts, *medium confidence*	Adverse and positive impacts, *high confidence*	Adverse impacts, *low confidence*	Adverse and positive impacts, *medium confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*
	14.5.1, 14.5.2, 14.5.3, Table SM4.3	14.5.4, Table SM14.2	14.5.4.1, Table SM14.2–14.5	14.5.1, 14.5.3, 14.5.4.2, 4.5.6, 14.7, Figure 14.6, Table SM14.7	2.4.2.7, 14.5.6, Box 14.2, CCB ILLNESS	14.4, 14.5.2, 14.5.6, Box 14.2, Figure 14.8	14.4, 14.5.6.8, 14.6.1, CCP6.2.6	14.5.9.1, 14.5.5.1	14.2.1	14.5.5.1, Box 14.4	14.5.3.1	14.5.1–14.5.7, 14.5.9, Box 14.1, Box 14.5, Box 14.6
Small islands	Adverse impacts, *high confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *high confidence*	Adverse impacts, *low confidence*	Adverse impacts, *high confidence*	Adverse impacts, *limited evidence*	Adverse impacts, *medium confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*
	Table SM4.3, 15.3.3.2, 15.3.4.3, 15.3.4.4, Figure 15.6	15.3.4.4	15.3.4.4	15.3.3.1, 15.3.4.4, Figure 15.6	15.3.4.2, 15.3.4.9.2	15.3.4.2, Box 15.1	15.3.4.2	15.3.4.6, Figure 15.6	15.3.4.6, Figure 15.6	15.3.3.1, 15.3.3.2, 15.3.4.1–15.3.4.5, 15.3.4.7	15.3.4.1, 15.3.4.4, Figure 15.6	15.3.3.2, 15.3.4.3, 15.3.4.4, Figure 15.6, Table SM4.3

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	HUMAN SYSTEMS											
	Water scarcity and food production				Health and well-being				Cities, settlements and infrastructure			
	Water scarcity	Agriculture/ crop production	Animal and livestock health and productivity	Fisheries yields and aquaculture production	Infectious diseases	Heat, malnutrition and other	Mental health	Displacement	Inland flooding and associated damages	Flood/storm induced damages in coastal areas	Damages to infrastructure	Damages to key economic sectors
Medi-terra-nean region	Adverse impacts, *high confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *low confidence*	Adverse impacts, *high confidence*	Not assessed	Adverse impacts, *low confidence*	Adverse and positive impacts, *low confidence*	Adverse impacts, *low confidence*	Evidence limited/ insufficient	Adverse impacts, *medium confidence*
	CCP4.1.2, CCP4.1.4, CCP4.2.1–CCP4.2.3	CCP4.1.4, Figure CCP4.5, Table SMCCP4.1	Table CCP4.5, SMCCP4	CCP4.1.4	13.7.1.3, Figure 13.27	CCP4.2.3, Figure CCP4.5, SMCCP4	–	CCP4.2.3	CCP4.1.4	CCP4.1.4, Figure CCP4.5	–	Figure 13.27
Arctic	Adverse and positive impacts, *low confidence*	Adverse and positive impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *low confidence*	Adverse impacts, *high confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *high confidence*	Adverse and positive impacts, *high confidence*
	4.2, Box 4.1, CCP6.2.6	CCP6.2.2.1, CCP6.2.3.2, Table CCP6.3	CCP6.2.2.1, CCP6.2.3.2, Table CCP6.3	CCP6.2.1.1, CCP6.2.1.4, CCP6.2.3.3, Table CCP6.4SROCC 3.2.4.1.1	2.4.2.7, CCP 6.2.6	CCP6.2, Figure CCP6.3	CCP6.2.6	CCP6.2.5	Table CCP6.1	CCP6.2.5, Table CCP6.1	CCP6.2.4.3, CCP6.2.5	{CP6.2.4, Table CCP6.3
Cities by the sea	Evidence limited/ insufficient	Evidence limited/ insufficient	Evidence limited/ insufficient	Adverse impacts, *high confidence*	Evidence limited/ insufficient	Adverse impacts, *high confidence*	Not assessed	Adverse impacts, *medium confidence*	Evidence limited/ insufficient	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*
	–	–	–	CCP2.2	–	CCP6.2.3, CCP2.2	–	2.3.5, 2.4.2, SMCCP2.1.2	–	CCP2.2, SMCCP2.2	CCP2.2, SMCCP2.2	CCP2.2, Table CCP2.1, SMCCP2.1
Moun-tain re-gions	Adverse and positive impacts, *high confidence*	Adverse and positive impacts, *medium confidence*	Adverse impacts, *medium confidence*	Evidence limited/ insufficient	Adverse impacts, *medium confidence*	Adverse impacts, *medium confidence*	Adverse impacts, *limited evidence*	Adverse impacts, *medium confidence*	Adverse impacts, *high confidence*	n.a.	Adverse impacts, *high confidence*	Adverse impacts, *high confidence*
	CCP5.2.2, CCP5.2.7, Figure CCP5.2, Figure CCP5.4, SMCCP5.2, Tables SMCCP5.5–5.14	CCP5.2.3, CCP5.2.5, CCP5.2.7, Figure CCP5.4, SMCCP5.2, Tables SMCCP5.5–5.14	CCP5.2.3, CCP5.2.5, CCP5.2.7, Figure CCP5.4, SMCCP5.2, Tables SMCCP5.5–5.14	–	CCP5.2.5, Table CCP5.1, Figure CCP5.4, SMCCP5.2, Tables SMCCP5.5–5.14, Table 7.6	CCP5.2.5, Table CCP5.1, Figure CCP5.4, SMCCP5.2, Tables SMCCP5.5–5.14	Table CCP5.1	CCP5.2.5, Table CCP5.1, Figure CCP5.4, SMCCP5.2, Tables SMCCP5.5–5.14	CCP5.2.5, CCP5.2.6, Figure CCP5.4, SMCCP5.2, Tables SMCCP5.5–5.14	–	CCP5.2.5, CCP5.2.6, Figure CCP5.4, SMCCP5.2, Tables SMCCP5.5–5.14	CCP5.2.4, CCP5.2.5, CCP5.2.6, Figure CCP5.4, SMCCP5.2, Tables SMCCP5.5–5.14

SMTS.2 Impacts and Risks from Climate Change Assessed in Burning Embers

SMTS.2.1 Assessment of Burning Embers for Regional and Global Risk Assessments

In addition to the burning embers for the global Reasons for Concern (TS.AII.3), the WGII assessment also presents similar graphic illustrations of the impact and risk assessments of specific chapters and cross-chapter papers {Figure SPM.3, Figure TS.4}. The sources for these assessments are listed in Table SMTS.3.

Table SMTS.3 | Impacts and risks from climate change assessed in burning embers {Figure SPM.3, Figure TS.4}

Group	Key risk	Scope	Sources
Terrestrial and Freshwater Ecosystems	Biodiversity loss	Loss of species erodes ecosystem integrity, functioning, provisioning of services (including climate regulation, food and water) and resilience to extreme events and future climate change.	2.5.4, Table 2.5, Figure 2.11, Table SM2.5
	Tree mortality	Tree mortality that exceeds natural levels degrades habitat for plant and animal species, increases carbon emissions, and reduces provision of water and other services for people.	2.5.4, Table 2.5, Figure 2.11, Table SM2.5
	Structure change	Increasing risk of large-scale changes in ecosystem structure; ecosystem structural change with most information derived for tropical forest, boreal forest, savannas and tundra for both observations and future projections	2.5.4, Table 2.5, Figure 2.11, Table SM2.5
	Wildfire increase	Increasing risk of wildfire that exceeds natural levels, damaging ecosystems, increasing illnesses and death of people, and increasing carbon emissions	2.5.4, Table 2.5, Figure 2.11, Table SM2.5
	Carbon loss	Increasing risk of ecosystem carbon losses from tipping points of loss of tropical forest and Arctic permafrost that could substantially raise the atmospheric carbon dioxide level	2.5.4, Table 2.5, Figure 2.11, Table SM2.5
Ocean Ecosystems	Warm-water corals	Increasing risks to biodiversity, structure and functioning	Figure SM3.1, SROCC 5.3.7, SROCC Figure 5.16, SROCC SM5.3
	Kelp forests	Increasing risks to biodiversity, structure and functioning	Figure SM3.1, SROCC 5.3.7, SROCC Figure 5.16, SROCC SM5.3
	Seagrass meadows	Increasing risks to biodiversity, structure and functioning	Figure SM3.1, SROCC 5.3.7, SROCC Figure 5.16, SROCC SM5.3
	Epipelagic	Increasing risks to biodiversity, structure and functioning in the upper part of the ocean with depth <200 m from the surface where there is enough sunlight to allow photosynthesis	Figure SM3.1, SROCC 5.3.7, SROCC Figure 5.16, SROCC SM5.2
	Rocky shores	Increasing risks to biodiversity, structure and functioning	Figure SM3.1, SROCC 5.3.7, SROCC Figure 5.16, SROCC SM5.3
	Salt marshes	Increasing risks to biodiversity, structure and functioning	Figure SM3.1, SROCC 5.3.7, SROCC Figure 5.16, SROCC SM5.3
Health	Heat-related morbidity and mortality	Temperature thresholds at which health risks change. Adaptation under SSP1, SSP2 and SSP3 significantly alters the warming thresholds at which risks accelerate.	7.3.1, Figure 7.9
	Ozone-related mortality		
	Malaria		
	Dengue and other diseases carried by *Aedes* spp.		
Regional: Africa	Food production from crops, fisheries and livestock systems	Loss of food production from crops, fisheries and livestock systems	9.2, 9.8, Figure 9.6, Table 9.2, Table SM9.1
	Biodiversity and ecosystems	Local or global extinction of species and reduction or irreversible loss of ecosystems and their services, including freshwater, land and ocean ecosystems	9.2, 9.6, Figure 9.6, Table 9.2, Table SM9.1
	Mortality and morbidity from heat and infectious diseases	Mortality and morbidity from increased heat and infectious diseases and infectious diseases (including vector-borne and diarrhoeal diseases)	9.2, 9.10, Figure 9.6, Table 9.2, Table SM9.1

Group	Key risk	Scope	Sources
Regional: Australasia	Loss and degradation of coral reefs	Loss and degradation of tropical shallow coral reefs in Australia and associated biodiversity and ecosystem service values due to ocean warming and marine heatwaves	11.6, Figure 11.6, Table 11.14, SM11.2, Table SM11.2b
	Cascading impacts on cities and settlements	Cascading, compounding and aggregate impacts on cities, settlements, infrastructure, supply chains and services due to extreme events	11.6, Figure 11.6, Table 11.14, SM11.2, Table SM11.2i
Regional: Europe	Coastal flooding to people and infrastructures	Level of risks due to coastal flooding with low to medium adaptation (keeping coastal protection as it is now)	13.10.2.4, Figure 13.28, Figure 13.32, SM13.10, Table SM13.30
	Heat stress, mortality and morbidity	Risk to human mortality and heat stress due to heat extremes and increase in average temperature	13.10.2.1, Figure 13.28, Figure 13.29, SM13.10, Table SM13.25
	Water scarcity to people in southeastern Europe	Risks of water scarcity with low adaptation	13.10.2.3, Figure 13.28, Figure 13.31, SM13.10, Table SM13.29
Regional: Arctic	Sea ice ecosystems from sea ice change	Sea ice ecosystems are rapidly transforming, resulting in an unprecedented accumulation of cascading effects that impact almost every sector of environment and society. Increasing light penetration initiates earlier seasonal primary production, and albedo an increased warming, earlier growing season for ice algae and phytoplankton biomass, and changes in health and habitat of sea ice fauna, mega-fauna and fish species. Biophysical changes cascade to socioeconomic and cultural systems by impacting safe travel in ice, subsistence hunting, changing economic opportunities and potential for Arctic maritime trade—all of which will lead to additional impacts, risks, and transformations, some of which may be inevitable and irreversible. At current levels of warming, sea ice in the Arctic is already showing clear signs of transformation and reduction in extent, and thickness combined with increased mobility are expected to continue.	CCP6.3.1, Figure CCP6.5, SMCCP6.5
	Fisheries catch for Pollock and Pacific cod	Risk transition analysis was focused on cod and pollock species in the Bering Sea under scenarios that include status quo ecosystem-based measures including a limit on total groundfish yields. These fisheries represent the largest (Pollock, *Gadus chalcogrammus*) and one of the most valuable (Pacific cod, *Gadus macrocephalus*) fisheries in the USA. Warming temperatures and change in sea ice, circulation and shifts in trophic pathways to less-energy-efficient food chains were used to drive changes in survival (predation), growth and recruitment, and subsequent catch, under future scenarios.	CCP6.3.1, Figure CCP6.5, SMCCP6.5
	Costs and losses for key infrastructure	Infrastructure is at risk from a variety of climate change hazards including sea level rise, storm surge, permafrost thaw and coastal erosion, among others. Impacts have already been observed for sewage systems, municipal buildings, roadways, pipelines, railways, ice roads and local trails between communities. Evaluation of risk transitions for infrastructure was based on observed and projected risks from relevant climate hazards to relevant Arctic infrastructure. Consideration of potential adaptation options available, including limits to adaptation (i.e., relocation, available technologies, potential for new technologies, existing building codes), were considered during expert evaluation.	CCP6.3.1, Figure CCP6.5, SMCCP6.5
Regional: Antarctic	Sea ice dependent ecosystems	See 'Sea ice ecosystems from sea ice change' for the Arctic (above). In the Antarctic, sea ice change is more variable than in the Arctic, and future projections are less certain.	CCP6.3.1, Figure CCP6.5, SMCCP6.5
	Krill fisheries	Regional physical and biological changes in Antarctic waters are expected to result in net declines in krill habitat and growth potential, although one study does indicate a potential increase; however, significant regional declines may not be detected until later in the century.	CCP6.3.1, Figure CCP6.5, SMCCP6.5
Regional: Mediterranean	Water quality and availability	As global warming levels are rising, hydrological, agricultural and ecological drought intensity and duration are increasing, runoff, streamflow, groundwater recharge and water quality are decreasing and in the south-Mediterranean, aridity is expanding. This in turn increasingly affects water management, including hydropower production and cooling capacity.	CCP4.3.4, CCP4.3.6, Figure CCP4.8, SMCCP4.2a
	Health and well-being	The population exposed to heat stress risks is escalating with rising global warming levels, resulting in increasing morbidity and mortality and cooling demand. The epidemic potential of dengue and other diseases is projected to increase.	CCP4.3.5, CCP4.3.6, Figure CCP4.8, SMCCP4.2f
	Delayed impacts of sea level rise	The Mediterranean region is characterized by a high exposure to sea level rise, including people, infrastructure, ecosystems and the cultural heritage sites. Stabilizing global warming at about 2°C commits sea level rise for millennia, ultimately drowning key coastal low-lying areas of the Mediterranean where people currently live.	CCP4.3.2, CCP4.3.6, Figure CCP4.8, SMCCP4.2h
Regional: North America	Viability of tourism-related activities	Overall economic viability of tourism activities are assessed by evaluating the reduction in season length for tourism activities: Nordic skiing and snowmobiling, alpine skiing, beach tourism and coral reef snorkelling, and parks and protected areas visitation. Many of these activities have adaptation limits by 2°C.	14.5.7, 14.5.8, 14.6.1, Figure 14.10, SM14.4
	Costs and damages related to maintenance and reconstruction of transportation infra-structure	The focus of this assessment was on road (including ice roads in the Arctic) and rail and transportation infrastructure such as bridges, airstrips, pipelines and port facilities. Near-term impacts expected to be incremental. With low adaptation, risks will be high before 4°C and cold amount to hundreds of billions in needed repairs.	14.5.7, 14.5.8.1, 14.6.1, Box 14.5, Figure 14.10, SM14.4
	Lyme disease	Temperature has contributed to the emergence of tick populations, their range and recent geographic spread, which are the main vector of Lyme disease. Risks are assessed for a SSP2 scenario with moderate challenges to adaptation.	14.5.6.4, 14.6.1, Figure 7.9, 7.3.1

SMTS.3 Details of Key Risks by System and Region Identified by WGII Chapters

Table SMTS.4 | Key risks of climate change by system and region. This table lists a selection of key risks identified by authors of chapters from across the WGII report. In addition to the nature of the key risk, the table provides a description of the consequences of the risk that would constitute a severe outcome (thereby meeting the definition of a key risk as potentially severe), and the hazard, exposure and vulnerability conditions that would contribute to the risk being severe. In addition, it provides the adaptation options identified by authors as having the highest potential for reducing the risk, and an assessment of the confidence in the judgement that this risk could become severe. For the methodology, see the note at the end of the table. {SM16.7.4, Table SM16.24}

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Chapter 2: Terrestrial and freshwater ecosystems and their services								
Plant and animal species extinctions	Global	Extinction of up to 54% under the highest emissions scenario	Increases in temperature or changes in precipitation that go beyond the tolerance limits of a species, rates of change that exceed dispersal capabilities, new climate combinations that species cannot tolerate, disappearance of suitable habitat, particularly at high elevations	All plant and animal species are exposed, deforestation, habitat fragmentation, air and water pollution, and competition from invasive species exacerbate exposure	Certain species have evolved in very specific climate conditions, certain species are endemic to a small geographic range, many plants and smaller animal species have limited dispersal capabilities	Reducing agricultural expansion, deforestation, and other forms of habitat destruction will reduce exposure; conservation of corridors or other critical areas can help maintain habitat connectivity; increasing global protected area will save more habitat	*High confidence*, (*robust evidence*, *medium agreement*)	2.4.2.2, 2.5.1.3
Wildfire increase	Global	Wildfire that substantially exceeds natural levels can cause extensive tree mortality, degrade ecosystem integrity, increase carbon emissions, which would exacerbate climate change in a self-reinforcing feedback, and increase property damage, illnesses, and death of people	Increased heat, decreased precipitation, and increased severity of drought, caused by anthropogenic climate change, which would increase aridity of vegetation and soil	All vegetated areas on Earth are exposed, deforestation severely exacerbates exposure to wildfire, other forms of habitat destruction, degradation, and fragmentation increase exposure; people who live in fire-prone areas or areas where smoke accumulates are more exposed to damage, illness and death from wildfire	Biomes and ecosystems that are normally wet or cold where wildfire has been rare are most susceptible to degradation of ecosystem integrity, particularly tropical rainforest and Arctic tundra; people in impoverished living conditions or with pre-existing health conditions are more vulnerable	Reducing deforestation, particularly in tropical and boreal forests will reduce human ignitions and help sustain natural vegetation and soil moisture; prescribed burning or allowing naturally ignited fires to burn in areas of unnatural fire suppression can reduce fuel loads and risks of catastrophic wildfire	*High confidence* (*robust evidence, high agreement*)	2.4.4.2, 2.5.3.2, FAQ 2.3

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Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Ecosystem carbon loss	Tropical rainforests and Arctic and boreal permafrost	Tipping points of conversion of major fraction of tropical rainforest to grassland or thawing of extensive areas of permafrost, releasing carbon in a short period equivalent to years or decades of current emissions that would substantially exacerbate climate change	In tropical forest, drought caused by heat of anthropogenic climate change and low precipitation in areas of high inter-annual variability, increased wildfire caused by heat of anthropogenic climate change that dries vegetation; in Arctic tundra, increased temperature substantially exceeding historical levels	All tropical forests and Arctic tundra areas are exposed; areas of tropical deforestation and the more southern tundra areas are most exposed	Tropical rainforests have evolved in wet, humid conditions, so they are susceptible to drought and wildfire; Arctic tundra permafrost requires below-freezing temperatures	Reducing deforestation and use of fire will reduce exposure of rainforests to drought and wildfire; reducing roads and other infrastructure in permafrost areas could reduce exposure to warmer conditions and ignitions from human activities	*Medium confidence* (*high agreement*, *medium evidence*)	2.4.4.4, 2.5.3.4
Chapter 3: Ocean and coastal ecosystems and their services								
Loss and degradation of warm-water coral reef ecosystems	Tropical and subtropical seas, small islands	Severe degradation of 70–90% of the world's warm-water coral reef ecosystems, with >1.5°C of global average surface warming due to mortality from frequent bleaching, and effects of acidification and sea level-rise	The frequency of severe bleaching-level heat stress exceeding required coral reef recovery time (i.e., Degree Heating Weeks ≥ 8°C per week more than once every 5 years); severe risks projected to occur with >1.5°C of global average surface warming. More extensive losses and reduction in reef growth and extent at greater rates of warming and atmospheric CO_2	Warm-water coral reef ecosystems in all ocean regions have been exposed to bleaching-level heat stress, with some ecosystems like the Great Barrier Reef experiencing decline in coral coverage from repeated bleaching-related morality	Vulnerability is currently high globally, with exceptions in locations with variable temperatures and lower non-climate hazards. Inability of corals to adapt via physiological acclimation or evolutionary processes will contribute to risk becoming severe with >1.5°C of global average surface warming	Some local risk may be reduced through marine protection and management (reduction of other non-climate stressors), coral restoration and possibly emerging technologies like assisted gene flow, assisted evolution or synthetic biology	*Very high confidence* (*robust evidence*, *high agreement*)	2.4.2.2, 2.5.1.3
Risk to marine coastal ecosystem services due to loss of habitat-forming species	Coastal ocean, including estuaries	Loss of ecosystem services (income, food, shoreline protection) from rapid transformations in coastal ecosystems dependent on foundational, habitat-forming species (e.g., corals, kelp and seagrasses) due to warming and marine heatwaves	Warming rate and frequency of marine heatwaves sufficient to promote shift to algae- and turf- dominated systems. Values vary regionally and between systems, but broadly associated with >1.5°C global mean surface warming for coral reefs and >2°C for kelp systems	Increasing population in coastal regions, particularly in reef islands near sea level	Vulnerability is highest at the warm end of species' ranges, and where societal dependence on aquaculture, fishing and mariculture is highest	Some local risk may be reduced through identification of refugia, marine protection and management (reduction of other non-climate hazards), and ecosystem restoration	*High confidence* (*medium evidence*, *high agreement*)	3.4.2.1, 3.4.2.2, 3.4.2.3

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Risk to species habitat and fisheries due to hypoxia	Shallow ocean waters, including shelf seas, semi-enclosed seas, and coastal waters	Expansion, increased duration and emergence of new seasonal 'dead zones' of hypoxic water, causing species die-offs, reducing habitat and affecting fisheries	Warming increases the rates of aerobic metabolism, especially among microbes, and also enhances stratification, limiting the ability of oxygenated waters to mix. Increased frequency of heavy or extreme precipitation might result in greater nutrient loading of coastal waters, which is known to further exacerbate hypoxia		Vulnerability exacerbated by nutrient loading from human activity, worsening hypoxia in regions dependent on fisheries for livelihoods	Managing nutrient inputs to coastal systems from terrestrial sources is a key tool for managing the occurrence and spread of hypoxic waters	*High confidence* (*robust evidence*, *high agreement*)	3.4.2.4, 3.4.2.7, 3.4.2.8, 3.4.2.9
Reduced growth and survival of calcifying species, including shellfish	Coastal ocean	Reduced growth and abundance of calcifying species, including shellfish, reef-building corals and calcareous red algae. For shellfish and calcifying algae, risk expected to be severe under RCP8.5 by the end of the century	The key hazard is ocean acidification, with potential synergistic interactions between ocean acidification, warming and deoxygenation. Available data indicated the hazard level is species dependent	As atmospheric CO_2 increases, a greater range of taxa will be exposed to the effects of ocean acidification. Exposure is greatest at mid-to-high latitudes and in warm-water coral reefs	Local warming and deoxygenation are known to exacerbate the vulnerability of some taxa to the effects of ocean acidification. Eastern Boundary-Current Upwelling systems are prone to rapid impacts from ocean acidification	Design considerations and small-scale interventions may reduce the effects of ocean acidification on shellfish operations	*High confidence* (*robust evidence*, *medium agreement*)	3.4.2.1, 3.4.2.2, 3.5
Risk to food security, employment and livelihoods due to impacts on fisheries yields	Global ocean, particularly low latitudes, shelf seas and semi-enclosed seas	Lower fisheries productivity and reduced fisheries yield, with consequences for food security, employment and livelihoods, particularly in areas reliant on seafood for protein and income. Absent management reforms, fishery yield could decline >50% by 2100 in some equatorial regions under RCP4.5	Warming shifts species distributions and warming-associated stratification of the water column reduces transfer of nutrients from the deep, and affects primary productivity. More frequent and intense marine heatwaves exacerbate the hazard	Changes are expected globally, with strongest warming-induced decline in fish biomass predicted for the Atlantic, Pacific and Indian Oceans	Vulnerability expected to be highest in coastal communities that depend directly on fisheries for income, livelihoods and food. Industrial fisheries are less vulnerable, but conflict and inequalities may arise from greater adaptive capacity of industrial fisheries. Implications for coastal communities in terms of lost employment (both direct and indirect) could be significant, as could implications for communities dependent on seafood for protein	Proactive (anticipatory) and adaptive fisheries management could reduce risks, as could diversification of employment and food sources. International agreements also can play a role in maintaining adaptive management over shifting stocks	*Medium confidence* (*medium evidence*, *medium agreement*)	3.3, 3.4.3, 3.4.4.2, 3.6.3

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Risk to regional marine biodiversity, ecosystem function and associated ecosystem services	Global ocean, but mainly poleward of the tropics	Expansion of species ranges and changes in phenology leading to homogenisation of marine biodiversity at regional scales, species invasions and trophic mismatches. Severe risk would include novel communities providing limited ecosystem services to society	Regional warming and increased heat content of the upper ocean, especially during cooler months, increasing habitat suitability for warmer-affinity species at poleward (leading) range edges. Organisms like phytoplankton that respond to surface temperature are changing phenology at faster rates than organisms that respond to bottom-water temperatures (e.g., eggs of commercially important fish), causing a mismatch between trophic levels	Warmer surface waters expand to mid- and high-latitude oceans	Vulnerability is highest in regions with high fish consumption and high dependence on fisheries for income and livelihoods. For trophic mismatches, risk is greatest with benthic ecosystems and species that spend part of their lives at depth	Implementation of ecosystem-based management to reduce fisheries pressure on geographic spawners, maintain diverse size and age structures, and reduce non-climate hazards, particularly in spawning grounds	*High confidence* (*medium evidence*, *high agreement*)	3.3, 3.4.3
Risk to coastal communities from flooding and sea level rise due to loss of coastal habitat	Coastal ocean, including sandy beaches and saltmarshes	Consequences include loss of life from extreme events, loss of land, and loss of key infrastructure. Flooding, erosion and salinisation of groundwater from sea level rise exceeding adaptive capacity of coastal systems, including soft-sediment shores and coral reefs, and adjacent human communities, including cities and high-value infrastructure	Sea level rise increasing the frequency and severity of flooding and wave overtopping events, of erosion in soft-sediment shorelines, and of salinisation of groundwater in soft-sediment and limestone shorelines	Increasing population and high-value infrastructure in coastal regions, particularly low-elevation coastal cities, delta regions and reef islands	Increasing density in cities and communities adjacent to soft-sediment shores, especially beaches; coastal developments and shoreline engineering degrading coastal habitats and reducing resilience to flooding and erosion	Proactive coastal zone management that blends ecosystem-based adaptation, protective measures and managed retreat from soft sediment shorelines, in order to allow the coast to equilibrate as sea levels rise over coming centuries	*High confidence* (*robust evidence*, *high agreement*)	3.4.2.1, 3.4.2.2, 3.4.2.4, 3.4.2.5, 3.4.2.6, 3.5
Degradation of Arctic ecosystems and loss of traditional Arctic livelihoods	Arctic Ocean	Loss of habitat and changes to the food web due to reduction of seasonal sea ice and to sea level rise, with consequences for Indigenous communities including loss of traditional livelihoods, relocation of communities, and injury from changes in ice/snow conditions	Reduction in sea ice extent and thickness, reducing safe travel, hunting and traditional fisheries; integrated effect of sea ice loss and sea level rise on coastal erosion and wave damage		Commercial activities, including, shipping, petroleum, fisheries and tourism, are increasing with warming, increasing the risks of compound impacts on ecosystems	Options for local and Indigenous communities includes improved and real-time ice forecasting, enhanced search and rescue capabilities, investment in local infrastructure, shift in diets and livelihoods, alleviate non-climate stressors, and commercial fisheries adapting to changes in stock productivity	*High confidence* (*robust evidence*, *high agreement*)	3.4.2.10

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Risk of water-related diseases affecting human health and ecosystem services	Global oceans, focus on coastal regions	Impacts on food provisioning, tourism, economy and human health due to increase in geographical extent and frequency of harmful algal blooms, spread of marine pathogens, exposure and bioaccumulation of contaminants	Key hazards include ocean warming, acidification, anoxia, sea level rise, extreme weather/ climate events, such as heatwaves, storm surges, heavy rainfall, flooding and drought	Global increase in the extent of areas displaying favourable conditions for proliferation of microbial pathogens and harmful algae	Vulnerability is highest in areas of high seafood consumption, and which are exposed to nutrient pollution from land; may be exacerbated by sea level rise increasing suitable habitats for microbial pathogens	Options includes reducing nutrient pollution from land-based activities; developing predictive model and capacity for improved monitoring and early warning systems; developing sensors for location detection of pathogens and harmful algal blooms	*High confidence*	3.4.2.7, 3.4.2.8, CCB-ILLNESS (Chapter 2), 3.6.2.2
Chapter 4: Water								
Freshwater supplies not meeting demand for agriculture or drinking	Global	Over 1 billion people experiencing 'chronic' water scarcity (less than 1000 m^3 of freshwater per person per year)	Annual mean river flows providing water supplies substantially lower than amount required to meet demand	Populations living in areas prone to reduced water availability	Low ability to manage, store and supply freshwater, due to low levels of wealth, inappropriate governance or inadequate planning and implementation of water infrastructure. The latter could arise from uncertainties in future regional climate projections and *low confidence* in decision-making	Improved water management infrastructure and consumer behaviour	*High confidence*	4.1.1
Loss of life and damage to property from river flooding	Global	More than 100 million people per year affected by river flooding	Peak river flows exceeding capacity of river channels or flood protection measures by substantial magnitude and/or with high frequency	Populations living on flood plains	Lack of access to early warnings to avoid personal exposure to floods. Poor sanitation governance leading to increased likelihood of disease during and following floods. Absence of insurance cover for property	Improved flood management measures, including communications networks for provision of early warnings and evacuation advice. Improved provision of emergency sanitation facilities. Increased access to insurance cover	*High confidence* (for changes due to hazard alone). *Medium confidence* if exposure and vulnerability considered	4.2
Loss of life and damage to property from wildfire	Global	Substantial increase in number of people per year affected by wildfire	High intensity of fire weather and/or long fire season	Populations living in fire-prone areas	Lack of access to early warnings to avoid personal exposure to wildfire. Pre-existing health conditions exacerbated by exposure to smoke. Absence of insurance cover for property	Improved wildfire management measures, including communications networks for provision of early warnings and evacuation advice. Improved access to healthcare for smoke inhalation-related conditions. Increased access to insurance cover	*High confidence* (for changes due to hazard alone). *Medium confidence* if exposure and vulnerability considered	4.2

TSSM

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Loss of valued aspects of culture due to changes in water (including cryosphere)	Global (especially cold regions for cryosphere impacts)	Loss of environmental character deeply associated with cultural identity	Sea ice reduced below levels that support traditional means of travel. Streamflows changed to levels that discourage species for traditional hunting	Populations with strong cultural identity links to water, snow and ice conditions			*High confidence*	4.4.4
Reduced energy supplies due to hydrological impacts	Global	Widespread and/or frequent disruption to energy supplies affecting large numbers of people	Reduced stream flows affecting hydropower. Increased water temperatures reducing cooling of thermal power stations. Increased flooding impacting electricity distribution networks	Energy infrastructure assets in areas prone to flooding. High reliance on single sources of energy production	Lack of alternative energy supplies or battery storage	Increased resilience of energy infrastructure, diversification of energy supply sources	*High confidence*	4.3.2
Reduced biodiversity in freshwater ecosystems	Global	Substantial loss of species in freshwater ecosystems	Substantial increase in drought conditions in ecosystems dependent on freshwater bodies	Large proportion of freshwater ecosystems in regions prone to drought	Fragmented landscape limiting capacity for species dispersal	Active landscape management, or removal of human land use, to enlarge and connect local freshwater ecosystems	*High confidence*	4.3.5
Chapter 5: Food, fibre and other ecosystem products								
I. Risks related to food security and malnutrition								
Short-term and/ or chronic food and feed shortage with cascading risk of civil unrest and social disruption	Global, but particularly in arid or flood-prone regions of low-income countries and civil unrest urban areas	Widespread food and feed shortages resulting in price spikes for staple crops, with disproportionate effect on the poor, potentially leading to civil unrest and social disruption. Increase in childhood stunting	Widespread summer heat and drought conditions across major breadbasket regions. Climate extreme events such as flooding or drought in low-income countries	The globally connected food system which relies on these staple crops for food and feed	Vulnerability is higher for those whose income is largely spent on food, in particular those living in persistent poverty, with limited social support, limited trade and transport of food; smallholder producers and countries that rely on agricultural production for livelihoods; low-income households living in flood zones; and areas with civil conflict and poor governance, particularly in urban areas	Policies to support research on agricultural productivity and resilience, increase international grain reserves, increase access to diverse food for low-income people.	*Medium confidence* (*medium evidence, medium agreement*)	5.2.2, 5.4.3, 5.12.4

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Water insecurity and usage conflict for inland fisheries, affecting food and nutritional security	Global, but in particular low-income Asian and African countries, representing 57% and 25% of global inland catches respectively	Decline in inland fisheries leading to potentially large increase in food insecurity and malnutrition of those people in communities and regions reliant on inland fisheries for food		Exposure will increase as precipitation changes and extreme events (floods, cyclones, storms, heatwaves) intensify	Large numbers of people in low-income countries currently reliant on inland fisheries for direct human consumption and nutritional security. Inland fish provide the equivalency of full dietary animal protein to 158 million people. 43% of inland fish capture comes from 50 low-income food-deficit countries	Local and national governance on water usage prioritisation incorporating food security and nutritional risks	*Medium confidence* (*medium evidence*, *medium agreement*)	5.8.2
II. Risks related to food safety and dietary health								
Risk to health and micronutrient availability due to CO_2- and temperature-related changes in crop quality and nutrition	Global	Worsened health and nutritional outcomes particularly in children and pregnant women, leading to stunting wasting and other forms of malnutrition, including obesity	Higher atmospheric CO_2 concentrations, together with other abiotic changes such as higher temperatures, alter nutrient density and composition in many crops including vegetables and fruits, enhancing underlying drivers of malnutrition	Global exposure	All populations, but the most vulnerable include the elderly, the urban poor, Indigenous communities, women, children and other marginalised groups	Provide integrated adaptation programmes that promote healthy eating, diversify farming systems and build livelihood and social support for low-income households. Increase productivity/resilience of current nutrient dense foods such as fruits and vegetables	*Robust evidence*, *medium agreement*	5.4.3, 5.12.3, 5.12.4
Risk of malnutrition, including obesity, due to climate-change-related loss of access to dietary diversity	Global	Limited dietary diversity and more cereal based food leading to malnutrition, including obesity or overweight	Heat, drought, floods or any other climatic shocks that would affect food availability and food prices, in particular animal-sourced foods, vegetables and fruits	Large number of low-income people are affected by volatile food prices	Vulnerability is higher for those in persistent poverty, with limited social support	Stress tolerant adaptation measures that would minimise the food production loss. Climate information services that would minimise the volatility of food price. Social support to increase food access for low-income population	*Medium confidence* (*medium evidence*, *high agreement*)	5.12.4

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Loss of food safety due to climate-related food poisoning or pollutant contamination	Global, but particularly in coastal areas of tropical and Asian countries with high dependence on fisheries and low -income countries which have flood-prone regions and/ or limited food safety infrastructure	Food poisoning or pollutant contamination of food through increased prevalence of pathogens, harmful algal bloom, and increased contaminant bioaccumulation	Increases in temperature, higher humidity and atmospheric CO_2 concentrations	Increased incidence and toxicity of harmful algal blooms, increased reliance on harvested aquatic foods due to dietary shortages elsewhere. Food production and storage conditions that would increase pathogen activity, toxic compounds such as mycotoxins and gastrointestinal illness from harvested aquatic species	Small-scale harvesters for home consumption and small economic gain. Larger-scale harvesters exporting products (consumer safety) and supporting community economic stability	Reduction in land-associated inputs in aquatic systems, e.g., those leading to eutrophication and gastrointestinal virus outbreaks. Improved food safety regulations, storage and transport conditions. Food storage and transport conditions that reduce moisture content and improve harvest technologies to reduce harvest damage	*High confidence* (*medium evidence*, *high agreement*)	5.11.1, 5.12.4
III. Risks related to livelihood of people in the food and ecosystem service sector								
Health and livelihood risks to agricultural labourers due to increased temperature and humidity	Humid tropics and regions with expected large temperature increases	Loss of agricultural livelihoods in humid tropics for farm labour, pastoralists and small-scale food producers. Increases in agricultural labour days lost in hot, humid regions	More frequent periods that combine high temperature with high humidity	Manual labourers and field workers, particularly in poor tropical countries will be increasingly exposed to moist heat stress as climate hazards intensify and spread	Farming communities in the humid tropics that rely extensively on manual agricultural labour; livestock keepers	Diversify livelihoods to provide alternative sources of income. Development of and access to remote technology and machines for minimising outdoor work	*Medium confidence* (*medium evidence*, *medium agreement*)	5.12.4
Risk to livelihoods of livestock keepers seriously affected by increasing heat stress suffered by their animals	Humid tropics and regions with expected large temperature increases coupled with changing humidity levels	Loss of livelihoods; production, fertility and reproductive capacity of domesticated animals (particularly cattle) greatly reduced	More frequent and longer periods that combine high temperature with high humidity		Farming communities in the humid tropics that rely extensively on livestock, particularly cattle	Provide shade or cooling for animals; increase access to water; change livestock species	*Medium confidence* (*medium evidence*, *medium agreement*)	5.5.2, 5.12.3

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Risk to livelihoods in smallholder farming, fishing and aquaculture communities, including Indigenous communities	Low- and medium-income countries in tropics and semi-tropics	Collapse of rural livelihoods and widespread migration of small-scale food producers and low-income households in rural communities	More frequent extreme events, such as droughts, floods and hurricanes, and rising temperatures and precipitation changes due to climate change	Continued population dynamics and relatively high poverty levels, primarily in low- and middle-income countries, leading to greater numbers of vulnerable people exposed to these climate hazards	Vulnerability is higher for small-scale food producers especially in low- and middle-income countries, the elderly, Indigenous communities, producers with marginal assets, women, children and other marginalised groups	Provide integrated adaptation programmes that diversify farming systems and build livelihood and social support for low-income households; improve educational opportunities for children of affected producers to offer alternative livelihoods	*Medium confidence* (*medium evidence*, *medium agreement*)	5.8.2, 5.9.3, 5.12.3
Risk of food shortages and income loss to island and coastal communities and those that rely on coastal food production, particularly rice and coastal aquaculture	Coastal regions, and low-lying island states	Food shortages, income impacts and loss of infrastructure in mainly rural coastal communities, as a result of reduction in fisheries or aquaculture production. Both smallholding and large rice plantations may become economically unviable	Rapid sea level rise, higher temperatures, altered precipitation, impacts distribution, abundance and suitable habitat of aquatic species on global and regional scales	Exposure will increase with sea level rise and storms becoming intensified	Coastal vulnerability is highest in rural areas and for Indigenous Peoples relying largely on aquatic products and tourism for their livelihoods, and in areas with insufficient institutional support for adaptation and recovery, particularly for severe infrequent events	Convert affected low-lying regions to aquaculture of resilient species, increase biogenic coastal protection facilitate relocation of affected populations. Farm insurance, resilient cropping systems (e.g., agroforestry) and adaption of the build environment to reduce impacts from flooding/landslides	*High confidence* (*robust evidence*, *high agreement*)	5.8.2, 5.8.4, 5.9.3
Risk of hunger, loss of livelihood for fisheries-dependent populations, and transboundary conflict arising from the movement of aquatic resources	Global, but most severe in low-income, tropical coastal regions and small islands	National catch potential of living marine resources projected to decrease up to 25% by 2100, with tropical regions losing 40% of species (under RCP8.5 by 2100). Loss of livelihoods due to projected movements (projected value decrease of USD 6 billion by 2100), increased food insecurity due to reduced global food provision from the sea	Further water warming, and synergistic effects of ocean acidification and deoxygenation affecting abundance and distribution of aquatic resources	Exposure levels will increase as global warming, acidification and deoxygenation will worsen.	Vulnerability is highest for people from coastal regions of low-income countries, including small islands, who are largely dependent on fisheries for income and nutrition, and have no productive alternatives (about 200 million people today)	Fisheries management can substantially expand capacity to respond to a changing climate through interventions in the form of policies, programmes, and actions at multiple scales, but a great deal of political will, capacity building and collective action will be necessary	*Medium confidence* (*medium evidence*, *medium agreement*)	5.8.2, 5.9, Cross-Chapter Box MOVING PLATE in Chapter 5

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
IV. Risks to ecosystem services								
Risk of severe decline in ecosystem provisioning services such as soil health and pollinators in terrestrial systems	Global, especially dryland areas and high-latitude areas	Negative impacts on pollinators, soil organic matter and microorganisms that support soil health, potentially reducing production of crops, fibre and other ecosystem products, and greenhouse gas mitigation capacity	Substantial warming can cause hotter droughts, more wildfires, greater variability in precipitation and shifts in biological events such as flowering		Vulnerability is highest in areas where ecosystem services already low, e.g., few pollinators or soil is already highly degraded	Support ecosystem adaptation approaches which support biodiversity and ecosystem services such as soil carbon sequestration as well as food production and livelihoods, e.g., conservation agriculture, agroecology, agroforestry	*Medium confidence* (*medium evidence*, *medium agreement*)	5.4.3, 5.10.4
Risk of biodiversity declines and reduction in carbon sequestration in aquatic systems	Global especially coastal areas	Species extinctions, reductions in ecosystem engineers, loss of ecosystem services such as food provisioning and greenhouse gas mitigation	Further water warming, ocean acidification and deoxygenation creating phenology, distribution and primary productivity shifts		Vulnerability will be further increased through coastal habitat modification (e.g., mangrove deforestation) and coastal land use changes (e.g., eutrophication)	Preservation of biogenic habitats, management of terrestrial inputs into aquatic systems	*High confidence* (*medium evidence*, *high agreement*)	3.5.5, 5.9.3
V. Climate-policy-related risks								
Risk to health and well-being due to increased food insecurity and malnutrition from climate-mitigation related policies that solely focus on reducing GHG emissions	Global	Increased food insecurity and malnutrition for vulnerable groups	Policy decisions related to climate change (e.g., biofuels production) that ignore or worsen quality, access and utilisation of food		Vulnerability highest for low-income households, Indigenous groups, ethnic and religious minorities, women, children, refugees and small-scale producers	Support community-based ecosystem adaptation approaches which support viable livelihoods and food systems	*High confidence* (*robust evidence*, *high agreement*)	5.13.2, 5.13.4

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Chapter 6: Cities, settlements and key infrastructure; Cross-Chapter Paper: Cities and Settlements by the Sea								
Risk to population from increased heat	Global but higher risk in temperate and tropical cities (Section 6.2.3.1)	Increased heat stress, mortality and morbidity events from urbanisation and climate change. Increased health risks and mortality in elderly population; vulnerability of the young to heat (Section 6.2.3.1)	Substantial increase in frequency and duration of extreme heat events, exacerbated by urban heat island effects. (Section 6.2.3.1) Concentration of a mixture of extreme heat and humidity (Section 6.2.3.1)	Large increases in exposure, particularly in urban areas, (Section 6.2.3) driven by population growth, changing demographics, and projected urbanisation patterns. Urbanisation increases annual mean surface air temperature by more than 1°C. Correlation between rising temperatures and increased heat capacity of urban structures, anthropogenic heat release and reduced urban evaporation (Section 6.2.3.1)	Changing demographics from ageing populations, potential for persistent poverty, slow penetration and increasing cost of air conditioning, and inadequate improvements in public health systems. (Section 6.2.3.1) Inadequate housing and occupations with exposure to heat (Section 6.2.3.1)	Nature-based solutions, e.g., urban greenery at multiple spatial scales; vegetation; shading; lower energy costs; green roofs; community gardens (Section 6.3.3.1) enhanced space conditioning in buildings; broader access to public health systems for most vulnerable populations. Less economic stress on residents through utilities, especially electricity (Section 6.2.3.1). Tree planting in communities that lack urban greening (Section 6.3.3.1)	*High confidence*, (*robust evidence*, *high agreement*)	6.2, 6.3
Urban infrastructure at risk of damage from flooding and severe storms	Global, but higher risk in coastal cities	Damage to key urban infrastructure (e.g., buildings, transport networks, and power plants) and services from flood events, particularly high risk within coastal cities, especially those located in low-elevation coastal zones (Section 6.2.3.2)	Substantial increase in frequency and intensity of extreme precipitation (Section 6.2.3.2) from severe weather events and tropical cyclones contributing to pluvial and fluvial floods, which are exacerbated by long-term sea level rise and potential land subsidence (Section 6.2.3.2)	Large increases in exposure, particularly in urban areas, driven by population growth, changing demographics, and projected urbanisation patterns with a geographical focus in coastal regions. Flooding is exacerbated both by encroachment of urban areas into areas that retain water, and lack of infrastructure such as embankments and flood walls (Section 6.2.3.2)	Costly maintenance of protective infrastructure, downstream levee effects, and increased concentrations of coastal urban population. Little investment in drainage solutions (Section 6.2.3.2)	Early warning systems, Adaptive Social Protection (ASP) to reduce vulnerable populations, nature-based solutions, e.g., in sponge cities to enhance flood protection and regulate storm- and floodwaters-this can be improved through reduced risk unto vulnerable urban systems such as stormwater management, sustainable urban drainage system, etc. (Section 6.2.3.2) Green infrastructure can be more flexible and cost effective for providing flood risk reduction (Section 6.3.3)	*High confidence*, (*robust evidence*, *high agreement*)	6.2, 6.3, CCP2

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Population at risk from exposure to urban droughts	Cities located in regions with high drought exposure, (e.g., Europe, South Africa, Australia)	Water shortages in urban areas, and restricted access to water resources to vulnerable populations and low-income settlements. People living in urban areas will be exposed to water scarcity from severe droughts (Section 6.2.3.3). Increased environmental health risks when using polluted groundwater (Section 6.2.3.3)	Projections of more frequent and prolonged drought events potentially compounded with heatwave hazards, and land subsidence from coastal cities that extract groundwater. Climate drivers (warmer temperatures and droughts) along with urbanisation processes (land use changes, migration to cities, and changing patterns of water use) contribute to additional risks (Section 6.2.3.3)	Large increases in exposure, particularly in urban areas, driven by population growth, changing demographics and projected urbanisation patterns. Limitations of engineered water infrastructure is also exposed by flash droughts (Section 6.2.3.3). Settlements are increasingly dependent on imported water resources by locales that may also be exposed to drought risk (Section 6.2.3.3)	Greater water demand from urban populations from in-migration and key economic sectors, and inefficient or ineffective water resource management (Section 6.2.3.3)	Demand and supply side management strategies that include incorporation of IKLK and practices, equitable access to water. Better water resource management will increase quality of water available. More beneficial physical and social teleconnections to bring mutual benefit of water resources between regions (Section 6.2.3.3)	*High confidence* (*robust evidence*, *high agreement*)	6.2, 6.3
Health risks from air pollution exposure in cities	Global, in cities located in Africa, South Asia, the Middle East and East Asia	Increased mortality and morbidity events from respiratory-related illnesses and co-morbidities towards vulnerable urban populations, arising from particulate matter ≤ 2.5 µm in diameter (PM2.5) and tropospheric ozone exposure	Increased emissions of pollutants from anthropogenic (e.g., transportation, electric power generation, large industries, indoor burning of fuel, and commercial and residential sources) and biogenic (e.g., forests, windblown dust, and biomass burning) emissions Potential for severe compound risks arising from droughts and wildfire. Projections for frequency of meteorological conditions indicate expected increase in PM2.5 concentrations (Section 6.2.3.4)	Large increases in exposure, particularly in urban areas, driven by population growth, changing demographics, projected urbanisation patterns and demand for energy combined with weak regulations for emissions control (Section 6.2.3.4)	High proportion of young or ageing populations vulnerable to respiratory illness, potential for persistent poverty, advection of pollutants from upwind, ex-urban areas and stay-in-shelter policies from COVID-19 (Section 6.2.3.4)	Enhanced monitoring of air quality in rapidly developing cities, investment in air pollution controls, e.g., stricter emissions regulations, and increased GHG emissions controls resulting in co-benefits with air quality improvements. Increase in trees or vegetated barriers with low volatile organic compound (VOC) emissions, low allergen emissions and high pollutant deposition potential to reduce particulate matter and maximise adaptation benefits (Section 6.3.3.2)	*High confidence* (*medium evidence*, *medium agreement*)	6.2, 6.3

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Health risks from water pollution exposure and sanitation in cities	Cities located in regions with high drought exposure resulting in polluted water	Increased environmental health risks when using polluted groundwater (Section 6.2.3.3). Vulnerability of users such as women, children, the elderly, ill or disabled (Section 6.3.4.6)	Decreased regional precipitation and changes in runoff and storage from droughts impairs the quality of water available. Less runoff to freshwater rivers can increase salinity, and concentrate pathogens and pollutants (Section 6.2.3.3)	Large increases in exposure, particularly in urban areas, driven by population growth, changing demographics and projected urbanisation patterns. Low flows from drought can lead to sedimentation, increase pollutant concentration and blocking of sewer infrastructure networks (Section 6.2.5.8)	Costly maintenance of protective infrastructure. Sanitation systems coupled with flood water management are at risk of damage and capacity exceedance from high rainfall (Section 6.2.5.8)	Investment in well-regulated water sections; wastewater treatment plants; pumping stations. Reducing impacts of floods on sanitation infrastructure through active management such as reducing blockage in sewer infrastructure (Section 6.3.4.6). Adaptive planning; integration of measures of climate resilience; improved accounting and management of water resources (Section 6.3.4.6)	*High confidence* (*medium evidence*, *medium agreement*)	6.2, 6.3
Chapter 7: Health, well-being and the changing structure of communities								
Heat-related mortality and morbidity	Global, but mainly low- to mid-latitude regions	Substantial increase in heat-related mortality and morbidity rates, especially in urban centres and for outside workers. Increased risk of respiratory diseases and cardiovascular disease (CVD) mortality	Substantial increase in frequency and duration of extreme heat events, especially in cities where heat will be exacerbated by urban heat island effects	Large increases in exposure, particularly in urban areas, driven by population growth and urbanisation. Exposure will increase in agricultural areas where there are large numbers of people working outside	Increases in the number of very young and elderly, and of those with other health conditions such as diabetes and associated comorbidities, lack of capacity to implement adaptation measures	Improved building and urban design, passive cooling systems acknowledging that not all will have access to mechanical space conditioning. Broader understanding of heat hazard and better access to public health systems for the most vulnerable	*High confidence* (*robust evidence*, *high agreement*)	7.3, 7.4
Vector-borne disease incidence	Africa and Asia	Increase in the incidence of some representative vector-borne diseases such as malaria, dengue and other mosquito-borne diseases, in endemic areas and in new risk areas (e.g., cities, mountains, Northern Hemisphere)	Substantial increase in average temperature, precipitation and/or humidity	Large increases in human exposure to mosquito vectors driven by growth in human and mosquito populations, globalisation, population mobility and urbanisation	Lack of effective vaccine, ineffective personal and household protection, poverty, poor hygiene conditions, insecticide resistance, behavioural factors	Improved housing, better sanitation conditions and self-protection awareness. Broader access to public health system for the most vulnerable. The establishment of early-warning system of vector-borne diseases. Cross-border joint control of outbreaks. Sound usage of insecticides	*Medium confidence* (*medium evidence*, *medium agreement*)	7.3, 7.4

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Occurrence and intensity of some water-borne diseases	Mostly developing countries (Africa and Asia); global for vibrios	Increase in the occurrence and intensity of water-borne diseases such as vibrios (particularly *V. cholerae*), diarrhoeal diseases, other water-borne gastro-intestinal illnesses	Substantial changes in temperature and precipitation patterns, increased frequency and intensity of extreme weather events (e.g., droughts, storms, floods), ocean warming and acidification, among others	Large increases in exposure, particularly in areas with poor sanitation, flood-prone areas and favourable ecological environment for water-borne disease pathogens	Poor hygiene conditions, lack of clean drinking water and safe food, flood and drought prone areas, vulnerabilities of water and sanitation systems	Improved personal drinking and eating habits, behaviour change, drainage systems, improved water, sanitation and hygiene conditions and better surveillance system	*Medium confidence* (*limited evidence*, *high agreement*)	7.3, 7.4
Occurrence and intensity of some food-borne diseases	Global	Increase in the occurrence and intensity of some food-borne diseases such as *Salmonella* and *Campylobacter*, including in high-income countries	Substantial changes in temperature and precipitation patterns, increased frequency and intensity of extreme weather events (e.g., droughts, storms, floods), ocean warming and acidification, among others	Large increases in exposure, particularly in areas with poor sanitation, flood-prone areas and favourable ecological environment for food-borne disease pathogens	Poor hygiene conditions, lack of clean drinking water and safe food, flood- and drought-prone areas, vulnerabilities of water and sanitation systems	Improved personal drinking and eating habits, drainage systems and improved water, sanitation and hygiene conditions and better surveillance system	*Medium confidence* (*limited evidence*, *high agreement*)	7.3, 7.4
Heat-related psychopathology	Global, but more likely in areas experiencing high temperatures	Substantial increase in psychopathology compared with base rate	Increased number of days with high temperatures		Lack of air conditioning. The elderly may be more susceptible	Emergency shelters for people to escape the heat; enhanced building design to protect inhabitants	*Medium confidence*	7.3
Psychopathology in response to extreme weather events	Global; some areas at greater risk for storms, flooding or wildfires	Substantial increase in psychopathology compared with base rate	Increased frequency of major storms, weather-related flooding or wildfires		Physical infrastructure that is vulnerable to extreme weather, inadequate emergency response and mental health services, social inequality	Improved urban infrastructure, warning systems and post-disaster social support	*High confidence*	7.3
Malnutrition due to decline in food availability and increased cost of healthy food	Global, with greater risks in Africa, South Asia, Southeast Asia, Latin America, Caribbean, Oceania	Substantial number of additional people at risk of hunger, stunting and diet-related morbidity and mortality. Severe impacts on low-income populations from low- and middle-income countries (LMICs). Risks especially high to groups that suffer greater inequality and marginalisation (see vulnerability column)	Climate changes leading to reductions in crop, livestock or fisheries yield, including temperature and precipitation changes and extremes, drought, and ocean warming and acidification	Large numbers of people in areas and markets particularly affected by climate impacts on food security and nutrition	High levels of inequality (including gender inequality), substantial numbers of people subject to poverty or violent conflict, in marginalised groups, or with low education levels. Additional contributions to vulnerability from slow economic development; ineffective social protection systems, nutrition services and health services. Low-income smallholder farmers and pastoralists	Multi-sectoral approach to nutrition-sensitive adaptation and disaster risk reduction/management, including food, health and social protection systems. Inclusive governance involving marginalised groups. Improved education for girls and women, maternal and child health, water and sanitation, gender equality, climate services, social protection mechanisms	*High confidence* (*robust evidence*, *high agreement*)	7.3

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Chapter 8: Poverty, livelihoods and sustainable development								
Risk of loss of livelihoods and forced migration (social tipping points) due to the degradation of livelihood assets by increasing drought and heat stress, particularly in already vulnerable regions	Sahel and South Asia	Substantial increase of health and livelihood risks due to climate change in countries with poor state support. Forced migration of particularly poor people engaged in climate-sensitive livelihoods and urban dwellers living under chronic poverty	Increasing drought stress in the Sahel region and increasing heat stress in urban areas, particularly affecting the livelihoods of the poor and most vulnerable groups	Increase of population being exposed, e.g., due to forced migration into cities (heat stress in urban areas)	The Sahel region and South Asia rank already today among the most vulnerable world regions also considering the level of poverty and the framework conditions for coping and adaptation (e.g., state fragility). In these regions, the number of people with climate-sensitive livelihoods is high, and thus the direct and indirect effects of increasing temperature will be felt severely; selected adaptation measures might even worsen the situation for the most vulnerable (e.g., relocation)	Adaptation options are limited, since the economic base and enabling conditions for effective adaptation are absent. Forced migration and even more severe challenges are expected	*High confidence*	8.2; 8.3
Risk of increasing chronic poverty due to climate change hazards on climate-sensitive livelihoods	Various regions	The direct and indirect impacts (e.g., due to the modification of access to resources) can increase the likelihood of chronic poverty. In an inequality scenario (SSP4), the number of people that are living in extreme poverty could increase by 100 million	Severe intensification of droughts and sea level rise in coastal zones	Millions of people are exposed to more intensive droughts and heat stress and sea level rise. There is a high probability that the present spatial hotspots will persist into the future even under a 1.5°C warming scenario by 2030	Very limited coping and adaptive capacities, dependency on specific climate-sensitive livelihoods, which increases the risk of chronic poverty, particularly if social safety nets are missing and state support is limited	Very limited adaptation options. Often, livelihood shifts are needed that would require external support or support from the national level, which is often not provided. Negative adaptation cascades	*High/medium confidence* (depending on the world region)	8.3
Cascading risks to vulnerability and inequality	Global hotspots of vulnerability (see vulnerability map in Chapter 8, Figures 8.5 and 8.6)	Exacerbation of vulnerability also increasing inequality and marginalisation	Changing sequences between different climatic hazard events and shorter intervals (higher frequency of events) as well as shifts in the spatial distribution of extreme events	In general, more people will be exposed to such conditions due to intensification of warm spells, droughts and heat stress in various world regions	Time to recover gets shorter—new sequences of hazard cascades leads to a further erosion of coping and adaptive capacities. New cascading vulnerabilities emerge (selling of livestock, forced migration)	Economic diversification, new warning systems, improved international and national support regimes (social safety nets)	*Medium confidence*	8.2, 8.3

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Increased risk of food and water insecurity among poor members of society	The highest risk in South Asia, East Asia and the Pacific, and Sub-Saharan Africa	Permanent and perennial loss of livelihoods among the poor due to extreme events. This includes urban households, rural poor, Indigenous People, rainfed-agriculture-dependent livelihoods and cattle ranching as well as fisheries-dependent communities in the Global South and especially in least developed countries	Global temperature warming exceeding 1.5°C, sea level rise and extreme events (droughts, floods, cyclones, etc.)		High level of poverty, precarious settlements and living conditions, informality, and high dependence on climate-sensitive livelihoods. High inequality (socioeconomic, gender, Indigenous People, caste, among others), absence of state programmes such as health, education and proper sanitation social support	Social protection, strengthening capacity building for climate-resilient agriculture, support local fisheries management. Addressing cross-scales and multiple forms of inequalities that amplify or create vulnerabilities)	*Medium confidence* (*medium evidence*, *high agreement*)	Table 8.1, 8.2.1.4, 8.4, 8.5, 8.6
Risk of increasing levels of extreme poverty	Global South Countries	Up to 122 million additional people in extreme poverty due to climate change. Risk highest for poor urban and rural households, including differential impacts by gender, age and ethnicity	Increasing global warming beyond 1.5°C, increased incidence of heatwaves, droughts, floods		Persistence of high socioeconomic inequalities within and across nations; increased numbers of low-income people, and precarious settlements (especially in risk prone areas), poor sanitation and health assistance		*High confidence* (*medium evidence*, *high agreement*)	8.2, 8.4, 8.5
Risk of loss of life, infrastructure and income due to floods, with cascading risks to food security and health	Southeast Asia and Africa, parts of Latin and South America	Material and non-material impacts associated with losses of life, infrastructure, agriculture, income, cascading to food insecurity, incidence of vector- and water-borne disease, in most urban poor, as well as agriculture- and fisheries-based communities	Increasing global warming temperature beyond 1.5°C, incidence of floods and cyclones; extreme precipitation and inland flooding; monsoon-affected countries, cyclones, typhoons and hurricanes	Increased numbers of low-income people, poor and precarious settlements (especially in risk prone areas); increasing population in risk-prone areas	High-level poverty, precarious settlements, informality, subsistence and inequality (by socioeconomic status, gender, ethnicity, caste, religious beliefs, among others). People living in high mountain regions, remoteness and poor infrastructure challenge access to other livelihood options	Social protection, capacity building for climate-resilient agriculture, support for local fisheries management and disaster prevention	*High confidence* (*medium to robust evidence*, *high agreement*)	Table 8.1, 8.4.
Risk of food and water security due to drought	Asia and southern and western Africa, and tropical countries in Latin America	Losses in agriculture, fisheries, forestry, cascading to food and water insecurity and forced migration	A warming scenario greater than 1.5°C will be increasing the frequency and intensity of droughts-detrimental for poor countries in the Global South		Inequalities in access and use of water resources		*Medium evidence*, *high agreement*	8.2, 8.4, 8.5

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Risk of mortality, morbidity, and loss of income in poor households due to extreme heat	Global South, mostly in India, Southeast Asia and Sub-Saharan Africa	Large increase in mortality due to extreme heat, mainly outdoor workers, the elderly, ethnic minorities, urban poor	Increasing global warming temperature beyond 1.5°C will exacerbate extreme heat, including urban heat island		High poverty level, informal and precarious settlements, lack of income and air conditioning, health systems. Continued or exacerbated income inequality combined with slow economic growth and ineffective or non-existent social protection, urban planning and cooling systems	Addressing inequalities, increasing investments in social protection, heath and sanitation	*Medium evidence*, *high agreement*	8.4 [Table 8.7], 8.5, 8.6
Chapter 9: Africa								
Local or global extinction of species and reduction or irreversible loss of ecosystems and their services in freshwater and land ecosystems	Africa	Extinction of around 10% of African species (5–33% depending on organism group)	Increase in annual average temperature and changes in precipitation (both increases and decreases). Quantitative extinction estimate provided for a global warming level of 4.3°C above pre-industrial (RCP8.5 in 2080–2100)		Vulnerability highest among poorly dispersing organisms (plants), ectotherms (e.g., insects), species with narrow and disappearing niches (e.g., mountain endemics) and exacerbated by non-climate hazards (e.g., habitat loss for expanded agriculture, bioenergy and mitigation afforestation projects); vulnerability is high for Protected Areas (PAs) surrounded by transformed land preventing species dispersal and PAs with limited elevational gradients that reduce their potential to act as climate refugia	Improved management and increased coverage and connectivity of protected areas, targeted conservation (e.g., assisted migration); management of land outside PAs to enhance dispersal (e.g., restoration); ecosystem restoration; diversified livelihoods for people dependent on PAs	*Medium confidence*	9.6.2
Risks to marine ecosystem health and livelihoods in coastal communities due to ocean heatwaves, increased acidification and sedimentation/turbidity	Africa, particularly nearshore habitats (coral reefs, seagrass beds and mangroves)	Destruction of 90% of coral reefs and severe degradation of seagrass beds and mangroves, and associated loss of livelihoods in coastal communities	Coral reef impacts provided for RCP4.5; mangroves and seagrass beds will be severely impacted from 2°C		Vulnerability highest for low-income coastal communities (e.g., artisanal fisherfolk, fishmongers) whose livelihood depends on healthy coral reefs, seagrass beds and mangroves	Adaptation options include: (i) ensuring that people have the assets to draw upon in times of need; (ii) providing the flexibility to change; (iii) learning about climate change and adaptation options; (iv) investing in social relationships; and (v) empowering people to have a say in what happens to them, ensuring the ability to determine what is right for them	*High confidence* (*robust evidence, high agreement*)	9.6.2, 9.8.5

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Risk of food insecurity, malnutrition (micronutrient deficiency) and loss of livelihood due to reduced food production from crops, livestock and fisheries	Africa: risk is more pro-nounced in dry lowlands and the Sudano-Sahelian savanna zones of Africa. For fisheries, tropical ocean regions are at higher risk due to ocean warming	Severe reduction in food security and increase in malnutrition due to declines up to 5–15% in yield of staple crops, and 30–45% in net primary productivity of rangelands, varying by crop and region. Declines in fish catch potential in tropical west Africa of >50%	Yield impact estimates provided for 1.5–2°C global warming relative to 1980–2010; primary productivity impact on rangelands estimates provided for RCP8.5 at 2050. Fisheries impacts for RCP8.5 in 2080–2100		Vulnerability is highest for food producers dependent on rainfall and temperature conditions, including subsistence farmers, the rural poor, pastoralists and populations reliant on fish for protein and micronutrients	The combination of (i) Climate Information Services (CIS), (ii) institutional capacity building and (iii) strategic financial investment can be effective adaptation responses to projected climate risks	*High confidence*	9.8.2
Risk to water and energy security due to drought-induced shortage of irrigation and hydropower	Africa (especially southern Africa)	Hydropower and irrigation revenues in Zambezi Basin decline up to USD 45 billion relative to baseline scenario. Consumer electricity expenditure could increase 47% across the Southern African Power Pool	Severe risks driven by long-term warming and drying and reduced river runoff, which occurs in some climate models (high uncertainty in hydrologic outcomes)	Increased urbanisation, population and economic growth, increasing electricity and food demand. Dramatic planned expansion in hydropower (+581%) and irrigation capacity (+63%) under the Program of Infrastructure Development in Africa	High reliance on hydropower for national electricity generation in East and Southern African countries (>90% in some countries). Planned for high reliance on irrigated food production. Limited electricity trade between major river basins. Concentrations of hydropower plants within river basins that will experience similar rainfall and runoff patterns. Limited electricity trade between river basins	Increased electricity trade between river basins, which have little correlation in yearly rainfall and runoff. More diverse electricity generation mixes. Catchment restoration and integrated water management schemes. Urban gardening and agriculture	*Medium confidence (medium evidence, high agreement)*	9.7.2, 9.9.4, Box 9.5
Risk of decreased economic output and increased poverty rates due to increased heat and frequency and severity of drought	Africa	Up to 10–20% reduction in aggregate GDP per capita for 1.5–2°C by 2100 and 80% reduction in GDP per capita by 2100 (RCP8.5, SSP5). Up to 43 million Africans pushed into extreme poverty by 2030 (SSP4) by climate change (GWL 1.2°C). Likely widespread across Africa, but with particular severity in Sub-Saharan countries. Most severe for the poor, agriculturally dependent and populations already inhabiting hot climates today	Severe impacts of 5–20% reduction in GDP per capita projected with global warming of 1.5–2°C above pre-industrial due to increases in temperature; increase in the frequency, duration and severity of drought	Effects are nonlinear, so that severe conditions occur when warming is substantial in places already experiencing high temperatures	Conditions underlying severe risk are lower income growth (caused by other factors besides climate change impacts), higher population levels, lower technology transfer from developed countries, low rates of structural economic change implying more of the labour force engaged in agriculture, construction, resource extraction and other highly climate-exposed industries due in part to physical labour outdoors (e.g., 2–16% loss of work hours due to heat, depending on region in Africa)	Structural transformation (e.g., lowering the share of the labour force in agriculture), income growth enhanced by non-climate factors, education of workers and employers on severity of risk and options for reducing risk (fans, cool water, regular breaks, shade, etc.), social transfer payments to alleviate short-run effects of drought and temperature on the poor	*Medium confidence (medium evidence, medium agreement)*	9.11.2

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Risk of increased mortality and morbidity due to increased heat	Africa	Hundreds to thousands of additional deaths per year per region due to heat	Substantial increase in frequency and duration of extreme heat events in an RCP4.5 or RCP8.5 scenario by 2100, including days over deadly heat threshold, exacerbated by urban heat island effects. 50–350 d yr^{-1} above deadly heat threshold, being most severe in West and Central Africa	Large increases in exposure to heat, particularly in urban areas, driven by population growth and increased urbanisation. Total population exposure to extreme heat in African cities will likely increase by a factor of as much as 52 times that of present exposure (i.e., 217 billion person-days per year) by the end of the 21st century. Large and growing urban population residing in informal settlements	Vulnerability is highest for elderly, pregnant women, individuals with underlying conditions, immune-compromised individuals (e.g., from human immunodeficiency virus [HIV]) and young children. Inadequate insulation in housing in informal settlements in urban heat islands. Inadequate improvements in public health systems	Options for reducing heat risk (building codes, use of insulating materials, fans, cool water, regular breaks, shade)	*High confidence*	9.10.2
Risk of increased mortality and morbidity due to increased vector-borne diseases	Africa	Millions of additional deaths over time due to vector-borne diseases	Expansion of geographic areas with suitable temperatures and precipitation for vector-borne diseases at 1.5–2°C global warming	Population at risk of dengue fever projected to double by 2050, and almost triple by 2080, in scenarios with over 2°C warming. New exposure to malaria will be rapid, with an additional 22–36 million projected to face new risk by 2030 (RCP4.5)	Elderly, pregnant women, individuals with underlying conditions, immune-compromised individuals (e.g., from HIV) and young children are most vulnerable to complications from exposure to the risk. Regions without vector control programmes in place or without detection and treatment regimens	Vector control, vaccination and integrated disease control programmes, and outbreak surveillance	*High confidence*	9.10.2
Risk of increased mortality and morbidity due to increased diarrhoeal diseases	Africa	Hundreds of thousands of additional deaths due to water-borne diarrhoeal diseases	Increasing temperatures (RCP4.5; early in the century) and surface-water runoff contaminating drinking water supplies, and changing sea salinity and temperatures influencing cholera prevalence		Elderly, pregnant women, individuals with underlying conditions, immune-compromised individuals (e.g., from HIV) and young children are most vulnerable to complications from exposure to the risk. Inadequate water and sanitation infrastructure, especially in rapidly expanding urban areas and informal settlements. Disruption of vaccination programmes and primary healthcare due to climate impacts on the healthcare system or conflict will exacerbate outbreaks	Improved water sanitation and hygiene as well as waste disposal management, vaccination and outbreak surveillance	*High confidence*	9.10.2

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Cascading and compounding risks to economies and governance due to severe, concurrent or successive climate-intensified natural disasters (floods, droughts, fires, wind, heat) affecting human settlements and infrastructure	Africa, particularly in coastal cities	Loss of life and disruption of livelihoods together with damage to key urban infrastructure and services from flood events, particularly high risk within coastal cities. Impacts overwhelm capability to recover, respond or adapt. Restricted access to water resources, and water shortages in urban areas disrupting sanitation and food processing and distribution systems	Increase in frequency and intensity of extreme precipitation, exacerbated by long-term sea level rise. More frequent and prolonged drought events, and land subsidence in coastal cities that extract groundwater	Large increases in exposure, particularly in urban areas, driven by population growth, changing demographics and projected urbanisation patterns	Unaffordable maintenance of protective infrastructure, downstream levee effects and increased concentrations of coastal urban populations. Greater water resource demand from urban and non-urban populations and key economic sectors	Early-warning systems. Water restrictions. Financial tools for risk management. Monitoring and forecasting systems. Economic incentives for behaviour change. Disaster risk preparedness, response and recovery plan. Enforced, robust environmental regulations and assessments for developments. Leadership locally accountable	*Medium confidence*	9.9, Box 9.4
Chapter 10: Asia								
Heat stress, mortality and morbidity from exposure to extreme heat, heatwaves	Across Asia	Increased heat mortality by up to a factor of 5–7 in some countries, along with increases in heat stress and incidence of morbidity	Mortality impact estimates are based on RCP4.5 and RCP8.5 and associated increase in frequency and duration of extreme heat events, hotter nights and days, all exacerbated by urban heat island	Increased exposure, particularly in dense urban areas, informal settlements driven by increase in built-up area, building type	Vulnerability is exacerbated by built form (e.g., informal settlers living in tin roof houses which heat up fast and take longer to cool down), changing demographics from ageing populations, unequal access to air cooling facilities, inadequate coverage of public health services	Nature-based solutions, e.g., investing in green infrastructure such as green roofs, urban green spaces; improved built form (e.g., passive cooling); increased public awareness about heat impacts and protection measures; more inclusive public health systems, especially for most vulnerable populations	*Medium evidence*, *high agreement*	10.3.7.3, Box 10.3, 10.4.8
Risk to life and property due to sea level rise and coastal flooding	South and Southeast Asia	Loss of life and substantial damage to property especially in East Asia, ranging up to hundreds of millions of dollars per year in damages in some cities .	Property damage estimates based on 0.2 m SLR and associated coastal flooding; 1.9 m SLR projected for some regions with 5°C warming	Land subsidence in coastal cities will exacerbate % of population exposed to SLR and coastal flooding. In coastal cities such as Bangkok and Ho Chi Minh City, projected land subsidence rates are comparable to, or exceed, expected rates of sea level rises, resulting in an additional 0.2 m sea level rise by 2025	Poor drainage, inadequate flood management interventions, population density of high-risk groups in exposed areas	Sustainable water management through improved storm water management. Infrastructure-based interventions such as polders, dykes, storm sewer upgradation, improving drainage, and increasing height of road embankments and minor bridges. Developing green infrastructure for improving permeability, managing runoff. Instituting flood early-warning systems, emergency plans to deal with flood risk and mitigate waterlogging.	*Medium evidence*, *high agreement*	10.3.7.3, 10.3.7.3.1, Box 10.3

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Risk to water security due to urban droughts	Across Asia	Restricted water access, regular tapping into beyond-city resources	Projections of more frequent and prolonged drought events	Large increases in exposure, particularly in urban areas, driven by population growth, changing demographics and projected urbanisation patterns	Greater water resource demand from urban populations and key economic sectors	Demand and supply side management strategies	*Limited evidence*	10.3.7.3, Box 10.3
Urban infrastructure damage due to flooding	Across Asia	Damage to key urban infrastructure and services from flood events	Substantial increase in frequency and intensity of extreme precipitation leading to up to 50% increase in area flooded in some cities	Increased exposure driven by population growth, increased built-up area	Vulnerability exacerbated by poor drainage, inadequate flood management interventions, inadequate or costly protective infrastructure, poor levee management systems, population density of high-risk groups in exposed areas	Adequate building codes to avoid infrastructure development in high-exposure locations. Designing an early-warning system to initiate flood mitigation procedures, such as isolating critical electrical and mechanical operating systems from water	*High confidence* (*robust evidence*, *high agreement*)	10.3.7.3, Box 10.3
Urban infrastructure damage due to permafrost thawing	Northern Russia	Large changes in bearing capacity affecting as much as 50% of residential buildings, 20% of critical infrastructure, tens of billions of dollars of potential damage; trade disruptions	Persistent thawing of ice-rich permafrost, ground subsidence		Presence of ageing infrastructure, high buildings in unstable areas	Land use practices, permafrost monitoring, maintenance of infrastructure and engineering solutions (such as use of thermosiphons) may temporarily offset negative effects of permafrost degradation in small, economically vital areas, but are unlikely to have an effect beyond the immediate areas	*Medium confidence* (*medium evidence*, *high agreement*)	10.3.7.3, Table 10.2
Migration, displacement from intersection of climatic and non-climatic drivers	South, Southeast Asia	Migration, displacement, implications on cohesion/ conflict	Increasing temperatures, climate variability, extreme events	Populations in climate hotspots facing multiple climatic and non-climatic risks simultaneously	Lack of livelihood opportunities in source areas, especially for poor/marginal social groups	Migration itself can be a successful adaptation strategy. Strong social safety nets in destination areas can support migration and enable positive outcomes for migrants	*Medium confidence* (*medium agreement*, *medium evidence*)	Box 10.2
Biodiversity and habitat loss	Asia	Species extinction, biological invasion which would cause damages to ecosystem function and services	Rapid climate warming plus accelerated human disturbances	Polar and high elevated regions, fragmented habitats such as nature reserves	Polar or mountain hills, fragmented habitats facing climate warming which prevent migration of organism	Setup of large national park, connection of isolated nature reserves and protection of polar species in gardens or zoos	*High confidence*	10.4.2.1.6 Biodiversity and habitat loss, 10.4.2.1.7 Invasive species

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
More frequent and extensive coral bleaching and mortality	Across Asia	Decline in coral recruitment, variation in coral community structure, changes in functional traits, coral—algal symbiosis, reduction in associated faunal biodiversity, reduction in ecosystem services including coastal protection, increase in disease prevalence and slow growth	Climate and non-climate hazards, including ocean warming, ocean acidification, sea level rise, marine heatwaves, resource extraction	Shallowness of reef coral location; increasingly frequent temperature-induced mortality events	Proximity to urban and industrial development area, land-based pollution and destructive shoreline practices; progressive reduction in coral size, cover and population fecundity leading to low recruitment	A coupled socio-ecological-political, restoration and management framework for restoration; ecosystem-based approach; use of coral nurseries as repositories for coral and reef species	*High confidence*	10.4.3, 10.4.6
Degradation and deforestation of mangrove forests and its functional services	Across Asia	Reduction in ecosystem services impacting fisheries, aquaculture and tourism; loss of protection from extreme events impact especially for coastal poor living below poverty line in Southeast Asia	Sea level rise, increasing frequency of tropical cyclones and floods, heavy rainfall, anthropogenic activities	Proximity to human settlement; increasing demand for conflicting coastal management priorities	Increase in coastal population, land use change and increasing extreme events	Interdisciplinary approach to mangrove management and conservation	*Medium confidence*	10.4.3, 10.4.6
Degradation and loss of seagrass meadows	Across Asia	Destruction of seagrass beds and their community structure; reduction in ecosystem services affecting habitat-dependent species, nursery grounds of fishes and leading to decline in fishery resources	Climatic factors such as ocean warming, extreme events, heatwaves	Extreme events and coastal eutrophication and non-climatic anthropogenic stressors leading to excessive sedimentation	Frequent warming episodes and increasing coastal population and activities such as boating and anchoring, and ecological factors such as grazing herbivores, diseases, increased turbidity/ sedimentation from agriculture/aquaculture activities	Restriction of destructive activities, restoration programmes	*Medium confidence*	10.4.3, 10.4.6
Economic risk to aquafarmers due to disease outbreak in aquaculture farms	Across Asia	Loss of crop, economic loss to aquafarmers, seafood traders	Increasing temperature, heavy precipitation leading to lowering of salinity		Vulnerability exacerbated by poor water quality, high stocking density, simple non-sophisticated small-scale farming systems	Better management systems, early diagnostic facilities	*Medium confidence*	10.4.6

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Decline in coastal fishery resources	Across Asia	Shifts or reduction in marine resource abundance; changes in trophic structure, prey–predator relationships, and their cascading effects in different trophic levels; fisheries and allied sectors; coastal communities	Increased surface warming, low/varied primary and secondary productivity, ocean acidification, hypoxic conditions, increasing stratification, changes in coastal upwelling timing and intensity, eutrophication, harmful algal blooms and more frequent extreme events (floods, tropical cyclones and marine heatwaves), loss of critical habitats to sea level rise	Extreme ocean heat will continue to become more frequent, more intense and longer in duration owing to climate change, affecting fisheries and food webs, and leading to mass mortality, disease outbreaks and reduced biodiversity across coastal systems	Unhealthy and reducing habitats (mangroves, macro-algal communities, coral reefs, estuaries and beaches); can affect the metabolism, growth, feeding behaviour, spawning and recruitment	Location/species specific fishery management protocols, restoration of coastal critical habitats for increased recruitment success	*High confidence*	10.4.6 (cross ref. to 10.4.3)
Deaths, injuries, infectious diseases and mental disorders due to floods	Across Asia	Increased flood-related deaths and lower well-being due to drowning, injuries, infectious diseases and mental disorders	Increase in frequency of heavy rainfall and subsequent flooding	A large number of people living in the flood-prone areas	Low preparedness and coping strategies in the communities to flooding such as river water management and early-warning system	Disaster preparedness including river water management, early-warning system and local coping strategies	*Medium confidence*	10.4.8
Risk to food and water security due to drought	Across Asia	Increased deaths due to starvation and other causes related with malnutrition	Increase in frequency of low rainfall and subsequent drought	A large number of people living in the drought-prone areas	Low preparedness and coping strategies in the communities to drought such as water management and early-warning system	Disaster preparedness including water management system, early-warning system and local coping strategies	*High confidence*	10.4.8
Risk of water and vector-borne diseases	Across Asia	Increased deaths due to water and vector-borne diseases	Population living in low hygiene and sanitation conditions and areas where the vectors exist	Rising ambient temperature and rainfall, and increased frequency of extreme events, including flooding and drought	Low hygiene and sanitation conditions, and inactive vector control programmes	Early-warning system, vector control programmes, water management and sanitation programmes	*Medium confidence*	10.4.8

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Chapter 11: Australasia								
Loss and degradation of tropical shallow coral reefs and associated biodiversity and ecosystem service values in Australia due to ocean warming and marine heatwaves	Australia	Widespread destruction of coral reef ecosystems and dependent socio-ecological systems. Three mass bleaching events from 2016 to 2020 have already caused significant loss of corals in shallow-water habitats across the Great Barrier Reef. Globally, bleaching is projected to occur twice each decade from 2035 and annually after 2044 under RCP8.5 and annually after 2051 under RCP4.5. A 3°C global warming could cause over six times the 2016 level of thermal stress.	Increase in background warming and heatwave events degrade reef-building corals by triggering coral bleaching events at a frequency greater than the recovery time. Fish populations also decline during and following heatwave events	Increasing geographic area affected by rate and severity of ocean warming	Vulnerability to increases in sea temperature is already very high because of other stressors on the ecosystem, including sediment, pollutants, and overfishing	Minimising other stressors on the ecosystem. Efforts on the Great Barrier Reef may slow the impacts of climate change in small regions, or reduce short-term socioeconomic ramifications, but will not prevent widespread bleaching	*Very high confidence*	11.3.2, Box 11.2, Table 11.14
Loss of alpine biodiversity in Australia due to less snow	Southeast Australian Alps Bioregion	Loss of endemic and obligate alpine wildlife species and plant communities (feldmark and short alpine herb-fields) as well as increased stress on snow-dependent plant and animal species	Projected decline in annual maximum snow depth by 2050 is 30–70% (low emissions) and 45–90% (high emissions); projected increases in temperature and decreases in precipitation	Alpine species face elevation squeeze due to lack of nival zone and alpine environments have restricted geographic extent	Narrow ecological niche of species including snow-related habitat requirements; encroachment from sub-alpine woody shrubs; vulnerability generated by non-climatic stressors including weeds and feral animals, especially horses	Reducing pressure on alpine biodiversity from land uses that degrade vegetation and ecological condition, along with weed and pest management	*High confidence*	11.3.1, Tables 11.2, 11.3, 11.4, 11.5, Table 11.14
Transition or collapse of alpine ash, snowgum woodland, pencil pine and northern jarrah forests in southern Australia due to hotter and drier conditions with more fires	Southern Australia	If regenerative capacities of the dominant (framework) canopy tree species are exceeded, a long lasting or irreversible transition to a new ecosystem state is projected with loss of characteristic and framework species, including loss of some narrow-range endemics	Hotter and drier conditions have increased extreme fire weather risk since 1950, especially in southern and eastern Australia. The number of severe fire weather days is projected to increase 5–35% (RCP2.6) and 10–70% (RCP8.5) by 2050	Shift in landscape fire regimes to larger, more intense and frequent wildfires over extensive areas (~10 million hectares) of forests and woodlands from longer fire seasons and more hazardous fire conditions and increasing human-sourced ignitions from urbanisation and projected increase in frequency of lightning strikes	The resilience and adaptive capacity of forests is being reduced by ongoing land clearing and degrading land management practices	Increased capacity to extinguish wildfires during extreme fire weather conditions; avoiding and reducing forest degradation from inappropriate forest management practices and land use	*High confidence*	11.2, 11.3.1, Box 11.1, Table 11.14

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Loss of kelp forests in southern Australia and southeast New Zealand due to ocean warming, marine heatwaves and overgrazing by climate-driven range extensions of herbivore fish and urchins	Southern Australia and southeast New Zealand	Observed decline in giant kelp in Tasmania since 1990, with less than 10% remaining by 2011 due to ocean warming. Extensive loss of kelp -140,187 hectares across Australia. Loss of bull kelp in southern New Zealand, replaced by the introduced kelp following the 2017/18 marine heatwave. Further loss of native kelp is projected with warming oceans.	Ocean warming and marine heatwave events	Coastal waters around Australia and New Zealand	Giant kelp are already Federally listed in Australia as an endangered marine community type. In Australia, kelp forests are vulnerable to nutrient poor East Australian Current waters pushing further south, warming waters and increased herbivory from range-extending species.	Minimizing other stressors, local restoration, and transplantation of heat-tolerant phenotypes.	*High confidence*	11.3.2, Table 11.14
Loss of human and natural systems in low-lying coastal areas from ongoing sea level rise	Australasia	Nuisance and extreme coastal flooding are already occurring due to sea level rise (SLR). For 0.2–0.3 m SLR, coastal flooding is projected to become more frequent, e.g. current 1-in-100 year flood would occur every year in Wellington and Christchurch. For 0.5 m SLR, the value of buildings in New Zealand exposed to coastal inundation could increase by NZ$12.75 billion and the current 1-in-100 year flood in Australia could occur several times a year. For 1.0 m SLR, the value of exposed assets in New Zealand would be NZ$25.5 billion. For 1.1 m SLR, the value of exposed assets in Australia would be A$164–226 billion. This would be associated with displacement of people, disruption and reduced social cohesion, degraded ecosystems, loss of cultural heritage and livelihoods, and loss of traditional lands and sites sacred	Rising sea level (0.2–0.3 m by 2050, 0.4–0.7 m by 2090), storm surges, rising ground water tables	Population growth, new and infill urbanisation, tourism development in low-lying coastal areas. Buildings, roads, railways, electricity and water infrastructure. The Torres Strait Islands and remote Māori communities are particularly exposed and sensitive	Ineffective planning regulations, reduced availability and increased cost of insurance, and costs to governments as insurers of last resort. Inadequate investment in avoidance and preparedness, exacerbating underlying social vulnerabilities. Financial and physical capacities to cope and adapt are uneven across populations, creating equity issues	Risk reduction coordinated across all levels of government with communities. Statutory planning frameworks, decision tools and funding mechanisms that can address the changing risk. Planning and land use decisions, including managed retreat where inevitable., Improved capacity of emergency services, early-warning systems improved planning and regulatory practice, and building and infrastructure design standards. Options that anticipate risk and adjust as conditions change	*High confidence*	11.2, Table 11.3, 11.3.2, 11.3.5, 11.3.10, 11.4, Box 11.6, Table 11.14

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Disruption and decline in agricultural production and increased stress in rural communities across south western, southern and eastern mainland Australia due to hotter and drier conditions	South western, southern and eastern mainland Australia	Projected decline in crop, horticulture and dairy production, e.g. decline in median wheat yields by 2050 of up to 30% in south-west Australia and up to 15% in South Australia. Increased heat stress in livestock by 31–42 days per year by 2050 Reduced winter chilling for horticulture. Increased smoke impacts for viticulture. Flow-on effects for agricultural supply chains, farming families and rural communities across south-western, southern and south-eastern Australia, including the Murray-Darling Basin (MDB).	Hotter and drier conditions with constraints on water resources and more frequent and severe droughts in south-western, southern and eastern Australia	Across south western, southern and eastern Australia, many production regions are exposed including the MDB which supports agriculture worth A$24 billion/year, 2.6 million people in diverse rural communities, and important environmental assets containing 16 Ramsar listed wetlands.	Existing financial, social, health and environmental pressures on rural, regional and remote communities. Existing competition for water resources among communities, industries and environment, and uncertainty about sharing of water under a drying climate.	Better planning to reduce and accommodate competing water demands. Improved governance and collaboration to build rural resilience, including regional and basin-scale initiatives. Improved water policies and initiatives (e.g. MDB Plan) and changes in management and technologies. Resilience-focused planning for rural settlements, land-use, industry, infrastructure and value chains. Adoption of information, tools and methods to better manage uncertainty, variability and change. Incremental changes in farm management practices (e.g. stubble retention, weed control, water-use efficiency, sowing dates, cultivars). In some regions, major changes may be necessary, e.g. diversification in agricultural enterprises, transition to different land-uses (e.g. carbon sequestration, renewable energy production, biodiversity conservation) or migration to another area. Flows in waterways based on Indigenous knowledge to protect cultural assets.	*High confidence*	11.2, 11.3.4, 11.3.6.3, 11.4.1, Table 11.11, Boxes 11.1 and 11.3, Table 11.14

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Increase in heat-related mortality and morbidity for people and wildlife in Australia	Australia	During 1987–2016, natural disasters caused 971 deaths and 4370 injuries, with more than 50% due to heatwaves. Annual increases are projected for excess deaths, additional hospitalisations and ambulance callouts. Heatwave-related excess deaths in Melbourne, Sydney and Brisbane are projected to increase by about 300/year (RCP2.6) to 600/year (RCP8.5) during 2031–2080 relative to 1971–2020, assuming no adaptation. Significant heat-related mortality of wildlife species (flying foxes, freshwater fish) has been observed and is projected to increase.	Increased frequency, intensity and duration of extreme heat events	Pervasive, but differentially affecting some wildlife species depending on their thermal tolerances and occupational groups (e.g., outdoor workers) and those living in high-exposure areas (e.g., urban heat islands). Health risks multiply with other harmful exposures, e.g., to wildfire smoke	Lower adaptive capacity for young/old/sick people, those in low-quality housing and with lower socioeconomic status, areas served by fragile utilities (power, water). Remote locations with extreme heat and inadequate cooling in housing infrastructure (such as remote Indigenous communities). For wildlife, impacts of extreme heat events are being amplified by habitat loss and degradation.	Urban cooling interventions including irrigated green infrastructure and increased albedo, education to reduce heat stress, heatwave/fire early-warning systems, battery/generator systems for energy system security, building standards that improve insulation/cooling, accessible well-resourced primary health care For wildlife, removing human stressors, reducing pressures from ferals and weeds, and ensuring there is suitable habitat.	*High confidence*	11.2, 11.3.1, 11.3.5, 11.3.6, 11.4, Table 11.14

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Cascading, compounding and aggregate impacts on cities, settlements, infrastructure, supply-chains and services due to extreme events	Australasia	Widespread and pervasive damage to human activities generated by interdependencies and interconnectedness of physical, social and natural systems. Examples include: Failure of transport, energy and communication infrastructure and services, heat-stress, injuries and deaths, air pollution, stress on hospital services, damage to agriculture and tourism, insurance loss from heatwaves and fires; failure of transport, stormwater and flood-control infrastructure and services from floods and storms; water restrictions, reduced agricultural production, stress for rural communities, mental health issues, lack of potable water from droughts; damage to buildings, roads, railways, electricity and water infrastructure, loss of assets and lives, displacement of people, reduced social cohesion, and degraded ecosystems from extreme sea-level rise. Large aggregate costs due to lost productivity and major disaster relief expenditure, creating unfunded liabilities and supply chain disruption, e.g., the 2019–2020 Australian fires cost A$8 billion. The impact of a 1, 2 or 3˚C global warming (relative to 1986–2005) on Australian GDP growth is estimated at -0.3%/year, -0.6%/year and -1.1%/year, respectively, while for New Zealand estimates are -0.1%/year, -0.4%/year and -0.8%/year, respectively. Impacts on Māori tribal investments in forestry, agriculture, horticulture, fisheries and aquaculture.	Heatwaves, droughts, fires, floods, storms and sea level rise. This includes cascading and compound events such as heatwaves with fires, storms with floods, or droughts followed by heavy rainfall and extreme sea levels. .	Highly populated areas, rural and remote settlements, traditional lands and sacred sites. Greater urban density and population growth increases exposure in high-risk areas. Different exposure for different hazards, e.g. heatwaves: urban and peri-urban areas; fire: peri-urban areas and settlements near forests; floods: people, property and infrastructure from pluvial floods in cities and settlements and fluvial floods on floodplains; storms: buildings and infrastructure in cities and settlements.	Existing social and economic challenges (e.g. those caused by COVID-19) and socio-economic and cultural inequalities; competing resource and land use demands across sectors; inadequate planning, policy, governance, decision making and disaster resilience capacity; and non-climatic stresses on ecosystems. Vulnerabilities generated by interdependencies and interconnectedness of physical, social and natural systems.	Flexible and timely adaptation strategies that prepare socio-economic and natural systems for surprises and unexpected threats. Multi-sector coordinated actions that address widespread impacts, redress existing vulnerabilities and building adaptive capacity and systemic resilience. Improved coordination between and within levels of governments, communities and private sector. Greater use of dynamic decision frameworks and suitable economic and social assessment tools. Improved emergency services and early warning systems; use of climate resilient standards for buildings and infrastructure. Transformational adaptations e.g. managed retreat, that can be planned in stages.	*High confidence*	11.2, 11.3.4, 11.3.5, 11.3.6, 11.3.7, 11.3.8, 11.3.9, 11.3.10, 11.4, 11.5.1, Boxes 11.1, 11.4 and 11.6

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Inability of institutions and governance systems to manage climate risks	Australasia	Climate hazards overwhelm the capacity of institutions, organisations, systems and leaders to provide necessary policies, services, resources, coordination and leadership. Failed adaptation at the institutional and governance level has widespread, pervasive impacts for all areas of society. This includes a reliance on reactive, short-term decision making that locks in existing exposures, leaves perverse incentives and interconnected and systemic impacts unaddressed, and generates high costs, fiscal impacts. This worsens vulnerability and leads to maladaptation, inequities and injustices within and across generations, as well as actions that do not uphold the rights, interests, values and practices of Indigenous Peoples. Resultant failure to take adaptation action generates litigation risk.	The increasing frequency, duration, severity and complexity of extreme weather events, droughts and sea-level rise	All sectors, communities, organisations and governments	Fragmented institutional and legal arrangements, under-resourcing of services, lack of dedicated funding instruments and resources to support communities and local government, uneven capability to deal with uncertainty, and conflicting values and competing policy and political interests	Pre-emptive options that avoid and reduce risks. Redesign of policy, statutory frameworks and funding arrangements for addressing changing risks and uncertainties that enable just and collaborative governance across scales and domains. Addressing existing vulnerabilities, and capacity, capability and leadership deficits within and across all levels of government, all sectors, Indigenous peoples and communities. Risk and vulnerability assessment methodologies and decision-making tools that build resilience and address changing risks and vulnerabilities. Co-designed adaptation approaches implemented with communities including Māori tribal organisations and Australian Aboriginal and Torres Strait Island peoples.	*High confidence*	11.2, 11.3.5, 11.3.6, 11.3.7, 11.3.8, 11.3.10, 11.4, 11.5.1, Boxes 11.1–11.6

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Chapter 12: Central and South America								
Risk of food insecurity due to frequent/extreme droughts	Central and South America	Disruption of food provision chains/inability to acquire food for large parts of the population, reduced capacity for production of goods (food, fibre, fuel), reduced food security and increased malnutrition	More frequent and/or longer drought and extreme hot periods. Desertification of semiarid regions. High variability in the yearly rainfall patterns, particularly a severe decrease in rainfall at the onset of the rainy season. Decrease in amount of rainfall overall	More people exposed to food insecurity due to spatially more extensive drought, high population growth rate (including rural areas) and more population dependent on goods	Reduced capacity of farmers, especially small-scale farmers, to adapt to changing climatic conditions. Soil degradation. Limited institutional and governance-related capacities, inefficient water management including water storage and irrigation systems. Insufficient governmental support via extension service, infrastructure, technology, insurance, early-warning systems, research and innovation	Improved water governance (storage, irrigation) with inclusion of climate change considerations, improved water eco-efficiency (recycling and reusing). Reducing grazing pressure on vulnerable lands, prevention of deforestation and recovery of degraded lands. Support for development and adoption of improved or less susceptible key food security and more lucrative crops. Institutional support to small-scale farmers (funding, information), reduced inequalities and power relations in food production systems, and more efficient food provision chains. Implementation of state and national Adaptation Plans. Improved seasonal climate forecasts	*Medium confidence* (*medium evidence*, *high agreement*)	12.3.1–12.3.8, 12.4, 12.5.9
Risk to life and infrastructure due to floods and landslides	Central America; South American Monsoon; and Northwest, North, Southeast and Southwest South America	Death and severe health effects, disruption of critical infrastructure and basic service provision systems	More frequent and stronger storms and heavy precipitation events. For some regions, possibly higher rainfall variabilities combined with higher extreme rainfall. Changing snow conditions and thawing of permafrost. Retreating glaciers resulting in glacier lakes forming and increased glacier lake outburst flood hazard	More people exposed to floods and landslides, due to changing hazards, land use and increased population, together with occupation of more risk-prone areas. More people in poverty living in high-risk areas on steep slopes in urban areas or flood plains in urban and rural areas	Vulnerable populations are usually low income and marginal. Low resilience in infrastructure and critical service systems. Limited government support through insurance, monitoring and early-warning systems, as well as poor disaster management after extreme events	Generally high potential for adaptation, with future risks strongly depending on adaptation and development pathways. Integrated disaster risk management, increasing resilience of infrastructure and service systems. Relocation of people in high-risk areas. Better land use planning and urban development planning	*Medium confidence* (*medium evidence*, *medium agreement*)	12.3.1–12.3.4, 12.3.6, 12.3.7, 12.4, 12.5.9

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Risk of water insecurity	Central America; South American Monsoon; and Northwest, North, Southeast and Southwest South America	Tens to more than hundred million people exposed to water stress and scarcity. For a 2.7°C global warming scenario in 2050, up to 112 million people will be exposed to increasing water resources stress in Meso-America, up to 28 million in Brazil, and up to 31 million in the rest of South America	Seasonal water availability change and decline due to glacier shrinkage and snow cover change, more pronounced dry periods, and precipitation and circulation changes. Following 2°C projections, regions between 10 and 30°C S may experience a reduction of 20% in precipitation during dry season (50% in central Brazil)	Increased demand from intensification of agriculture, mining, hydropower and urbanisation. Increase in population and water use/demand dependent on high contribution of glacier/snow melt, especially during drought conditions	Unjust and unequal water consumption and distribution, decreasing water management and storage. Low governance capacities, dependence on melt water contribution, low water infrastructure efficiency, vulnerable and growing urban areas	Improved and integrated water governance (management strategies that consider dams, water use and hydropower plans). Reduction of hydroelectric power and investment in other renewable energy sources. Ecosystem-based adaptation projects. Efficient water storage for dry periods. Diversification of water sources (wastewater reuse, rainwater harvesting). Strong public participation and knowledge integration, including IKLK	*High confidence*	12.3.1, 12.3.2, 12.3.4–12.3.7, 12.4, 12.5.9
Risk of severe health effects due to increasing epidemics (in particular, vector-borne diseases)	Central America; South American Monsoon; and Northwest, North, Southeast and Southwest South America	Severe health effects and damage to health systems. Higher epidemics of vector-borne diseases malaria, dengue fever, Zika and leishmaniasis, together with diarrhoeal diseases. Following the RCP8.5 scenario, the geographic distribution of the malaria pathogen Plasmodium falciparum could cover 35–46% of South America by 2070	Higher max and min temperatures increase the geographical range of vectors, leading to predicted area of climate suitability and elevation ranges expansion	Density of population increased by urbanisation, resulting in higher transmission rates. Increased population exposed to arboviruses due to expansion of *Aedes* spp., including places of higher altitude and latitude—Argentina, Guatemala, Ecuador, Brazil, Bolivia	Low sanitation conditions, particularly in low-income neighbourhoods and for Indigenous Peoples. Insuffi-cient coverage of appropriate water provision and sewage systems. Underfunding of health system services. Poor malaria control status and low structural and economical capacity to cope. Water accumulation in puddles and containers increases breeding sites for mosquitoes. Increase in infections can increase the incidence of more severe forms of dengue	Improved housing protection. More distributed and better public health services, together with improved infrastructure. Changes in water storage technologies, as well as water supply practices and systems. Integration of Indigenous knowledge and vulnerabilities into current debates on adaptation, especially funding, within the UNFCCC. Social and educational measures	*High confidence* (*robust evidence*, *high agreement*)	12.3.1–12.3.7, 12.4, 12.5.9
Systemic risks of surpassing infrastructure and public service systems	Central and South America	Break-down of public service systems, including infrastructure and health services due to cascading impacts of natural hazards and epidemics, affecting large part of the population	Higher frequency and magnitude of climate hazards (storms, floods, landslides) together with an increase in spatial and temporal distribution of pathogens/vectors for malaria, dengue, Zika and leishmaniasis	More people and infrastructure exposed to climate/weather events. Increase in the population exposed to arboviruses due to expansion of the area of occurrence of competent vectors	Increasing vulnerability of public service and infrastructure systems. Insufficient disaster management. Little improvement, maintenance and expansion of public health care systems. Low/decreasing system resilience	Increase of systems' resilience, based on identification of thresholds in the system and where impacts cascades can be broken	*Medium confidence* (*medium evidence*, *medium agreement*)	12.3.1–12.3.8, 12.4, 12.5.9

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Risk of large-scale changes and biome shifts in the Amazon	South American Monsoon; and North and Northeast South America	Transitioning from tropical forest into other biomes such as seasonal forest or savannah through forest degradation and deforestation. Risk of shift from carbon sink to source. Projected tropical forest area reduction due to only climate forcing is 15% larger by 2050 for RCP8.5 than for RCP2.6. Combined effect of climate change and deforestation and forest fires predict over 60% reduction by 2050 (RCP8.5). Socioeconomic damage (primarily from changes in ecosystem services) over a 30-year period after Amazon Forest dieback is estimated to USD 957–3589 billion	More frequent, stronger and persistent dry conditions. Temperature increase and reduction in annual rainfall. Mean decrease in precipitation of up to 20% during July–November in the Amazon Basin is projected for 2070–2099	Reduced availability of natural sources (food, fibre), for local people. Land use and land cover change (e.g., mining, deforestation). Loss of biodiversity and ecosystem services. Health impacts from increased forest fires, particularly for Indigenous Peoples	Strong dependence on non-climatic drivers, in particular land use change, deforestation, forest fire practises. Low or decreased capacity to monitor and control deforestation	Policies for reduced rates of deforestation and slash-and-burn, increased reforestation. Landscape planning and increase of conservation areas protected from any economic and human activity outside of Indigenous Peoples. Community-led fire management based on Indigenous knowledge. Use of biological assets and biomimetic designs to create high-value products and services for current and new markets learning from Amazonian natural processes and ecosystems, improving local economies	*Medium confidence*	12.3.3–12.3.5, 12.4, 12.5.9
Risk to coral reef ecosystems due to coral bleaching	Central America; and North and Northeast South America	Degradation and possible death of the Mesoamerican coral reef, the second-largest reef in the world. Severe damage to habitat for nearly a thousand marine species, as well as degrading coastal protection and other ecosystem services, decreased food security from fisheries, lack of income from tourism. For RCP4.5 scenario, by year 2050, virtually entire coral reef will experience annual severe bleaching events	Ocean sea surface temperature increase, surface seawater aragonite saturation stress due to higher atmospheric CO_2 concentration, leading to ocean acidification and coral bleaching	Continued exposure to increased atmospheric CO_2 levels and increased sea surface temperatures together with destruction from coastal development, fishing practises and tourism	Ecosystem highly sensitive to water temperature and pH fluctuations. High levels of negative human interference with reefs	Limit global warming and CO_2 emissions. Reducing bleaching events to every 5 years could be enough for reefs to recover. Rapidly approaching hard adaptation limits	*High confidence* (*robust evidence*, *high agreement*)	12.3.1, 12.3.3, 12.3.5, 12.4, 12.5.9

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Risks to coastal socio-ecological systems due to sea level rise, storm surges and coastal erosion.	Central America; and Northwest, North, Northeast, Southeast, South, and Southwest South America	Coastal flooding and erosion causing severe damage to coastal population and infrastructure. Loss of fisheries and aquaculture, reef degradation and other declines in coastal protection due to increased storm surges and waves. Destruction of coastal marshes and mangroves. Salt-water intrusion and land subsidence. More than 4 million people could be exposed to flooding from relative sea level by 2100, assuming RCP8.5 without adaptation. When projecting sea level rise and increased population, >9 million people could be exposed	Continuing and high trajectories of sea level rise, with 0.29–0.59 cm under RCP2.6 and 0.61–1.10 cm under RCP8.5 by 2010 (relative to 1985–2005) projected. More intense and persistent coastal flooding, salt-water intrusion, coastal erosion	Increased number of people, infrastructure and services exposed, need of relocation of millions of people	Poor planning in coastal development and infrastructure, disproportionate vulnerability and limited adaptation options for rural communities and Indigenous Peoples, increasing urbanisation in coastal cities. Vulnerable touristic facilities in coastal regions generating large economic losses and unemployment	Coastal integrated management strategies, ecological restoration and nature-based solutions, specifically coastal protection including protection and rehabilitation of reefs, planting of seagrasses and mangroves. Artificial hard structures such as concrete breakwaters, seawalls, groins and revetments. Planned relocation of settlements based on need of relocation of up to millions of people.	*Medium confidence*	12.3.1–12.3.3, 12.3.5–12.3.8, 12.4, 12.5.9
Chapter 13: Europe								
Risk of stress and mortality to people due to increasing temperatures and heat extremes	Europe (whole continent), but risk increases from Northern to Southern Europe	On average, three times more heat-related deaths at 3°C GWL (compared with 1.5°C GWL). With 2°C warming), up to 200 million people could be at high risk of heat stress (compared with 2 million for the period 1986–2005) with more than 50% of the population at risk of thermal discomfort	Increased frequency and duration of heatwaves and hot temperature extremes coupled with high humidity across the whole continent irrespective of scenarios by mid-century, with an increasing gradient towards southern regions (WGI AR6 Chapter 11 and, Chapter 12)	Substantial population growth (especially in Southern Europe) largely contributes to the risk severity (as from SSP3, SSP5)	Increasing proportion of elderly population (in most SSP scenarios except SSP5), inequalities (SSP3) and prevalence of underlying health conditions	Bundle all measures to achieve full acclimatisation: (1) building retrofitting, (2) urban planning (including green/blue infrastructures), (3) behavioural changes; (4) public health intervention programmes and plans, and (5) active cooling	*High confidence* (*medium confidence* in adaptation potential)	13.6, 13.7, 13.10.2.1, SM13.10
Risk of marine and terrestrial ecosystems disruptions	Europe	Large-scale reorganisation of marine, terrestrial and freshwater ecosystems. Considerable reduction of recovery capacity and biome shift. Habitat loss, amplified in coastal areas by sea level rise, amplified risk of wildfires	Increased frequency and duration of heatwaves (including marine heatwaves) and hot temperatures, especially during critical organismal developmental changes	Stresses to ecosystems due to synergistic drivers such as pollution, habitat fragmentation, negative impacts of adaptation and mitigation options	Lower migration potential of species due to life cycle and habitat, habitat fragmentation not allowing movement of species, lack of statutory policies to provide protection and facilitate rewilding	Reduction of additional stressors to increase adaptation potential. Increasing network of effective protected areas to allow fast recovery after shocks	*High confidence* in the direction, *medium confidence* in the relative change	13.4, 13.5, 13.10.2.1, SM13.10

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Risk of losses in crop production, due to compound heat and dry conditions, and extreme weather	Southern Europe (*high confidence*), Central Europe (*medium confidence*)	Reduced crop production; up to 50% loss in yields with highest losses in southern region. Decreasing water availability constrains the use of irrigation as an adaptation option. Combined with limited effectiveness of other adaptation options, this leads to lower production and abandonment of cropland	Projected increase in co-occurring droughts and heatwaves with dominant signal in heatwaves occurrence, which will lead to more frequent hot and dry events and projected increase in wildfire hazards (WGI AR6 Chapters 11 and 12)	High population growth (e.g., in SSP5); increase in the extent of natural systems exposed to heat and drought hazards	Lack of water to increase irrigation; increase in soil loss and erosion and dry soils with little potential for evapotranspiration; lack of governance for some mixed farming practices	(1) Changes in sowing and harvest dates, and crop varieties, (2) drought-risk management, including protective vegetative cover and irrigation, (3) mixed farming practices, including agroforestry, (4) diversification and change of crop and animal species to those better adapted to warmer temperatures and less water requirement, (5) soil management	*Medium* to *high confidence*, but *high confidence* in Southern Europe, *medium confidence* in Central Europe	13.2, 13.5, 13.10.2.2, SM13.10
Risk of water scarcity to multiple interconnected sectors	Southern Europe, Central and Eastern Europe	One-third to over one-half million people exposed to moderate water scarcity in southern regions by mid-century owing to competing demands from agriculture, energy generation, domestic and municipal water consumption	Drought increase (especially in the Mediterranean) up to 10%; more severe and persistent reductions in runoff, changes in groundwater recharge; changes in seasonal precipitation patterns, with condition worsening for higher levels of warming (3°C) WGI AR6 Chapters 11 and 12)	Land use change (SSP3); population growth and rate of urbanisation (SSP5)	Most water currently needed by agriculture. Current development and economic trends point at an increase in vulnerability for those sectors highly relying on water resources mostly under conditions of SSP3 and SSP5	(1) reduce water demand (e.g., increasing irrigation efficiency); (2) enhance water availability; (3) changed priorities of water uses (who gets water first); (4) integrated land and water management and water–food–energy nexus solutions	*High confidence* (Southern Europe) and *medium confidence* (Central and Eastern Europe)	13.2, 13.5, 13.6, 13.10.2.3, SM13.10
Risks of mortality and damage to coastal infrastructure and economic assets due to coastal and inland flooding	Low-lying European coastal zones (lower concern in Scandinavia), and some river floodplains; small catchments and mountain area (pluvial flooding)	Expected annual damage (number of people) costs increase by a factor of at least 10 (at least 16), with large adaptation and mitigation. Local loss of marine and terrestrial ecosystems reduces or eliminate their ability to lessen the impacts	Increase in events with peak discharge >100-year return period; sea level rise exceeding locally relevant thresholds (e.g., small dunes and walls) beyond 2050; extreme rainfall events exacerbated by climate change	Exposure to flood risk is projected to stabilise or increase in the future depending on SSPs	Current trends show a decrease in flood vulnerability in high-income countries which will continue into the future. In the longer term, inability to adapt infrastructure such as drainage systems would contribute to vulnerability; inappropriate building practices	(1) protect: flood mitigation (dikes, barriers, drainage, pumps, nourishment, wetlands), (2) accommodate: damage mitigation (floodproofing, floating, temporary use of land, storage basins), (3) relocate: retreat landwards (managed realignment, no building zone, planned retreat) (4) relate: move seawards/advance (islands, new extend coastline)	*High confidence*	13.2, 13.6, 13.10.2.4, SM13.10

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Chapter 14: North America; Cross-Chapter Paper 6: Polar								
Risk to ecosystems and human health and well-being within and beyond polar regions due to sea ice loss and attendant ecosystem alterations	Polar seas	Loss of sea ice results in loss of habitat and altered trophic pathways. Reductions in sea ice extent and altered timing of sea ice melt cascade through the food web, with consequences for polar ecosystems including changes in the source and strength of primary productivity and borealisation of arctic marine ecosystems. Loss of migration, feeding and breeding areas for sea-ice-dependent species lead to severe declines. Cumulative changes impair large commercial fisheries, especially those that provide critical macronutrients globally (e.g., krill, walleye pollock)	Sea ice loss (reductions in extent and thickness) in the Arctic scales with, and lags, atmospheric carbon (decades or more). September sea ice loss is anticipated under all future scenarios but is greatest under SSP5 8.5, where near ice-free conditions may occur between 2040 and 2060. Warmer conditions lead to delayed sea ice formation and earlier sea ice melt, and phenological mismatch with phytoplankton, nutrients, mixing and spring daylight, impacting blooms, stratification and other critical ecological processes with impacts on key subsistence and fishery species. Changes in sea ice and warming will alter species distributions and location of fishery resources	All sea ice habitats are exposed, especially under high-emission scenarios. Exposure is highest at edges of polar boundaries and in the Arctic near-shore regions	These seasonal systems, which depend on ice-derived nutrients and productivity during the 'light' season are highly sensitive to change. Sea-ice-dependent species (e.g., seals; polar bears) that rely on sea ice for habitat will be directly impacted; changes in the timing of sea ice melt and extent will impact ice-driven trophic pathways and polar systems that rely on ice algae and sea-ice-driven phytoplankton blooms. Large catcher–processer vessels may be able to follow shifting resources more easily than small-scale shore-based vessels. Increased pressure for fisheries to follow poleward shifting species will challenge international agreements and regional management plans. Limited resources for monitoring of polar regions hinders assessment of current and future resources	Few adaptation options exist under end of century SSP58.5 owing to significant loss of sea ice. Under moderate and high mitigation scenarios, ecosystem management and indigenous co-management can help sustain productive ecosystems. Combined with mitigation monitoring, forecasts and climate-informed ecosystem-based management of fisheries, species and habitats can increase productivity and offset climate impacts to some extent through reducing non-climate pressures. Effectiveness declines with increasing atmospheric CO_2	*High confidence* (*robust evidence*, *high agreement* for risk, *medium confidence* for adaptation)	3.4.2.10, Cross-Chapter Box MOVING PLATE in Chapter 5, CCP6.2, 14.5.2, 14.5.6, 14.6, 14.7, SM14.6, WGI AR6 SPM

TSSM

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Multiple risks to arctic socio-ecological system function, structure and productivity	Arctic	Changes to sea ice increase human safety issues, wave energy and shoreline erosion. Loss of sea ice and ecosystem alterations impair access to, and availability of, subsistence resources, impacting the well-being and health of Indigenous Peoples and local communities. Compounding impacts alter Arctic Indigenous communities through loss of traditional livelihoods, relocation of communities, and injury from changes in ice/snow (e.g., falling through the ice). Loss of mental, emotional and spiritual health benefits, including stress relief; impacts on cultural well-being, including connections to identity, history, traditions and ancestors	Substantial loss of multi-year ice, reduction in seasonal sea ice extent, thickness and predictability and sea level rise. Compound impacts on the productivity of local and subsistence resources	Marine social-ecological systems along Arctic coasts and in regions of seasonal sea ice formation and melt. Subsistence hunters and fishers that traverse sea ice to access subsistence resources areas will be impacted. Local communities that provision with local resources and depend on ice and snow for travel	Sea-ice-dependent marine species are sensitive to compounding impacts of loss of sea ice and ecosystem change. Redundancy and diversity in subsistence use attenuates impacts, but systematic loss of species and resources can erode resilience and increase risk for Indigenous Peoples that depend on the cultural and provisioning services of Arctic ecosystems	Measures that protect or enhance diversity and flexibility in subsistence resources and measures that stabilise access to critical provisioning resources will increase resilience in the near term. Co-management, co-production of knowledge, increased communication via technology, improved access to real-time ice forecasting, enhanced search and rescue capabilities, investment in local infrastructure, access to a diversity of subsistence resources, stabilisation of income and food resources help promote adaptation. Efficacy of such measures scale positively with carbon mitigation	*High confidence* (*robust evidence*, *high agreement*)	CCP6.2.2–4, CCP6.2.7, 14.5.4, 14.5.6, 14.5.2, 14.6, Chapter 14 Executive Summary
Ecological and cultural risks due to increased shipping (due to sea ice reduction)	Arctic	Increased potential for fuel spill with high consequences for biodiversity and ecology as well as linked to food security and cultural impacts for Indigenous Peoples. Underwater noise impacts sensitive marine mammals. Potential for invasive species introduction	Reduction in sea ice extent; potential increase in navigability	Increased shipping associated with near ice-free areas in the Arctic (projected for 2040–2060 under SSP5 8.5), sensitive nearshore areas, especially those near navigational hazards	Fragile ecosystems increasingly stressed by heat (warming and extreme heat), wave action and ecosystem-wide changes. Areas with low regional biodiversity (high impact of spills), distance from ports and emergency response, lack of rapid response, difficulty of remediating oil spills on ice, limited search and rescue and other infrastructure, etc.	International agreements and treaties (e.g., Polar Code) and other regulations, investment in infrastructure, research and science, identification of particularly sensitive areas (especially culturally significant areas)	*High confidence* (*robust evidence*, *high agreement*)	CCP 6.2, 6.3, Box 6.1, 14.5.4, 14.5.9

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Permafrost loss impacting human communities and cities in the Arctic	Arctic	Increased human safety concerns related to loss of and damage to homes, roads, travel and access; road infrastructure failure from permafrost loss, landslides and subsidence, impacts on oil and gas extraction facilities and access. Trade disruptions related to transportation infrastructure, especially around critical food and medical resources, impact safe navigation, travel ability; decreased access to wild foods, loss of freedom and autonomy	Rising air temperatures contributing to persistent permafrost loss; heat and precipitation extremes contributing to sudden thawing and erosion events	Towns and communities in areas with permafrost. Areas of rapid thaw and combined impacts of land and coastal erosion	Cities and towns built on permafrost, terrestrial Arctic ecosystems, infrastructure and extractive platforms built on permafrost, coastal areas. Areas with intensifying warming and rapid thaw. Limited or ageing infrastructure, especially lack of resources to increase road, drinking water and building infrastructure. Limited disaster relief funds or support for relocation	Multiple adaptation options (e.g., design changes, changes to operating and maintenance protocols) depending on type of infrastructure, site conditions and location, project climate change impacts and other factors; investment in local infrastructure, relocation, disaster relief	*High confidence* (*robust evidence*, *low agreement* on adaptation)	CCP6.2.5, CCP6.2.6, CCP6.2.7, 14.4.6, 14.4.9, 14.5
Sea level rise, storms and flooding pose a risk to coastal cities, commerce and trade	North America	Damage and losses to property, loss of life, cost of evacuation, local transportation interruption, port-facility damage and delays, supply-chain delay	Sea level rise exceeding current design and accelerating deterioration of buildings and transportation infrastructure; storm surge and flooding from hurricanes and other large storm events. Seawater intrusion of drinking water. King tide flooding events that erode infrastructure. Loss of natural barriers to environmental degradation and changes in river output and sediment deposition	Low-lying cities and townships in regions with high sea level rise (Box 14.4), coastal population along the south and southeast coast of the USA and the East coast of Mexico where large hurricanes increase storm flooding and damage	Ageing infrastructure, lack of emergency response, lack of planning, especially around climate change. High use ports with few nearby alternatives	Various adaptation plans are in place in North America outlining city- and town-specific measures to reduce risk and inform urban planning. High-resolution projections of sea level rise can inform infrastructure design. Conservation and restoration of natural shoreline protection can attenuate storm surge (e.g., mashes, wetlands), planned relocation	*High confidence* (*medium evidence*, *high agreement*)	14.5.9, 14.5, 14.5.5, Box 14.4
Major ecosystem change, including species and biome shifts, altered abundances, which may be accelerated by indirect effects of disturbances	North America	Shifts or loss of ecosystems that provide significant ecosystem services	Warming and drying that leads to unfavourable conditions for species both directly as well as indirectly through increased disturbances	Terrestrial ecosystems in the south and southwest USA exposed to drought and warming, Arctic ecosystems exposed to sea ice and permafrost loss, coastal nearshore ecosystems subject to OA, urbanised estuarine ecosystems, mid- to low-elevation forests	Degraded ecosystems with reduced biodiversity and reduced redundancy in linkages and species niches. Systems with a few highly connected species that are sensitive to climate conditions. Ecosystems subject to increasing frequency of disturbances or those experiencing multiple hazards simultaneously	Ecosystem conservation and restoration, climate-informed resource management, monitoring and science-based decision making can help reduce cumulative impacts from non-climate stressors and increase connectivity and biodiversity	*Medium confidence* (*medium evidence*, *medium agreement*)	14.5.1, 14.2, 14.7

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Risks to health and ecosystems from increased frequency, duration or extent of harmful algal blooms or other hazardous water quality conditions	North America	Major drinking water contamination episodes resulting in exposure to gastrointestinal diseases; numerous and extensive cyanobacteria (blue-green algae) blooms causing highly hazardous conditions at water recreational sites and destruction of aquatic biota and aesthetic quality of lakes and other water bodies	Joint occurrence of very warm temperatures and high nutrient loading, e.g., from extreme precipitation and high runoff from agricultural lands, especially causing breaching of manure lagoons	Ageing drinking water treatment systems drawing on surface water sources subject to contamination. Algal bloom events in heavily used recreational waters near major population centres	Especially vulnerable are populations with weak immune systems (elderly and young); individuals and pets making frequent use of susceptible water recreational sites. Inadequate monitoring and warning systems; lack of planning for distribution of safe alternative drinking water during quality emergencies	Upgrade water supply, sewer and stormwater infrastructure; implement nitrogen-loading reduction programmes in agricultural areas	*High confidence* (*robust evidence*, *high agreement*)	14.4.3, 14.4.4, 14.5
Heat-related human morbidity and mortality	Canada, USA, Mexico (North America)	Substantial increase in heat-related mortality rates, especially in urban areas, elderly, and outdoor workers	Substantial increase in frequency and duration of extreme heat events	Large increases in exposure, particularly in urban areas (e.g., urban heat effect)	Ageing populations, poverty, continued lack of access to air conditioning, and inadequate improvements in public health systems	Improved access to cool environments (e.g., cooling stations, green spaces, air conditioning in buildings [especially residential]); increased public health response during heatwaves (e.g., increased access to cooling stations). Broader access to public health systems for the most vulnerable	*Very high confidence* (*robust evidence*, *high agreement*)	14.5.6, 14.5
Loss of life and property, increased morbidity, mental and physical health impacts, and ecosystem disturbance and transformation from large wildfires	North America	Substantial increases in costs of firefighting and suppression, loss of life and damages to property and structures; impaired air and water quality; physical and mental health impacts, significantly altered ecosystems, forest structure and function, tree stress, moose physiology and disease, changes in vegetation type, tree regeneration, changes in species composition, and watershed sedimentation from post-wildfire erosion	Warming and increased frequency and duration of drought, extreme heat combined with reduced humidity, changes to fire weather	Population centres with and without proximity to densely forested areas, temperate and low- to mid-elevation forests, grasslands, above ground power lines, populations in regions with drought and aridification (e.g., California, Colorado, Oregon, eastern Washington, southwest British Columbia)	Distance from fire response resources, places without shelter in place infrastructure, limited early-warning systems, limited evacuation potential. Smoke and air quality impacts are highest for those with pre-existing medical or mental health conditions. Regional proximity to forest ecosystems exposed to heat and aridification and changes in freshwater resources	Rapid response, risk communication and fire monitoring, emergency planning, shelter in place facilities. Forest management to reduce density of dry fuel, freshwater preservation (e.g., through conversion of irrigated grasslands to temperate forests), preservation of riparian zones around rivers and streams	*Medium confidence* (*robust evidence*, *medium agreement*)	14.4.1, 14.4.4, Box 14.2, CCP6.2.2

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Climate-sensitive mental health outcomes from compound climate hazards	Northern Canada, USA, Mexico	Increased occurrence of mental health problems exacerbated by climate change direct and indirect impacts	Temperature rise, leading to extreme heat events, severity and prevalence of intense storms, increased wildfires, changes in wildlife and vegetation, and disruptions to ecosystems	Negative mental health impacts from climate change are widespread across North America and differ by region and community depending on the hazard	Those experiencing poverty; elders/seniors; youth; those with already-present mental health challenges; those living at the frontlines of a changing climate; those most closely reliant on the land and environment for livelihoods, culture, identity and sustenance	No effective adaptation options identified with confidence	*Very high confidence* (*very high agreement*, *medium evidence*)	CCP6.2.7, 14.5.6, 14.5
Compounding and cascading climate change impacts on fisheries and aquaculture and food and nutritional security	Documented in all large marine ecosystems of North America	Disruption of fisheries through redistribution and declines in biomass. Loss of fisheries reduces access to marine sources of protein and nutrition and threatens regional and global food and nutrition security	Marine heatwaves, harmful algal blooms (HABs), low-oxygen zone, OA, substantial increase in ocean temperatures concomitant changes to marine food webs and ocean productivity (e.g., food resources), changes in ocean chemistry (OA, salinity, dissolved oxygen), shifts in ocean circulation	Exposure of fished species to changing ocean conditions, fisheries at southern (trailing) edges of species distributions, fisheries near geopolitical boundaries, fisheries near boundaries of protected areas. Fisheries in regions with protected species	Fisheries for species with narrow physiological tolerances at various life stages (e.g., larval phase), lack of diversity in income or target species portfolios. Fisheries already utilised at or near maximum sustainable yield (MSY), small-scale or shore-based fisheries with less ability to follow shifting resources, historically large fisheries with high investment, concentration of wealth and power and lack of representation in management; strong self-reinforcing density dependence in target fisheries, marine food webs sensitive to bottom-up productivity, and ectothermic nature of fish; transboundary populations	Ecosystem-based fisheries management, co-management, policy flexibility, portfolio approach to rationalised fisheries (diversification), disaster relief, adjustments in fisheries harvest rates (may release prey species from predation) or fishery locations (to follow poleward fish redistribution), maintenance of redundant subpopulations (portfolio of stocks); coordinated planning between aquaculture and fisheries management	*High confidence* (*robust evidence and high agreement* for shifting stocks, *medium evidence* on productivity changes and adaptation)	14.5.4, 14.5.6, 14.4.2, 14.6, CCP6.2.3

TSSM

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Risks to agricultural income and livelihoods, food security, due to drought, changes in temperature, and reduced surface water availability	Terrestrial agriculture and livestock systems across North America	Reduced crop yields and profits, lost livelihoods, higher food prices, pressures to transfer water out of agriculture, increased conflicts (especially where water rights are poorly defined and enforced), accelerated aquifer depletion, increased stream desiccation due to reduced return flows	Temperature rise; extended drought, together with loss of groundwater and/or snowpack water storage	Aridification especially in Southwest USA, and northern Mexico; extensive irrigated agriculture in areas dependent on snow-fed streams, especially where reservoir capacity is limited and water distribution systems are tuned to current seasonal flow patterns	Numerous water users located in small catchments lacking access to alternative sources of supply. Prior severe depletion of groundwater preventing its use as a late-season or drought-year substitute for surface sources. Insufficient reservoir capacity to provide both winter flood protection and reliable summer water deliveries. Inflexible, poorly documented water rights impeding development of efficient water markets	Utilising traditional and sustainable agriculture methods that promote soil quality and reduce erosion, agroforestry and ecosystem-based approaches can improve microclimates. Implement groundwater sustainability regulations and investment in recharge. Create incentives for water conservation and phased retirement of relatively unproductive irrigated land. Enhance flexibility of water allocation by improving water rights; documentation and enforcement to facilitate water banking and voluntary transfers; cultivate crops with drought tolerance, shift agricultural regions to favourable areas, diversify agriculture crops at the farm level, utilise sustainable intensification practices, repair and restore soil condition to retain water, prevent erosion	*High confidence* (*high agreement*, *medium evidence*)	14.4.3, 14.4.2,14.5

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Risk to the well-being, health, property and safety of communities and cities in North America from cascading and compounding climate change hazards, non-climate stressors and social structural predisposing factors	North America	Large losses in livelihoods and welfare (through impoverishment, malnutrition, migration, displacement) decrease ability of households and governments to manage adverse effects of climate change. This may also further increase inequity and impair effective adaptation and response	Heatwaves and warming contribute to increased heat stress, altered conditions impact food production, compounding and cascading impacts of multiple hazards erode infrastructure and increase costs especially in the near term from extreme weather events (e.g., hurricanes, flooding, heatwaves) and in the longer term from persistent change (e.g., OA, sea level rise)	Large population centres with ageing infrastructure, urban forests and those along shorelines and coastal areas. Livelihoods around resource utilisation and provision services	Small rural communities, large coastal cities with limited or outdated urban planning; systemic racial and economic inequalities that result in structural legacies that reinforce inequity and increase disproportionate impacts; lack of early-warning systems, weak international agreements on borders and rapidly increasing access to valuable resources in the Arctic, impoverished populations, uninsured populations; populations highly dependent on natural resources, food buyers, remote communities with limited access to public infrastructure and services	Multiple adaptation activities depending on sector that are often less expensive than costs from exposure. This is facilitated by inclusive governance and dynamic decision-making tools. Implementation of early-warning systems, social equality programmes, inclusive decision making and governance, livelihood diversification, coastal protection through nature-based solutions, increasing urban vegetation and tree cover, access to cooling infrastructure, livelihood and property insurance, shelter-in-place and other emergency response planning and investments	*High confidence* (*robust evidence*, *high agreement*)	14.5.5, 14.5.2., 14.5.4, 14.6, 14.5.9, Box 14.7
Chapter 15: Small Islands								
Loss of marine and coastal biodiversity and ecosystem services (KR1)	Small islands	Further and accelerating degradation of ecosystems leading to ecosystem loss or impaired provision of services (e.g., coastal protection, carbon sequestration, tourism, fisheries)	Accelerated sea level rise with increased wave height and energy, shoreline retreat, increase in frequency and/or intensity of extreme wave events; increase in the frequency and intensity of bleaching events, increase in acidity of the oceans	Increasing human populations: larger numbers of people living along the coast and depending on marine and coastal ecosystem services, e.g., for provision of food security or income	Limited financial resources to promote alternative options to ecosystem services, limited human capacity, small land area, pollution and other stresses, increase in development and populations, increase in anthropogenic pressures exerted on marine and coastal ecosystems (e.g., through overfishing, tourism development and other activities causing habitat degradation)	Conservation strategies, such as Marine Protected Areas (MPAs) and protection of terrestrial ecosystems, that would protect ecosystems and reduce other stresses; protection of resilient sites from local anthropogenic disturbances; habitat restoration (coral, seagrass and mangrove replanting); building on higher grounds to reduce direct human pressure exerted on marine and coastal ecosystems	*High confidence* (*robust evidence*, *medium agreement*)	15.3.3.1

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Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Submergence of reef islands (KR2)	Small Islands	Increase above natural rate of island disappearance, especially over the second half of this century and for the smallest reef islands	Under RCP8.5, rapid increase in the rate of sea level rise associated with increased wave height and energy; and intensification of tropical cyclones in some regions	Risk will be exacerbated by projected population growth in some countries and territories (e.g., Maldives, Kiribati), although still high at current population	Limited land and relocation alternatives, increasing human disturbances caused to the reef-island system, population growth increasing both the pressure exerted on land and land needs	Over the next decades: on natural and rural islands, nature-based solutions; on urban islands, engineering-based protection. High-end scenario: internal and potentially international migration and limits to adaptation	*Low confidence* (*limited evidence*, *low agreement*)	15.3.3.1.2
Loss of terrestrial biodiversity and ecosystem services (KR3)	Small Islands	Increased habitat and climatic niche loss and/or degradation, resulting in further and accelerating loss/impairment of ecosystem services, structure and/or functioning, and decreased biodiversity (particularly decreased functional redundancy)	Continued global warming, increasing/accelerated SLR, increasing intensity of intense tropical cyclones; increased frequency of drought, floods and wildfires	Increasing human population on islands exposes more natural landscape area to risk of conversion/impairment and associated impacts	(i) High levels of biodiversity limited to one or a few neighbouring islands with a large proportion of endemics (but low functional redundancy) and food/habitat specialists with limited range dispersal capacities; (ii) significant and increasing proportions of natural habitat lost/degraded/fragmented (e.g., agriculture or settlement; (iii) encroachment of protected areas due to limited resources available for adequate protection, poor governance, poor management	Development of ridge to reef conservation strategies which maintain, protect and include conservation of critical habitat outside of protected areas. These should allow for species shifts not just across individual islands but across regional and archipelagic extents (including neighbouring continents). Greater inclusion of community/private stakeholders in conservation strategies	*High confidence* (*medium evidence*, *high agreement*)	15.3.3.3
Water insecurity (KR4)	Small Islands	Freshwater demand increasingly exceeding supply, resulting in increasing populations unable to meet consumption, food production and economic needs, especially but not only on atoll islands (half of the SIDS already experiencing freshwater resource stress)	Increasing aridity, negative trends in annual and seasonal total and extreme precipitation, increasing duration and/or frequency of drought, decrease in groundwater recharge, decreased streamflow, salinisation and size reduction of freshwater lens due to sea level rise and extreme sea level events; groundwater recharge is projected to decrease by 58% for 31 Small Island States	Population growth, population density increases, especially in urban and coastal areas, increasing urbanisation in coastal areas, expansion of economic activities with high water demands (e.g., tourism); more remote island communities may become progressively less viable, resulting in their involuntary relocation to places where water insecurity may already exist	Increased domestic water consumption; limited technological transition; increased poverty and inequality; persistent limited water management and governance capacities; accelerated urbanisation; limited water quality monitoring and assessment; limited environmental awareness	Improve community awareness about the need for water conservation and maintaining the cleanliness of drinking water. Identification/use of traditional (pre-modern) water supply systems, especially at times of water shortage	*Medium* to *high confidence* (*robust evidence*, *medium agreement*). '*Medium agreement*' reflects the presence of considerable diversity across islands; '*robust evidence*' reflects the existence of water insecurity as an issue for almost every small island	15.3.4.3

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Risk of loss of lives and assets, food insecurity and economic disruption due to destruction of settlements and infrastructure (KR5)	Small Islands	Widespread loss of human lives, assets, food insecurity and economic disruption as settlements are rendered unliveable and infrastructure is destroyed	Substantial increase in frequency and intensity of precipitation impacting on severity of flooding and aggravated by the intensification of tropical cyclones and sea level rise. Substantial decrease in precipitation and more frequent and prolonged drought	Large increases in exposure, particularly in urban settlements, driven by population growth and projected urbanisation patterns	Persistent poverty, slow economic recovery and growth. Inadequate infrastructure maintenance	Nature-based solutions; ecosystem-based adaptation; traditional and indigenous architecture; revised building codes and planning standards; drainage infrastructure upgrade; water demand management. Relocation as a last resort	*High confidence* (*medium evidence*, *high agreement*)	15.3.4.1, 15.3.4.4, 15.3.4.5
Degradation of human health and well-being (KR6)	Small islands	Increase in vector-borne disease, food- and water-borne disease, heat-related illness, malnutrition, disruption to health and sanitation systems, mortality and psychological trauma resulting from extreme events	Altered frequency and/or severity of extreme weather events (floods, inundation, extreme rainfall, extreme heat, etc.). Altered rainfall patterns and rising air temperatures. Rising seawater temperatures. Changes to ecological systems	Increases in exposure due to population growth and urbanisation and persistently large numbers of low-income people, especially in urban areas and in coastal locations (where they may be more exposed to disease vectors or physical risks). Compromised safety or supply of food and clean water	Vulnerability exacerbated by limited economic growth, high income inequalities, limited financial capacities, limited land alternatives, limited access to clean and safe freshwater, persistent food insecurity, overstretched health infrastructure, unfamiliar pests and pathogens, malnutrition, human migration/population displacement leading to poorer health outcomes and disease transmission	Greater investment in health and sanitation infrastructure (hospitals, clinics, etc.). Surveillance of disease vectors (e.g., mosquitos, water- and food-borne pathogens). Widespread uptake and use of mosquito nets. Reduction of poverty and inequalities	*Low confidence* (*limited evidence*, *medium agreement*)	15.3.4.2
Economic decline and livelihood failure (KR7)	Small Islands	Substantial decrease in revenues from fishing licences and substantial increase in the destruction of production systems are likely to affect the whole population of some countries	Increase in atmospheric and sea surface temperatures, increased wave height and energy, sea level rise, increased intensity of tropical cyclones in some island regions	Large increases in exposure due to increasing population growth with low-income households	Prevalence of climate-sensitive economic activities (especially fisheries and aquaculture, agriculture, tourism); loss of fisheries and tourism revenue; limited diversification of economic activities and economic opportunities	Diversification of economic activities; limits to adaptation	*High confidence* (*medium evidence*, *high agreement*)	15.3.4.4, 15.3.4.5
Loss of cultural resources and heritage (KR8)	Small Islands	Loss or significant change in cultural resources that contribute to adaptive capacity and resilience, including IKLK, identity, social cohesion, social and kinship reciprocity networks, practices	Increased climate impacts including inundation of significant cultural areas on land, species range shifts and biodiversity loss associated with increasing sea surface temperatures	Population and settlement concentration in coastal areas increases exposure of cultural heritage to climate-driven coastal hazards and risk of uninhabitability and associated loss of intangible cultural systems	Incapability of maintaining cultural heritage due to lack of resources for protection and continuation. Loss of cultural asset reduces resilience building opportunities by undermining IKLK-based climate adaptation options	Integrating cultural heritage into climate adaptation plans and strategies; promote nature-based solutions that are congruent with cultural heritage; utilise appropriate technologies to protect culturally sensitive natural capital	*Low confidence* (*limited evidence*, *medium agreement*)	15.3.4.7

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Risk of reduced habitability of reef and non-reef islands leading to increased migration (KR9)	Small islands	Substantial increase in island land areas deemed permanently uninhabitable by people, resulting in the displacement, resettlement or permanent out-migration of entire island communities	Under RCP4.5, increase in the frequency, magnitude and spatial extent of extreme sea level events and associated coastal flooding, with associated salinisation of freshwater resources, terrestrial ecosystem degradation, and land loss due to increased coastal erosion or permanent submergence. Increase in aridity and/or frequency and duration of drought events and/or negative precipitation trends associated with decline in quantity and quality of ground and surface water resources	Large increases in population exposure due to population growth and urbanisation; degradation of coral reefs reducing coastal protection (as a result of repeated bleaching events and human activity); degradation of mangrove ecosystems	Limited economic growth, high income inequalities, limited financial capacities, limited land alternatives, and persistently large numbers of low-income people, especially in urban areas in coastal locations; persistent limited freshwater and terrestrial resource management technology, infrastructure and policy	Over the next decades: promote alternatives to natural threatened resources (e.g., freshwater), promote accommodation (e.g., building standard). High-end scenario: planned and participatory internal and international migration (permanent and circular) and limits to adaptation	*High confidence* (*medium evidence*, *high agreement*)	15.3.4.6
Cross-Chapter Paper 1: Biodiversity hotspots								
Loss of species in biodiversity hotspots	Global (land and ocean)	Increasing risk of extinction of 20% of animal and plant species in biodiversity hotspots	Risk increases rapidly beyond 2°C global warming	Warming and/or climate change velocities above the global average	Present human impacts already exceed predicted impacts of climate change in many areas. If species are endemic (unique to an area), they will be unable to disperse into more suitable climatic conditions	Expanded network of protected areas connected by dispersal corridors; restoration of lost and degraded habitats, and biodiversity-friendly use of land and sea	*High confidence* (*medium evidence*)	CCP1.2.1
Loss of freshwater biodiversity	Global	Increasing risk of local species extinctions and population declines, especially of endemic species in biodiversity hotspots	Increase in drought, heatwaves, warming beyond 2°C	Warming and/or climate change velocities above the global average	Present human impacts already exceed projected impacts of climate change. Vulnerability exacerbated by water withdrawals for human use, dams, pollution and invasive species	Reduce present human impacts. Facilitate species dispersal by removing barriers. Prevent pollution and excessive water removal from rivers and lakes	*High confidence* (*strong evidence*)	CCP1.2.3
Loss of terrestrial biodiversity	Global	Increasing risk of local species extinctions and population declines, especially of endemic species in biodiversity hotspots	Increase in drought, wildfires, floods, storms and warming greater than 2°C	Warming and/or climate change velocities above the global average	Present human impacts already exceed predicted impacts of climate change. Vulnerability exacerbated by habitat loss due to deforestation, farming and urbanisation, pollution, invasive introduced species	Improve management of and expand network of protected areas and dispersal corridors. Restore lost and degraded habitats, including native forests. Nature-friendly farming, forestry and land use	*High confidence* (*medium evidence*)	CCP1 101.2.2

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Decline of marine biodiversity	Global	Further loss of thousands of species in low latitudes with decline of tropical fisheries and associated food security. Increased risk of species extinctions and population declines, especially of endemic species in enclosed seas	Increase in marine heatwave frequency to intervals of less than 6 years, warming of greater than 1.5°C	Warming and/or climate change velocities above the global average	Direct human impacts from overexploitation and pollution. Failure to allow recovery of natural food webs, especially top predators, impacted by fisheries. Vulnerability exacerbated by fishing of all kinds through direct (removal of top predators, habitat destruction, bycatch) and indirect (food webs) impacts	Expand network of fully protected Marine Reserves to 30% of ocean where most biodiversity occurs. Cessation of habitat destruction by seabed trawling and dredging. Allow recovery of natural food webs through sustainable ecosystem-based fishing practices	*High confidence* (*medium evidence*)	CCP1 101.2.4
Cross-Chapter Paper 5: Mountains								
People and infrastructure at risk from landslide and flood hazards	Mountain Areas in Central-South America, Asia and Africa	About 13% of people at risk of increased landslide activity in certain regions (e.g. High mountain Asia) and twofold average increase in the number of people exposed to inland flooding with highest increases in South Asia, Southeast Asia and Northwestern South America; flood magnitude exceeding current safety thresholds (by mid-century in many regions); moderate to high increase of land, people and infrastructure at risk of glacier outburst floods by the end of the century	Increase in extreme precipitation (all mountain regions), change in freeze/thaw transitions or changes in snowpack conditions (WGI AR6 Chapter 12); likelihood of severe consequences higher at 1.5°C and very high at 4°C	People and infrastructure settling in new hazard prone locations, increase in agricultural activities and urban areas. Present levels of exposure are already critical in mountain areas. SSP3 conditions lead to highest risks	Current levels of vulnerability continuing into the future in certain regions mostly related to conditions such as limited financial resources and low adaptive capacity (Northwestern South America and South Asia) which are realised mostly under SSP3 and SSP4 conditions.	Low-regret measures (e.g., raising awareness, consider long planning horizons), mix of hard and soft measures, flood defence with capacity for return period >80–100 years, resettlements	*Medium evidence*, *medium agreement*	CCP5.2.7.2, CCP5.3.1, CCP5.2.1, CCP5.4, SMCCP5.4
Risks to local livelihoods and the economy from changing water resources	All mountain regions with hot spots in Northwestern South America and South Asia.	By mid-century up to 50–100% of the lowland population being water stressed in area already water stressed today (e.g. dependent on essential but largely insufficient share of freshwater). Water tower function critically impaired in some regions (e.g., Upper Indus Basin)	Temperature increase and decrease in solid precipitation (snow), which leads to decrease in snow and to accelerated melting of glaciers (WGI AR6 Chapters 12 and 11, SROCC Chapter 2)	SSP3 conditions will lead to highest exposure especially in regions predicting high demographic trends (e.g., Asia)	Current level of unsustainable agriculture (extensive irrigation, inadequate seed varieties), current level of high dependency of water supplies from snow melt and glaciers. Higher competition for water, little diversification of economic sectors (from today's conditions). Highest risk under SSP3 conditions	Implementation of integrated water resource management, improved community-level water governance, consideration of water–food–energy nexus	*High agreement*, *medium evidence*	CP5.2.7.2, CCP5.2.2.1, CCP5.3.2.2, CCP5.4, SMCCP5.4

Key risk as identified in AR6 WGII chapters	Geographic region	Consequence that would be considered severe, and to whom	Hazard conditions that would contribute to this risk being severe	Exposure conditions that would contribute to this risk being severe	Vulnerability conditions that would contribute to this risk being severe	Adaptation options with highest potential for reducing risk	Confidence in key risk identification	Chapter and section
Risks of ecosystem change and species extinctions due to temperature shifts	All mountain regions	Extinction of 15% of species (4–48%) at 5°C global surface air temperature increase	Increasing mean annual and seasonal temperature and increased frequency of droughts (WGI AR6 Chapter 12) and crossing of thresholds, e.g., melting of ice	Presence of endemic species on isolated mountain tops with no scope to disperse to higher altitudes or latitudes	Species unable to survive higher temperatures or competition with species better adapted to the new conditions. Those with low capacity to disperse and colonise new areas	Translocation of species, management of competition from colonising species, better fire management	*Medium evidence*, *high agreement* (with respect to risk, not the adaptation options)	CCP5.3.1, CCP5.3.2.3, SMCCP5.4
Risk to intangible losses and cultural values	All mountain regions	Intrinsic value and place attachment losses due to change in landscape character, which can also translate to economic losses for regions where aesthetic mountain landscape is valuable for tourism	Temperature increases leading to glacier retreat and variable- or low-snow seasons	Not assessed	Low adaptability to societal value change, deep attachment to irreplaceable physical, social and cultural dimensions of place and lack of diversification options (e.g., for tourism, agriculture)	Addressing 'ecological grief' and addressing changes in societal values by exploring opportunities due to changes in landscape character, redefine 'aesthetics'	*Limited evidence*, *medium agreement*	CCP5.3.2.4

Note:

Methodology: Guidance was provided to each chapter consisting of a general description of the table, explanations of the information requested in each column and examples of the type of information sought in each column. The general description of the table included the definition of a key risk (a 'potentially severe' risk) and the five types of criteria for identifying them, as described in Section 16.5.1. There is no unique means for applying the criteria to the identification of a key risk. Identification is an expert judgment made by chapter authors, based on the scientific literature and the key risk criteria. The tables attempt to make clear the conditions of hazards, exposure and vulnerability associated with the key risks. A fuller assessment of these key risks can be found in the underlying chapters in sections indicated in the last column.

SMTS.4 Figure TS.13d: Africa Case Study

Table SMTS.5 | Summary assessment, data and background information for the Africa Case Study in Figure TS.13d on making appropriate choices for fostering climate resilient development pathways. Appropriate choices are made by considering the portfolio of risks, the potential for adaptations to satisfactorily reduce risks and not exacerbate others, the potential for mitigation measures to interact with risks and adaptations within and across sectors, and how and whether adaptations can be enabled. The graphic table was developed based on a possible assembly (not exhaustive) of these considerations for four sectors (agriculture, water, built environments, ecosystems) in the region Africa, as well as more general considerations where appropriate. For each of these sectors, the following were elaborated: (i) the potential for cascading and compounding effects amongst key risks within sectors, between sectors and across boundaries and the possible limits to adaptation and the adaptation gap to be filled; (ii) the potential for adaptations to reduce key risks, including their feasibility, their interaction with other adaptations addressing the same or interacting risks, and whether they are limited by global warming level (GWL); (iii) the potential for interactions of adaptations with mitigation measures (grouped into categories that might interact with risks and adaptations), including showing their importance and whether the interaction would be potentially positive, negative or a mixture of both (note: 'carbon' refers to carbon sequestration); (iv) Enabling conditions for sectors grouped into categories of enablers common across many sectors, showing their importance and how they may be suitable across a number of sectors, along with an assessment of the gap in the enabler for satisfactory adaptation. Confidence levels, lines of sight to chapter sections, suitable keywords and additional supporting text are provided for each assessed component of the graphic table.

Africa

General for region

	Enabler	Impor-tance	Magnitude of gap	Confi-dence Level	Lines of sight	Keywords	Additional Supporting Text
CRD enablers	Finance	High	Large	*High*	9.1, 9.4.1, 9.4.5, 9.5.2	Broad-based	Climate-related research in Africa faces severe data constraints, as well as inequities in funding and research leadership that reduces adaptive capacity (*very high confidence*). Many countries lack regularly reporting weather stations, and data access is often limited. From 1990–2019, research on Africa received just 3.8% of climate-related research funding globally: 78% of this funding for Africa went to EU and north American institutions and only 14.5% to African institutions. The number of climate research publications with locally based authors are among the lowest globally and research led by external researchers may focus less on local priorities. Increased funding for African partners, and direct control of research design and resources can provide more actionable insights on climate risks and adaptation options in Africa. Adaptation generally is cost-effective, but annual finance flows targeting adaptation for Africa are billions of US dollars less than the lowest adaptation cost estimates for near-term climate change (*high confidence*). Finance has not targeted more vulnerable countries. From 2014–2018 more finance commitments were debt than grants and—excluding multilateral development banks—only 46% of commitments were disbursed (compared to 96% for other development projects). Adaptation costs will rise rapidly with global warming (*very high confidence*). Increasing public and private finance flows by billions of dollars per year, increasing direct access to multilateral funds, strengthening project pipeline development and shifting finance from readiness activities to project implementation would help realise transformative adaptation in Africa (*high confidence*). Concessional finance will be required for adaptation in low-income settings. Aligning sovereign debt relief with climate goals could increase finance by redirecting debt-servicing payments to climate resilience.

	Enabler	Impor-tance	Magnitude of gap	Confi-dence Level	Lines of sight	Keywords	Additional Supporting Text
	Cross-sectoral and transboundary solutions	High	Moderate	*High*	9.3.2, 9.4.2, 9.4.3, 9.6.4, 9.11.5, Box 9.3, Box 9.5, Box 9.6	Integrated Planning, Options across multiple sectors; Transboundary and multistakeholder cooperation; Multilevel Equity; Benefit sharing	Cross-sectoral 'nexus' approaches provide significant opportunities for large co-benefits and/or avoided damages (*very high confidence*). For example, climate change adaptation benefits pandemic preparedness, 'One Health' approaches benefit human and ecosystem health, and ecosystem-based adaptation can deliver adaptation and emissions mitigation (*high confidence*). Without cross-sectoral, transboundary and long-term planning, adaptation and mitigation response options in one sector can become response risks, exacerbating impacts in other sectors and causing maladaptation (*very high confidence*). For example, maintaining indigenous forest benefits biodiversity and reduces greenhouse gas emissions mitigation, but afforestation—or wrongly targeting ancient grasslands and savannas for reforestation—harms water security and biodiversity, and can increase carbon loss to fire and drought. Planned hydropower projects may increase risk as rainfall changes impact water, energy and food security exacerbating trade-offs between users, including across countries. Governance for climate-resilient development includes long-term planning, all-of-government approaches, transboundary cooperation and benefit-sharing, development pathways that increase adaptation and mitigation and reduce inequality, and implementation of Nationally Determined Contributions (NDC) (*high confidence*).
	Inclusive and enabling institutions and decision processes	High	Large	*High*	9.4.2	Engagement Options	In Africa, climate governance occurs in a context of deep inequality and asymmetric power relations—both within countries and between countries—making adequate mechanisms for multi-stakeholder participation essential. This requires creation of avenues for the voices of marginalised groups in policy processes and enabling policy environments that can catalyse inclusive action and transformational responses to climate change

	Enabler	Impor-tance	Magnitude of gap	Confi-dence Level	Lines of sight	Keywords	Additional Supporting Text
	Governance	High	Large	*High*	9.4.4	Adaption Legal frameworks	Robust legislative frameworks, both climate change specific and non-specific, can foster adaptive responses to climate change, particularly in LDCs. As discussed in Chapter 17, there are many reasons for this. The successful implementation of policy objectives across the continent is often contingent upon or at least supported by an underlying legislative framework. There are also wider systemic and structural reasons for developing climate change legislation, including the promotion of coordination within government, its policy entrenching role, its symbolic value and its potential to support climate finance flows. Robust legislative frameworks that develop or amend laws to mainstream climate change into their empowerment and planning provisions will facilitate effective design and implementation of climate change response options (*high confidence*). The Paris Agreement acknowledges, in Article 7.5, that adaptation should be based on and guided by, among other things, 'traditional knowledge, knowledge of indigenous peoples and local knowledge systems'. The accumulated knowledge within Indigenous knowledge systems is particularly important as it can assist governments in determining how the climate is changing, how to characterise these impacts and provide lessons for adaptation. In this context, Indigenous knowledge systems can play an important role in the effective design of local laws, as well as national laws. Doing so can contribute to the success of climate change response strategies, including enhancing local participation and the implementation of community-based and ecosystem-based adaptations. For example, the Makorongo Village Forest Management By-Law in Tanzania codifies local customary practices relating to forest management and sustainable harvesting with associated dual adaptation and mitigation benefits and includes all villagers in the decision-making processes relating to forest management. The inclusion of beneficial Indigenous knowledge systems within local by-laws is contingent on the active involvement of members of the Indigenous community and awareness of climate change considerations within the local sphere of government, and a willingness to foster such practices.

	Enabler	Impor-tance	Magnitude of gap	Confi-dence Level	Lines of sight	Keywords	Additional Supporting Text
	Technological, information, decision support, climate services & literacy	High	Large	*High*	9.4.5, 9.5.1, 9.8.4, 9.10.3, Figure 9.11	Climate services & literacy; Planning, Information, Diverse Knowledges	Climate information services that are demand driven and context specific (e.g., for agriculture or health) combined with climate change literacy can be the difference between coping and informed adaptation responses (*high confidence*). Across 33 African countries, 23–66% of people are aware of anthropogenic climate change—with larger variation at sub-national scales (e.g., 5–71% among states in Nigeria). Climate change literacy increases with education level but is undermined by poverty, and literacy rates average 12.8% lower for women than men. Around 71% of Africans that are aware of climate change agree it should be stopped. Production of salient climate information in Africa is hindered by limited availability of and access to weather and climate data. Policy actors across Africa perceive that anthropogenic climate change is already impacting their locales through a range of negative socioeconomic and environmental effects. They are highly concerned about and motivated to address these impacts. Transformative responses to the impacts of climate change facilitate CRD and are informed by perceptions of climate variability and change and climate change literacy. Perception of climate change in Africa can occur without knowledge of its anthropogenic causes and its effect on risk, as awareness of the concept of climate change is generally low across Africa. This can lead to coping responses to climate change which fall short of adaptation. Climate change literacy can fill this knowledge gap and, together with climate services, extend responses to climate change to include consideration of future risk through awareness of the anthropogenic cause of climate change and its effect on risk.

Agriculture

	Key Risks	Magnitude of adaptation gap	Limits to adaptation (GWL)	Confidence Level	Lines of sight	Keywords	Additional Supporting Text
Interacting key risks, adaptation gaps & limits to adaptation	Food security	Large	1,5	*High*	9.4.3, Boxes 9.3 and 9.5, 9.4.5, 9.6.1, 9.8.2, Figure 9.24, Table SM16.24	Reduced production (crops, livestock, fisheries); woody plant encroachment; water scarcity, competition	Key Risk: Risk of food insecurity, malnutrition (micronutrient deficiency) and loss of livelihood due to reduced food production from crops, livestock and fisheries. Severe reduction in food security and increase in malnutrition due to declines up to 5–15% in yield of staple crops, and 30–45% in net primary productivity of rangelands, varying by crop and region. Declines in fish catch potential in tropical west Africa of >50%. Climate change threatens livestock production across Africa (*high agreement*, *low evidence*). Rangeland net primary productivity is projected to decline 42% for west Africa by 2050 at 2°C global warming. Vector-borne livestock diseases and the duration of severe heat stress are both projected to become more prevalent under warming. {9.8.2, Figure 9.24, 9.8.2.4}. Future climate change will have compounding impacts on livestock, including negative impacts on fodder availability and quality, availability of drinking water, direct heat stress and the prevalence of livestock diseases. For example, in Zimbabwe by 2040–2070, net revenues from livestock production, compared to a 2011 survey, are projected to decline by 8–32% under RCP4.5 for 2°C and 11–43% under RCP8.5 for 2.7°C global warming due to a decline in fodder availability. Heat stress may already be the largest factor impacting livestock production in many regions in Africa, as the combination of high temperatures and high relative humidity can be dangerous for livestock and has already decreased dairy production in Tunisia. Climate change is projected to increase heat stress for all types of livestock, especially in the tropics {Figure 9.2.4}. More studies quantifying the impact of heat stress on other types of livestock production loss are needed in Africa. Planned hydropower projects may increase risk as rainfall changes impact water, energy and food security exacerbating trade-offs between users, including across countries. In Africa, climate change is reducing crop yields and productivity (*medium confidence*). Agricultural productivity growth has been reduced by 34% since 1961 due to climate change, more than any other region. Maize and wheat yields decreased on average 5.8% and 2.3%, respectively in sub-Saharan Africa due to climate change in the period 1974–2008. Farmers and pastoralists perceive the climate to have changed and over two thirds of Africans perceive climate conditions for agricultural production have worsened over the past ten years. Woody plant encroachment has reduced fodder availability. By 1.5°C global warming, yields are projected to decline for olives (North Africa) and Sorghum (West Africa) with a decline in suitable areas for coffee and tea (East Africa). Although yield declines for some crops may be partially compensated by increasing atmospheric CO_2 concentrations, global warming above 2°C will result in yield reductions for staple crops across most of Africa compared to 2005 yields (e.g., 20–40% decline in West African maize yields), even when considering adaptation options and increasing CO_2 (*medium confidence*). Relative to 1986–2005, global warming of 3°C is projected to reduce labour capacity in agriculture by 30–50% in sub-Saharan Africa.

	Key Risks	Magnitude of adaptation gap	Limits to adaptation (GWL)	Confidence Level	Lines of sight	Keywords	Additional Supporting Text
	Human health	Large	1,5	*High*	Box 9.5, Figure 9.25, Section 9.8.5, Table SM16.24	Water competition; malnutrition	9% declines in maize yield for West Africa and 20–60% decline in wheat yield for southern and northern Africa, as well as declines in coffee and tea in East Africa and sorghum in West Africa {Figures 9.22 and 9.23; Section 9.8.2.1 and 9.8.2.2}, and >12% decline in marine fisheries catch potential for multiple West African countries, potentially leaving millions at risk of nutritional deficiencies. Increasing demand for water for agricultural and energy production is driving an increasing competition over water resources between food and energy industries which, among other effects, compromises the nutritional needs of local populations.
	Living standards & equity	Large	1,5	*High*	9.8.2.3, 9.10.2.2.2, 9.4.5.2, Table SM16.24	Wild harvest declines, food insecurity	Wild-harvested foods (e.g., fruits, vegetables and insects) provide dietary diversification and for many people in Africa, wild-harvested food plants may provide a livelihood and/or nutritional safety net when other sources of food fail, such as during drought. Food insecurity and nutritional deficiencies, projected to increase with increasingly variable climates, has been shown to increase sexual risk-taking and migration, as well as increase susceptibility to other infections. A recent Afrobarometer study covering 34 African countries found 67% of Africans perceive climate conditions for agricultural production to have worsened over time, and report drought as the main extreme weather event to have worsened in the past decade. Additionally, people engaged in occupations related to agriculture (farming, fishing or forestry) were more likely to report negative weather effects (59%) than those with other livelihoods (45%).
	Terrestrial and ocean ecosystem services	Large	1,5	*High*	9.8.2, 9.8.5, 9.9.4, 9.10.2, 9.11.2, 9.6.2, Figure 9.19	Habitat loss; Fish declines; Invasives	Multiple African countries are projected to face compounding risks from reduced food production across crops, livestock and fisheries, increased heat-related mortality, heat-related loss of labour productivity and flooding from sea level rise, especially in west Africa (*high confidence*). African biodiversity loss is projected to be widespread and escalating with every 0.5°C increase above present-day global warming (*high confidence*). Above 1.5°C, half of assessed species are projected to lose over 30% of their population or area of suitable habitat. At 2°C, 36% of freshwater fish species are vulnerable to local extinction, 7–18% of terrestrial species assessed are at risk of extinction, and over 90% of east African coral reefs could be destroyed by bleaching. Above 2°C, risk of sudden and severe biodiversity losses becomes widespread in west, central and east Africa. Climate change is also projected to change patterns of invasive species spread.

	Key risks	Feasibility	Limits to adaptation (GWL)	Confidence Level	Lines of sight	Keywords	Additional Supporting Text
Example adaptations for key risks	Food security	Moderate	1,5	*High*	9.3.1, 9.3.2, 9.8.3, 9.8.4, 9.4.1	Irrigation; Water management, Land management; Climate smart agriculture	Different types of irrigation including drip and small-scale irrigation can contribute towards increased agricultural productivity (SDG 2), improved income (SDG 1) and food security (SDG 2) and increase resilience to long-term changes in precipitation (SDG 13). In Kenya and Tanzania, small-scale irrigation provides employment opportunities and income to both farmers and private businesses (SDGs 8 and 9). Land management practices including the use of fertilizers and mulching have also been highlighted as adaptation options improving soil fertility for better yields (SDG 2) and delivering opportunities to reduce the climate change effects (SDG 13). there was *limited evidence* to assess the continued effectiveness of these options at higher global warming levels with some options, such as bulk water infrastructure (particularly large dams), expected to face increasing risk with continued warming with damages cascading to other sectors {Box 9.5}, while others, such as crop irrigation and adjusting planting times, may increasingly reach adaptation limits above 1.5°C and 2°C global warming. Sustainable Water Management (SWM) includes rainwater harvesting for irrigation, watershed restoration, water conservation practices (e.g., efficient irrigation) and less water-intensive cropping, and was the most reported adaptation response in the food sector. SWM was assessed with medium economic and social feasibility and low environmental, institutional and technological feasibility. The feasibility of this adaptation category may depend largely on socioeconomic conditions. Climate-smart agriculture (CSA) offers opportunities for smallholder farmers to increase productivity (SDG 2), build adaptive capacity while reducing the emission of GHGs (SDG 13) from agricultural systems. CSA practices including conservation agriculture, access to climate information, agroforestry systems, drip irrigation, planting pits and erosion control techniques can improve soil fertility, increase yield and household food security, thereby contributing to the realisation of SDG 2 in Africa. In contrast, adaptation actions may induce trade-offs with mitigation objectives, as well as other adaptation and developmental outcomes, delivering negative impacts and compromising the attainment of the SDGs. For example, increased deployment of renewable energy technologies can drive future land use changes and threaten important biodiversity areas if poorly deployed. The use of early maturing or drought-tolerant crop varieties may increase resilience (SDGs 1, 2), but adoption by smallholder farmers can also be hindered by affordability of seed. Cultivation of biodiesel crops also can hinder food security (SDG 2) at local and national levels. Technological (including on-farm engineering), institutional, and financing factors are major barriers to climate adaptation feasibility in Africa (*high confidence*). There is *limited evidence* for economic growth alone reducing climate damages, but under scenarios of inclusive and sustainable development, millions fewer people in Africa will be pushed into extreme poverty by climate change and negative impacts to health and livelihoods can be reduced by 2030 (*medium confidence*).
	Human health	Moderate	Not assessed	*Medium*	9.10.3, 9.11.3	Food supply chains; social protection	Transformative adaptation requires integration of resilience and mitigation across all parts of the food system including production, supply chains, social aspects and dietary choices. Adaptation to prevent malnutrition goes hand-in-hand with adaptation to prevent food insecurity {5.12.5, 9.8.3}. Social protection has been used for decades, particularly in eastern and southern Africa, to safeguard poor and vulnerable populations from poverty and food insecurity. Instruments of social protection include public works programmes, cash transfers, in-kind transfers, social insurance and microinsurance schemes that assist individuals and households to cope during times of crisis and minimise social inequality.

TSSM

	Key risks	Feasibility	Limits to adaptation (GWL)	Confidence Level	Lines of sight	Keywords	Additional Supporting Text
	Living standards & equity	Large	Not assessed	*High*	ES.9, 9.11.3	Social protection	Integrating climate adaptation into social protection programmes, such as cash transfers, public works programmes and healthcare access, can increase resilience to climate change (*high confidence*). Social protection has been used for decades, particularly in eastern and southern Africa, to safeguard poor and vulnerable populations from poverty and food insecurity. Instruments of social protection include public works programmes, cash transfers, in-kind transfers, social insurance and microinsurance schemes that assist individuals and households to cope during times of crisis and minimise social inequality.
	Terrestrial and ocean ecosystem services	Moderate	Not assessed	*Medium*	9.6.2, 9.8.2.3, 9.8.5	Natural forest maintenance	Natural forests provided 21% of rural household income across 11 African countries and wild-harvested foods (including fisheries) provide important nutrition to millions of Africans, including through important micronutrients and increased dietary diversity.

	Mitigation measures	Importance of interaction with adaptation	Direction of effect	Confidence Level	Lines of sight	Specific examples / case studies	Additional Supporting Text
Potential interaction with mitigation measures	Technology	High	+	*High*	9.3.2	(+) Carbon (soils – climate-smart agriculture)	Climate-smart agriculture (CSA) offers opportunities for smallholder farmers to increase productivity (SDG 2), build adaptive capacity while reducing the emission of GHGs (SDG 13) from agricultural systems. CSA practices including conservation agriculture, access to climate information, agroforestry systems, drip irrigation, planting pits and erosion control techniques can improve soil fertility, increase yield and household food security.
	Nature based	High	+	*High*	Table 9.6, 9.3.2	(+) Carbon (ecosystem protection & restoration; forest sustainability, soil management)	Improved ecosystem care and restoration are cost-effective for carbon sequestration while providing multiple environmental, social and economic co-benefits. Sustainable Water Management (SWM), watershed restoration, was assessed with medium economic and social feasibility and low environmental, institutional and technological feasibility. Ecosystem protection and restoration [outcome: Carbon sequestration and storage], conservation agriculture practices, sustainable land management, and integrated catchment management can support climate resilience. Maintaining existing indigenous forest and indigenous forest restoration is a win–win, maximising benefits to biodiversity, adaptation and mitigation (*high confidence*). Forestry and other land use: Restoration/ reforestation – Sustainable forestry and land management; Restoration of degraded ecosystems and enhanced carbon sequestration; Reducing pressure on forests for food and energy needs Land management practices including the use of fertilizers and mulching have also been highlighted as adaptation options improving soil fertility for better yields (SDG 2) and delivering opportunities to reduce the climate change effects (SDG 13).
	Land management	High	+/–	*High*	Box 9.3, Tabel 9.6	(–) Energy (renewable energy farms, biofuel crops), Carbon (afforestation of ancient grasslands) (+) Carbon (Protection/ restoration of indigenous vegetation)	Adaptation actions may induce trade-offs with mitigation objectives, as well as other adaptation and developmental outcomes, delivering negative impacts and compromising the attainment of the SDGs. For example, increased deployment of renewable energy technologies can drive future land use changes. Cultivation of biodiesel crops also can hinder food security (SDG 2) at local and national levels. Afforestation—or wrongly targeting ancient grasslands and savannas for reforestation—harms water security and biodiversity, and can increase carbon loss to fire and drought.

	Enablers	Importance	Magnitude of gap	Confidence Level	Lines of sight	Keywords	Additional Supporting Text
CRD enablers	Finance	High	Large	*High*	9.3, 9.4.1, 9.4.1.4, 9.4.4.1	Ownership; Targeted projects	Technological, institutional, and financing factors are major barriers to climate adaptation feasibility in Africa (*high confidence*). The present situation reflects not only an insufficient level of finance being mobilised to support African adaptation needs {9.4.1} but also problems in accessing and using funding that is available. While supporting readiness activities is important for strengthening country ownership and institutional development, research suggests adaptation finance needs to shift towards implementation of concrete projects and more pipeline development if the goal of transformative and sustained adaptation in Africa is to be realised. There are also wider systemic and structural reasons for developing climate change legislation, including the promotion of coordination within government, its policy entrenching role, its symbolic value and its potential to support climate finance flows.
	Poverty reduction	High	Large	*High*	9.3.2	Drought-resistant crops; agroforestry, diversification	Adaptation options such as access to climate information, provision of climate information services, growing of early maturing varieties, agroforestry systems, agricultural diversification and growing of drought-resistant varieties of crops may deliver co-benefits, providing synergies that result in positive outcomes. For instance, in Sub-Saharan Africa drylands including northern Ghana and Burkina Faso and large parts of the Sahel, migration as a result of unfavourable environmental conditions closely linked to climate change has often provided opportunities for farmers to earn income (SDG 1) and mitigate the effects of climate-related fluctuations in crop and livestock productivity (SDG 2).
	Inclusive and enabling institutions and decision processes	High	Large	*High*	9.3, 9.4.1	Stakeholder Engagement	Technological, institutional, and financing factors are major barriers to climate adaptation feasibility in Africa (*high confidence*).
	Technological, information, decision support, climate services & literacy	High	Large	*High*	9.3, 9.4.1	Information-technology; climate services	Technological, institutional, and financing factors are major barriers to climate adaptation feasibility in Africa (*high confidence*).

Water

	Key Risks	Magnitude of adaptation gap	Limits to adaptation (GWL)	Confidence Level	Lines of sight	Keywords	Additional Supporting Text
Interacting key risks, adaptation gaps & limits to adaptation	Water security	Large	2	*Medium*	Box 9.5, 9.3.1, Table SM16.24	Drought; Urbanisation; Energy	Key Risk: Risk to water and energy security due to drought-induced shortage of irrigation and hydropower. Severe risks driven by long-term warming and drying and reduced river runoff, which occurs in some climate models (high uncertainty in hydrologic outcomes). Increased urbanisation, population and economic growth, increasing electricity and food demand. Dramatic planned expansion in hydropower (+581%) and irrigation capacity (+63%) under the Program of Infrastructure Development in Africa. The study found that hydropower revenues in the driest climate scenarios could be 58% lower in the Zambezi River basin, 30% lower in the Orange basin and 7% lower in the Congo basin relative to a scenario with current climate conditions. Hydropower revenues in the wettest climate scenario could be more than 20% higher in the Zambezi River basin and 50% higher in the Orange basin. The biggest risk to the production of irrigated crops is in the eastern Nile where irrigation revenue could be 34% lower in the driest scenario and 11% higher in the wettest than in a scenario without climate change.
	Food security	Moderate	2	*Medium*	Box 9.5, 9.3.1, Table SM16.24	Irrigation; Infrastructure; Cascading risks	Irrigation revenues in Zambezi Basin decline up to USD 45 billion relative to baseline scenario bulk water infrastructure (particularly large dams), expected to face increasing risk with continued warming with damages cascading to other sectors {Box 9.5}, while others, such as crop irrigation and adjusting planting times, may increasingly reach adaptation limits above 1.5°C and 2°C global warming.
	Living standards & equity	Moderate	2	*Medium*	Box 9.5, Table SM16.24	Irrigation revenues	Irrigation revenues in Zambezi Basin decline up to USD 45 billion relative to baseline scenario.
	Critical physical infrastructure, networks & services	Large	2	*Medium*	Box 9.5, Table SM16.24, 9.8.5	Irrigation; Energy	Hydropower and irrigation revenues in Zambezi Basin decline up to USD 45 billion relative to baseline scenario. Consumer electricity expenditure could increase 47% across the Southern African Power Pool. Hydropower development carries risk of regrets due to damages when a different climate than was expected materialises. Energy costs for cooling demands are projected to accumulate to USD 51.3 billion by 2035 at 2°C global warming and to USD 486.5 billion by 2076 at 4°C.

	Key Risks	Magnitude of adaptation gap	Limits to adaptation (GWL)	Confidence Level	Lines of sight	Keywords	Additional Supporting Text
	Peace & human mobility	Large	1.5	*Medium*	9.7.2, 9.9.1, 9.9.3, Box 9.8	Extreme events; drought; urban pressure; Poverty	Over 2.6 million and 3.4 million new weather-related displacements occurred in sub-Saharan Africa in 2018 and 2019. Hydrological fluctuations are associated with drought, flood and cyclone events which have had multi-sector impacts across Africa, including: reduced crop production, migration and displacement, food insecurity and extensive livestock deaths, electricity outages, increased incidence of cholera and increased groundwater abstraction amplifying the risk of saline intrusion from sea level rise. Climate-related displacement is widespread in Africa, with increased migration to urban areas in sub-Saharan Africa linked to decreased rainfall in rural areas, increasing urbanisation and affecting household vulnerability {Box 9.9}. Much of this growth can occur in informal settlements which are growing due to both climatic and non-climatic drivers, and which often house temporary migrants, including internally displaced people. Poverty is a significant factor of flood-induced displacement in Africa, where even small flood exposure can lead to high numbers being displaced. Compared to population in 2000, human displacement due to river flooding in sub-Saharan Africa is projected to increase 600% by 2066–2096 with moderate-to-high population growth and 2.6°C global warming, with risk reducing to a 200% increase for low population growth and 1.6°C global warming.

	Key Risks	Feasibility	Limits to adaptation (GWL)	Confi-dence Level	Lines of sight	Keywords	Additional Supporting Text
Example adaptations for key risks	Water security	Moderate	1.5	*Medium*	Box 9.5, 9.3.1, Table SM16.24, 4.7.2	Dams; irrigation	Increased electricity trade between river basins, which have little correlation in yearly rainfall and runoff. There was *limited evidence* to assess the continued effectiveness of these options at higher global warming levels with some options, such as bulk water infrastructure (particularly large dams), expected to face increasing risk with continued warming with damages cascading to other sectors {Box 9.5}, while others, such as crop irrigation and adjusting planting times, may increasingly reach adaptation limits above 1.5°C and 2°C global warming. Studies assessing the future effectiveness of irrigation related responses {Figure 4.28} focus on a range of specific approaches, including increasing irrigation efficiency, deficit irrigation, irrigated area expansion or shifting from rain-fed to irrigated agriculture, as well as specific types of irrigation (21 studies; 103 data points). As a frequently implemented option with direct entry points to agricultural models, this option provides the most robust set of data points across regions and warming levels. For all regions, a reduction in effectiveness is apparent from 1.5°C to higher levels of warming, leading to increased residual risk with increasing warming (*high confidence*).
	Food security	Small	2	*Medium*	Box 9.5, 9.3.1, Table SM16.24, 4.7.2	Irrigation; Planting regimes; Cropping Patterns	Catchment restoration and integrated water management schemes. Crop irrigation and adjusting planting times, may increasingly reach adaptation limits above 1.5°C and 2°C global warming. Changes in cropping patterns and crop systems {Figure 4.28} (5 studies; 31 data points) indicate limited potential to reduce projected climate risks, with the majority of studies providing results of up to 1.5°C of warming and *limited evidence* for higher warming levels. At 1.5°C, effectiveness in Africa is mostly insufficient, with substantial maladaptive potential.
	Living standards & equity	Large	1.5	*Medium*	9.10.3, 9.11.3, 9.11.4	Inclusive sustainable development; social protection	There is *limited evidence* for economic growth alone reducing climate damages, but under scenarios of inclusive and sustainable development, millions fewer people in Africa will be pushed into extreme poverty by climate change and negative impacts to health and livelihoods can be reduced by 2030 (*medium confidence*). Social protection has been used for decades, particularly in eastern and southern Africa, to safeguard poor and vulnerable populations from poverty and food insecurity. Instruments of social protection include public works programmes, cash transfers, in-kind transfers, social insurance and microinsurance schemes that assist individuals and households to cope during times of crisis and minimise social inequality.
	Critical physical infrastructure, networks & services	Moderate	1.5	*Medium*	Box 9.5, 9.3.1, Table SM16.24	Eco-urban infrastructure	Urban gardening and agriculture bulk water infrastructure (particularly large dams), expected to face increasing risk with continued warming with damages cascading to other sectors {Box 9.5}, while others, such as crop irrigation and adjusting planting times, may increasingly reach adaptation limits above 1.5°C and 2°C global warming.

	Key Risks	Feasibility	Limits to adaptation (GWL)	Confidence Level	Lines of sight	Keywords	Additional Supporting Text
	Peace & human mobility	Moderate	Not assessed	*Medium*	Box 9.8, 9.3.1	Opportunities for movement	Migration is an important and potentially effective climate change adaptation strategy in Africa and must be considered in adaptation planning (*high confidence*). The more agency migrants have (that is, degree of voluntarily and freedom of movement), the greater the potential benefits for sending and receiving areas (*high agreement*, *medium evidence*) {Cross-Chapter Box MIGRATE in Chapter 7}. In a synthesis of 63 studies covering over 9700 rural households in dryland sub-Saharan Africa, 23% of households employed migration (primarily temporary economic) to adapt to changes in rainfed agriculture. Migration responses to climate change tend to be stronger among wealthier households, as poorer households often lack financial resources necessary to migrate.

	Mitigation measures	Importance of interaction with adaptation	Direction of effect	Confidence Level	Lines of sight	Specific examples / case studies (optional)	Additional Supporting Text
Potential interactions with mitigation measures	Land management	High	+/–	*High*	ES.9, 9.4.3, Boxes 9.3, 9.5	(–) Carbon (afforestation of ancient grasslands); (+) Energy (hydro dams)	Maintaining indigenous forest benefits biodiversity and emissions mitigation, but afforestation—or wrongly targeting ancient grasslands and savannas for reforestation—harms water security and biodiversity, and can increase carbon loss to fire and drought. Planned hydropower projects may increase risk as rainfall changes impact water, energy and food security exacerbating trade-offs between users, including across countries.
	Nature based	High	+	*High*	9.6.4	(+) Carbon (forest restoration)	Afforestation reduces water availability but forest restoration and removing invasive plant species can increase water flows in regions facing water insecurity from climate change.
	Buildings & infrastructure	High	–	*High*	Boxes 9.3 and 9.5, 9.9.5	(+/–) Energy (Dams – take water, store water); (–) Carbon (afforestation)	Placing cross-sectoral approaches at the core of CRD provides significant opportunities to deliver large benefits and/or avoids damages across multiple sectors including water, health, ecosystems and economies (*very high confidence*) {Boxes 9.5, 9.6, 9.7}. They can also prevent adaptation or mitigation action in one sector, exacerbating risks in other sectors and resulting in maladaptation, for example, from large-scale dam construction or large-scale re/afforestation (e.g., water–energy–food nexus and large-scale tree planting efforts) {Boxes 9.3, 9.5}. Planned infrastructure developments, including those related to the AU's PIDA, along with other energy plans, and China's Belt and Road Initiative, may increase or decrease both climate change mitigation and adaptation depending on whether infrastructure planning integrates current and future climate change risks. Under the Nationally Appropriate Mitigation Action programme, investments in public transport and transit-oriented development are highlighted as desired mitigation–adaptation interventions within cities of South Africa, Ethiopia and Burkina Faso. These interventions simultaneously reduce the vulnerability of low-income residents to climate shocks, prevent lock-ins into carbon-intensive development pathways and reduce poverty (*high confidence*). The combined mitigation–adaptation interventions in the land use transport systems of African cities are also expected to have sufficient short-term co-benefits (reducing air pollution, congestion and traffic fatalities) to be 'no regret' investments (*very high confidence*).

	Mitigation measures	Importance of interaction with adaptation	Direction of effect	Confidence Level	Lines of sight	Specific examples / case studies (optional)	Additional Supporting Text
	Energy	High	+/–	*High*	Boxes 9.3 and 9.5, 9.6; 9.7	(–) Energy (Hydropower) (+) Cross basin risk pooling / transfer	Placing cross-sectoral approaches at the core of CRD provides significant opportunities to deliver large benefits and/or avoids damages across multiple sectors including water, health, ecosystems and economies (*very high confidence*). They can also prevent adaptation or mitigation action in one sector, exacerbating risks in other sectors and resulting in maladaptation, for example, from large-scale dam construction or large-scale re/afforestation (e.g., water–energy–food nexus and large-scale tree planting efforts).

	Enablers	Importance	Magnitude of gap	Confidence Level	Lines of sight	Keywords	Additional Supporting Text
CRD enablers	Coordination and integration	High	Large	*High*	9.4.3, Box 9.5, Table SM16.24	Integrated approaches across related sectors	Placing cross-sectoral approaches at the core of climate-resilient development provides significant opportunities to deliver large benefits and/or avoids damages across multiple sectors including water, health, ecosystems and economies (*very high confidence*). Cross-sectoral or 'nexus' approaches can improve the ability of decision-makers to foresee and prevent major climate impacts. Barriers to developing nexus approaches arise from rigid sectoral planning, regulatory and implementation procedures, entrenched interests and power structures and established sectoral communication structures. Opportunities for overcoming these barriers include creating a dedicated home for co-development of nexus risk assessment and solutions, promoting co-leadership of projects by multiple sectors, specific budget allocations for nexus projects, facilitating and coordinating services, compiling useful strategies into toolkits, ameliorating inequitable power relations among participants and measuring progress on nexus approaches through metrics. An integrated response can be enhanced through the inclusion of community-based organisations, such as water resource user associations and the wide range of other multi-sectoral actors involved in and affected by development decisions.
	Inclusive and enabling institutions and decision processes	High	Large	*High*	Box 9.5, Table SM16.24	Multi-level Inclusivity	An integrated response can be enhanced through the inclusion of community-based organisations, such as water resource user associations and the wide range of other multi-sectoral actors involved in and affected by development decisions. Collaboration between scientists and policy-makers to address the complexity of decision-making under uncertainty, coupled with community involvement in participatory scenario development and participatory GIS to aid in collaborative planning that is context-specific are powerful tools for more beneficial adaptive and resilience building actions.
	Technological, information, decision support, climate services & literacy	High	Large	*High*	Box 9.5, Table SM16.24	Tools to address complexity, uncertainty, change & contestation	Understanding of water-energy-food nexus interlinkages can help characterise risks and identify entry points and the relevant institutional levels for cross-sectoral climate change adaptation actions. Longer (multi-decadal) hydrological datasets and model improvements are required, and models should incorporate the quantification of the wider benefits, risks and political opportunities arising from reservoir development to better inform decision-makers to achieve a higher level of (transboundary) cooperation.

	Enablers	Importance	Magnitude of gap	Confidence Level	Lines of sight	Keywords	Additional Supporting Text
	Cross-sectoral and transboundary solutions	High	Moderate	*High*	9.4.3, Box 9.5, Table SM16.24, Box 9.8	Options to improve multiple sectors	Placing cross-sectoral approaches at the core of climate-resilient development provides significant opportunities to deliver large benefits and/or avoids damages across multiple sectors including water, health, ecosystems and economies (*very high confidence*). Cross-sectoral or 'nexus' approaches can improve the ability of decision-makers to foresee and prevent major climate impacts. Barriers to developing nexus approaches arise from rigid sectoral planning, regulatory and implementation procedures, entrenched interests and power structures and established sectoral communication structures. Opportunities for overcoming these barriers include creating a dedicated home for co-development of nexus risk assessment and solutions, promoting co-leadership of projects by multiple sectors, specific budget allocations for nexus projects, facilitating and coordinating services, compiling useful strategies into toolkits, ameliorating inequitable power relations among participants and measuring progress on nexus approaches through metrics. An integrated response can be enhanced through the inclusion of community-based organisations, such as water resource user associations and the wide range of other multi-sectoral actors involved in and affected by development decisions. Most climate-related migration and displacement observed currently is within countries or between neighbouring countries, rather than to more geographically distant high-income countries.

Built environments (urban/rural)

	Key Risks	Magnitude of adaptation gap	Limits to adaptation (GWL)	Confidence Level	Lines of sight	Keywords	Additional Supporting Text
Interacting key risks, adaptation gaps & limits to adaptation	Coastal socio-ecological systems	Large	< 1.5	*Medium*	Table SM16.24, Box 9.4	Water scarcity; extreme events; sea level rise	Cascading and compounding risks to economies and governance due to severe, concurrent or successive climate-intensified natural disasters (floods, droughts, fires, wind, heat) affecting human settlements and infrastructure. The Cape Town drought illustrates how a highly diverse. African city and its citizens responded to protracted and unanticipated water scarcity. Anthropogenic climate change made the drought five to six times more likely. After three consecutive years of low precipitation, Cape Town braced for a 'Day Zero' where large portions of the city would lose water supply. The risk of day zero was anticipated to cascade to affect risks to health, economic output and security. The case study highlights the importance of communication, budgetary flexibility, robust financial buffers and insurance mechanisms, disaster planning, intergovernmental cooperation, nature-based solutions, infrastructure transformations and equitable access for climate adaptation in African cities facing water scarcity.

	Key Risks	Magnitude of adaptation gap	Limits to adaptation (GWL)	Confidence Level	Lines of sight	Keywords	Additional Supporting Text
	Living standards & equity	Large	< 1.5	*High*	Table SM16.24, Box 9.4, 9.9.2, 9.9.3	Poverty alleviation; Water security; SME impacts	Globally, sub-Saharan Africa has the largest population living in extreme poverty that are exposed to high flood risk (~71 million people or 55% of global total) . Poverty is a significant factor of flood-induced displacement in Africa, where even small flood exposure can lead to high numbers being displaced. Africa's large population of urban poor and marginalised groups and informal sector workers, further contribute to high vulnerability to extreme weather and climate change in many settlements (*high confidence*). The risk of day zero was anticipated to cascade to affect risks to health, economic output and security. Business disruptions from climate impacts have implications for deepening poverty. Small and medium enterprises (SMEs) employ 60–90% of workers in many African countries and contribute 40% or more to the GDP in Ghana, Kenya, Nigeria, South Africa, Tanzania and Zimbabwe. The viability of businesses and economic well-being of large populations employed in SMEs is severely affected by climate hazards as reported for local wind storms in Ibadan, El Niño-related flooding (Nairobi), drought-induced water supply disruption (Gaborone) and power outages (Lusaka).
	Human health	Moderate	< 1.5	*High*	Table SM16.24, Box 9.4	Disruption, loss of life; Cascading risks; Sanitation	Loss of life and disruption of livelihoods. Restricted access to water resources, and water shortages in urban areas disrupting sanitation and food processing and distribution systems. The risk of day zero was anticipated to cascade to affect risks to health, economic output and security.
	Food security	Moderate	< 1.5	*Medium*	Table SM16.24, Box 9.4	Water security, sanitation in food processing, distribution	Restricted access to water resources, and water shortages in urban areas disrupting sanitation and food processing and distribution systems. Loss of life and disruption of livelihoods. The risk of day zero was anticipated to cascade to affect risks to health, economic output and security.
	Water security	Large	< 1.5	*High*	Table SM16.24, Box 9.4	Water scarcity; Cascading risks	Restricted access to water resources, and water shortages in urban areas disrupting sanitation and food processing and distribution systems. Loss of life and disruption of livelihoods. The risk of day zero was anticipated to cascade to affect risks to health, economic output and security.
	Critical physical infrastructure, networks & services	Large	< 1.5	*High*	Table SM16.24, Box 9.4	Flood damages	Damage to key urban infrastructure and services from flood events, particularly high risk within coastal cities.

	Key Risks	Magni-tude of adapta-tion gap	Limits to adap-tation (GWL)	Confi-dence Level	Lines of sight	Keywords	Additional Supporting Text
	Peace & human mobility	Large	Not assessed	*High*	9.9.1, Box 9.9, 9.9.3	Water scarcity; Floods; Landslides; Poverty	Climate-related displacement is widespread in Africa, with increased migration to urban areas in sub-Saharan Africa linked to decreased rainfall in rural areas, increasing urbanisation and affecting household vulnerability. Much of this growth can occur in informal settlements which are growing due to both climatic and non-climatic drivers, and which often house temporary migrants, including internally displaced people. Such informal settlements are located in areas exposed to climate change and variability and are exposed to floods, landslides, sea level rise and storm surges in low-lying coastal areas, or alongside rivers that frequently overflow, thereby exacerbating existing vulnerabilities. Globally, sub-Saharan Africa has the largest population living in extreme poverty that are exposed to high flood risk (~71 million people or 55% of global total). Poverty is a significant factor of flood-induced displacement in Africa, where even small flood exposure can lead to high numbers being displaced. Africa's large population of urban poor and marginalised groups and informal sector workers, further contribute to high vulnerability to extreme weather and climate change in many settlements (*high confidence*).
Example adaptations for key risks	Coastal socio-ecological systems	Large	2	*High*	9.6.4, 9.9.3.1, 9.8.5.2	Habitat restoration; Storm surge protection; EbA	Marine and coastal ecosystems such as mangroves, seagrass and coral reefs provide storm protection and food security for coastal communities (*high confidence*). Restoring reef systems reduced wave height in Madagascar, but there is *limited evidence* for the efficacy of coral reef restoration at large scales with increased warming {Section 3.6.3}. Populations at risk from storm surge and/or sea level rise coincide with areas of high coastal ecosystem-based adaptation (EbA) potential from Mozambique to Somalia, and coastlines of the Gulf of Guinea, Gambia, Guinea-Bissau and Sierra Leone. Understanding hotspots of EbA potential is particularly important for west Africa with some of the highest levels of human dependence on marine ecosystems at high risk from climate change and large populations vulnerable to sea level rise.
	Living standards & equity	Large	Not assessed	*High*	9.4.2, 9.10.3, 9.11.4	Social protection; Health care	Integrating climate adaptation into social protection programmes, such as cash transfers, public works programmes and healthcare access, can increase resilience to climate change (*high confidence*). Nevertheless, social protection programmes may increase resilience to climate-related shocks, even if they do not specifically address climate risks.
	Human health	Large	Not assessed	*High*	9.8, 9.9, 9.9.5, 9.10, 9.11	Water management; Sanitation; Social protection; Nature-based solutions	Reduced drought and flood risk, and improved water and sanitation access, can be delivered by water sensitive and climate scenario planning, monitored groundwater use, waterless on-site sanitation, rainwater harvesting and water re-use, reducing risk to human settlements Integrating climate adaptation into social protection programmes, such as cash transfers, public works programmes and healthcare access, can increase resilience to climate change (*high confidence*). Nevertheless, social protection programmes may increase resilience to climate-related shocks, even if they do not specifically address climate risks. Nature-based solutions are also being deployed in mitigating and adapting to climate change, with demonstrated long-term health, ecological and social co-benefits.

	Key Risks	Magnitude of adaptation gap	Limits to adaptation (GWL)	Confidence Level	Lines of sight	Keywords	Additional Supporting Text
	Food security	Large	Not assessed	*Medium*	9.10.3	Urban agriculture, forestry; mental health; heat management	Urban agriculture and forestry can improve nutrition and food security, household income and mental health of urban farmers while mitigating against some of the impacts of climate change, like flooding and landslides (by stabilising the soil and reducing runoff, for example), heat (by providing shade and through evapotranspiration) and diversifying food sources in case of drought.
	Water security	Moderate	2	*High*	ES.9, 9.3.1, 9.7.3, 9.8.5, 9.8, 9.9, 9.10, 9.11	Water management; Integrated solutions; Flood management	Risk-sensitive infrastructure delivery and equitable provision of basic services can reduce climate risks and provide net financial savings (*high confidence*). However, there is *limited evidence* of proactive climate adaptation in African cities. Proactive adaptation policy could reduce road repair and maintenance costs by 74% compared to a reactive policy. Adapting roads for increased temperatures and investment in public transport are assessed as 'no regret' options. In contrast, hydropower development carries risk of regrets due to damages when a different climate than was expected materialises. Energy costs for cooling demands are projected to accumulate to USD 51.3 billion by 2035 at 2°C global warming and to USD 486.5 billion by 2076 at 4°C. Water sector adaptation measures show medium social and economic feasibility but low feasibility for most African cities due to technical and institutional restrictions, particularly for large supply dams and centralised distribution systems (*medium confidence*). Use of integrated water management, water supply augmentation and establishment of decentralised water management systems can reduce risk. Integrated water management measures including sub-national financing, demand management through subsidies, rates and taxes, and sustainable water technologies can reduce water insecurity caused by either drought or floods (*medium confidence*). Reduced drought and flood risk, and improved water and sanitation access, can be delivered by water sensitive and climate scenario planning, monitored groundwater use, waterless on-site sanitation, rainwater harvesting and water re-use, reducing risk to human settlements.

	Key Risks	Magni-tude of adapta-tion gap	Limits to adap-tation (GWL)	Confi-dence Level	Lines of sight	Keywords	Additional Supporting Text
	Critical physical infrastructure, networks & services	Moderate	2	*High*	ES.9, 9.3.1, 9.7.3, 9.8.5, 9.8, 9.9, 9.10, 9.11	Risk-sensitive design; water and sanitation access	Risk-sensitive infrastructure delivery and equitable provision of basic services can reduce climate risks and provide net financial savings (*high confidence*). However, there is *limited evidence* of proactive climate adaptation in African cities. Proactive adaptation policy could reduce road repair and maintenance costs by 74% compared to a reactive policy. Adapting roads for increased temperatures and investment in public transport are assessed as 'no regret' options. In contrast, hydropower development carries risk of regrets due to damages when a different climate than was expected materialises. Energy costs for cooling demands are projected to accumulate to USD 51.3 billion by 2035 at 2°C global warming and to USD 486.5 billion by 2076 at 4°C. Water sector adaptation measures show medium social and economic feasibility but low feasibility for most African cities due to technical and institutional restrictions, particularly for large supply dams and centralised distribution systems (*medium confidence*). Use of integrated water management, water supply augmentation and establishment of decentralised water management systems can reduce risk. Integrated water management measures including sub-national financing, demand management through subsidies, rates and taxes, and sustainable water technologies can reduce water insecurity caused by either drought or floods (*medium confidence*). Reduced drought and flood risk, and improved water and sanitation access, can be delivered by water sensitive and climate scenario planning, monitored groundwater use, waterless on-site sanitation, rainwater harvesting and water re-use, reducing risk to human settlements.
	Peace & human mobility	Large	Not assessed	*Medium*	9.3.1, Box 9.8, Cross-Chapter Box MIGRATE in Chapter 7	Support networks; Financial support; Agency for migrants	Migration and social infrastructure (including decentralised management, strong community structures and informal support networks) show high potential for risk reduction. Limited financial and technical support for migration limits the extent to which it can make meaningful contributions to climate resilience. International and domestic remittances are an important resource that can help aid recovery from climate shocks, but inadequate finance and banking infrastructure can limit cash transfers {Box 9.8}. Male migration can increase burdens of household and agricultural work, especially for women. The more agency migrants have (that is, degree of voluntarily and freedom of movement), the greater the potential benefits for sending and receiving areas (*high agreement*, *medium evidence*).

	Mitigation measures	Importance of interaction with adaptation	Direction of effect	Confidence Level	Lines of sight	Specific examples / case studies	Additional Supporting Text
Potential interaction with mitigation measures	Buildings & infrastructure	High	+/–	*High*	Boxes 9.3 and 9.5, 9.9.5	(+) Energy (transport diversification, eco-building) (–) Energy (Dams divert water)	Placing cross-sectoral approaches at the core of CRD provides significant opportunities to deliver large benefits and/or avoids damages across multiple sectors including water, health, ecosystems and economies (*very high confidence*) {Boxes 9.5, 9.6 and 9.7}. They can also prevent adaptation or mitigation action in one sector, exacerbating risks in other sectors and resulting in maladaptation, for example, from large-scale dam construction or large-scale re/afforestation (e.g., water–energy–food nexus and large-scale tree planting efforts) {Boxes 9.3 and 9.5}. Planned infrastructure developments, including those related to the AU's PIDA, along with other energy plans, and China's Belt and Road Initiative, may increase or decrease both climate change mitigation and adaptation depending on whether infrastructure planning integrates current and future climate change risks. Under the Nationally Appropriate Mitigation Action programme, investments in public transport and transit-oriented development are highlighted as desired mitigation–adaptation interventions within cities of South Africa, Ethiopia and Burkina Faso. These interventions simultaneously reduce the vulnerability of low-income residents to climate shocks, prevent lock-ins into carbon-intensive development pathways and reduce poverty (*high confidence*). The combined mitigation–adaptation interventions in the land use transport systems of African cities are also expected to have sufficient short-term co-benefits (reducing air pollution, congestion and traffic fatalities) to be 'no regret' investments (*very high confidence*).
	Technology	High	+	*High*	9.11.4	(+) Energy (Decentralised & low carbon energy access)	Pro-poor policies that link mitigation and adaptation, such as using renewable energy to increase rural electrification or using revenues from a carbon tax, combined with international financial support to increase social assistance, could support sustainable eradication of poverty under near-term climate change.
	Societal (behavioural)	High	–	*Medium*	9.11.4	(–) Options affected by social inequality in energy, water and food security	Analysis of INDCs across 54 African countries suggests current climate policies do not, on average, target social inequality in energy, water and food security; proposed mitigation and adaptation actions fell about 23% for every 1% rise in social inequality across these sectors.

	Enablers	Importance	Magnitude of gap	Confidence Level	Lines of sight	Keywords	Additional Supporting Text
CRD enablers	Governance	High	Not assessed	*High*	Table 9.3	Multi-level Engagement	High-level engagement: Climate policies, traditionally overseen by environment ministries, are increasingly receiving priority from finance and planning ministries. Zambia's Climate Change Secretariat is currently led by the Ministry of Finance, while Tanzania's environmental division sits in the office of the Vice-President.
	Finance	High	Not assessed	*High*	9.4.1	Adaptation finance	Existing estimates are expected to substantially underestimate eventual costs with adaptation costs possibly 2–3 times higher than current global estimates by 2030, and 4–5 times higher by 2050.

	Enablers	Impor-tance	Magni-tude of gap	Confi-dence Level	Lines of sight	Keywords	Additional Supporting Text
	Technological, information, decision support, climate services & literacy	High	Not assessed	*High*	9.4.5, Table SM16.24	Early warning systems; Perception management	Early-warning systems. Monitoring and forecasting systems Understanding the human cause of climate change has been shown to be a strong predictor of climate change risk perception and a critical knowledge foundation that can affect the difference between coping responses and more informed and transformative adaptation.
	Coordination and integration	High	Not assessed	*High*	9.4.3	Options to improve multiple sectors	Traditional risk assessments typically only consider one climate hazard and one sector at a time, but this can lead to substantial misestimation of risk because multiple climate risks can interact to cause extreme impacts. Because multiple risks are interlinked and can cascade and amplify risk across sectors, cross-sectoral approaches that consider these interlinkages are essential for climate-resilient development, especially for managing trade-offs and co-benefits between SDGs, mitigation and adaptation responses.
	Processes for innovation, adjustment and learning	High	Not assessed	*High*	9.9.5	Innovation & planning; social learning	Autonomous responses to climate impacts in 40 African cities show that excess rainfall is the primary climate driver of adaptation, followed by multi-hazard impacts, with 72% of responses focused on excess rainfall. Innovation for adaptation in areas such as home design, social networks, organisations and infrastructure, is evident. Social learning platforms also increase communities' adaptive capacities and resilience to risk.

Biodiversity and Ecosystem Services

	Key Risks	Magni-tude of adapta-tion gap	Limits to adap-tation (GWL)	Confi-dence Level	Lines of sight	Keywords	Additional Supporting Text
Interacting key risks, adaptation gaps & limits to adaptation	Coastal socio-ecological systems	Large	2	*High*	Table SM16.24, 9.6.4, 9.8.5	Habitat loss; Extreme events	Risks to marine ecosystem health and livelihoods in coastal communities due to ocean heatwaves, increased acidification and sedimentation/turbidity. Destruction of 90% of coral reefs and severe degradation of seagrass beds and mangroves.
	Living standards & equity	Moderate	2	*High*	Table SM16.24, Figure 9.25, 9.6.4, ES.9	Livelihoods dependent on wild systems (tropics)	Risks to marine ecosystem health and livelihoods in coastal communities due to ocean heatwaves, increased acidification and sedimentation/turbidity. Fisheries provide the main source of protein for ~30% of Africa's population and support the livelihoods of 12.3 million people. At 1.5°C global warming, marine fish catch potential (MFCP) decreases 3–41% by 2081–2100 relative to 1986–2005, increasing to 12–69% at 4.3°C, with the highest declines for tropical countries. Under 1.7°C global warming, reduced fish harvests could leave 1.2–70 million people vulnerable to iron deficiencies, up to 188 million for vitamin A deficiencies, and 285 million for vitamin B12 and omega-3 fatty acids by mid-century.

	Key Risks	Magnitude of adaptation gap	Limits to adaptation (GWL)	Confidence Level	Lines of sight	Keywords	Additional Supporting Text
	Terrestrial and ocean ecosystem services	Large	2	*High*	Table SM16.24, 9.6.4, 9.5.10, 9.6.1, 9.8.2	Heat stress; ocean acidification; Extreme events; declining fisheries	Risks to marine ecosystem health … due to ocean heatwaves, increased acidification and sedimentation/turbidity. Increases in frequency, intensity, spatial extent and duration of marine heatwaves are projected for all coastal zones of Africa. At 1°C and 3.5°C of global warming, the probability of marine heatwave (MHW) days is between 4–15 times and 30–60 times higher compared to the preindustrial (1861–1880) 99th percentile probability, with highest increases over equatorial and sub-tropical coastal regions {Figure 9.16}. These events are expected to overwhelm the ability of marine organisms and ecosystems to adapt to these changes. Mangroves, seagrasses and coral reefs support nursery habitats for fish, sequester carbon, trap sediment and provide shoreline protection. Climate change is compromising these ecosystem services (*medium confidence*). Marine heatwaves associated with El Niño-Southern Oscillation (ENSO) events triggered massive coral bleaching and mortality over the past 20 years. The assessed temperature range for the transition to very high risk is wider for food production than for biodiversity and health. Projected impacts for food include: 10–30% decline in marine fisheries catch potential for the Horn of Africa region and southern Africa and more than 30% decline for West Africa at 2°C global warming, with greater declines at higher levels of warming.
Example adaptations for key risks	Coastal socio-ecological systems	Large	1.5	*High*	9.6.4	Maintenance and restoration	Marine and coastal ecosystems such as mangroves, seagrass and coral reefs provide storm protection and food security for coastal communities (*high confidence*). Restoring reef systems reduced wave height in Madagascar, but there is *limited evidence* for the efficacy of coral reef restoration at large scales with increased warming. Understanding hotspots of ecosystem-based adaptation (EbA) potential is particularly important for west Africa with some of the highest levels of human dependence on marine ecosystems at high risk from climate change and large populations vulnerable to sea level rise.
	Living standards & equity	Large	Not assessed	*High*	9.11.3, 9.11.4	Social protection	Social protection has been used for decades, particularly in eastern and southern Africa, to safeguard poor and vulnerable populations from poverty and food insecurity. Instruments of social protection include public works programmes, cash transfers, in-kind transfers, social insurance and microinsurance schemes that assist individuals and households to cope during times of crisis and minimise social inequality.
	Terrestrial and ocean ecosystem services	Large	1.5	*High*	9.6.4	Maintenance and restoration. Protection of hotspots. EbA.	Marine and coastal ecosystems such as mangroves, seagrass and coral reefs provide storm protection and food security for coastal communities (*high confidence*). Restoring reef systems reduced wave height in Madagascar, but there is *limited evidence* for the efficacy of coral reef restoration at large scales with increased warming. Understanding hotspots of EbA potential is particularly important for west Africa with some of the highest levels of human dependence on marine ecosystems at high risk from climate change and large populations vulnerable to sea level rise.

	Mitigation measures	Importance of interaction with adaptation	Direction of effect	Confidence Level	Lines of sight	Specific examples / case studies	Additional Supporting Text
Potential interactions with mitigation measures	Buildings & infrastructure	High	–	*High*	Boxes 9.3, 9.5	(–) Energy (dams altering water flows)	Placing cross-sectoral approaches at the core of CRD provides significant opportunities to deliver large benefits and/or avoids damages across multiple sectors including water, health, ecosystems and economies (*very high confidence*) {Boxes 9.5, 9.6, 9.7}. They can also prevent adaptation or mitigation action in one sector, exacerbating risks in other sectors and resulting in maladaptation, for example, from large-scale dam construction or large-scale re/afforestation (e.g., water–energy–food nexus and large-scale tree planting efforts).
	Societal (behavioural)	High	+	*Medium*	9.4.4, 9.11.3	(+) Governance (Indigenous systems); land management (reduce emissions)	Improving land management practices of charcoal producers and artisanal gold miners, combined with appropriate alternative livelihood and energy sources, can reduce emissions and increase resilience (e.g., reduce erosion and sedimentation, increase water infiltration). The Makorongo Village Forest Management By-Law in Tanzania codifies local customary practices relating to forest management and sustainable harvesting with associated dual adaptation and mitigation benefits and includes all villagers in the decision-making processes relating to forest management. The inclusion of beneficial Indigenous knowledge systems within local by-laws is contingent on the active involvement of members of the Indigenous community and awareness of climate change considerations within the local sphere of government, and a willingness to foster such practices.
	Nature based	High	+	*High*	Box 9.3	(+) Carbon (Forest restoration & sustainable management; Soil management)	Maintaining existing indigenous forest and indigenous forest restoration is a win–win, maximising benefits to biodiversity, adaptation and mitigation (*high confidence*).
	Land management	High	+	*High*	9.6.4	(–) Carbon (Afforestation using water, taking over ancient grasslands)	Afforestation—or wrongly targeting ancient grasslands and savannas for reforestation—harms water security and biodiversity, and can increase carbon loss to fire and drought.

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	Enablers	Importance	Magnitude of gap	Confidence Level	Lines of sight	Keywords	Additional Supporting Text
CRD enablers	Finance	High	Large	*High*	Table SM16.24	Response to extreme events	Ensuring that people have the assets to draw upon in times of need.
	Inclusive and enabling institutions and decision processes	High	Large	*Medium*	Table SM16.24	Inclusivity	Empowering people to have a say in what happens to them, ensuring the ability to determine what is right for them.
	Coordination and integration	High	Large	*Medium*	9.4.3	Coordination; Transboundary agreements	Enhanced transboundary governance arrangements suggest that countries are joining forces to coherently manage and protect natural resources … Angola, for example, outlines regional adaptation as a priority and one of its unconditional adaptation strategies (which is already funded) is enhancing resilience in the Benguela fisheries system, a project shared with Namibia and South Africa.
	Governance	High	Large	*High*	9.6.3	Protected areas to support biodiversity and livelihoods.	Establishing protected areas African protected areas store around 1.5% of global land ecosystem carbon stocks and support biodiversity. They also support livelihoods and economies, such as through nature-based tourism and improved fisheries. Climate change and land use change will interact to influence the effectiveness of African protected areas (*high confidence*).
	Processes for innovation, adjustment and learning	High	Large	*High*	Table SM16.24	Diversification	Providing the flexibility to change (livelihood diversification).