18 Climate Resilient Development Pathways

Coordinating Lead Authors: E. Lisa F. Schipper (Sweden/UK), Aromar Revi (India), Benjamin L. Preston (Australia/USA)

Lead Authors: Edward. R. Carr (USA), Siri H. Eriksen (Norway), Luis R. Fernández-Carril (Mexico), Bruce Glavovic (South Africa/New Zealand), Nathalie J.M. Hilmi (France/Monaco), Debora Ley (Mexico/Guatemala), Rupa Mukerji (India/Switzerland), M. Silvia Muylaert de Araujo (Brazil), Rosa Perez (Philippines), Steven K. Rose (USA), Pramod K. Singh (India)

Contributing Authors: Paulina Aldunce (Chile), Aditya Bahadur (India), Natália Barbosa de Carvalho (Brazil), Ritwika Basu (India), Nick Brooks (UK), Donald A. Brown (USA), Anna Carthy (Ireland), Vanesa Castán Broto (Spain/UK), Ralph Chami (USA), John Cook (USA), Daniel de Berrêdo Viana (Brazil), Frode Degvold (Norway), Shekoofeh Farahmend (Iran), Roger Few (UK), Gianfranco Gianfrate (France), H. Carina Keskitalo (Sweden), Florian Krampe (Germany/Sweden), Rinchen Lama (South Africa), Julia Leventon (Czech Republic/UK), Rebecca McNaught (New Zealand), Yu Mo (China/UK), Marianne Mosberg (Norway), Michelle Mycoo (Trinidad and Tobago), Johanna Nalau (Australia/Finland), Karen O'Brien (Norway), Meg Parsons (New Zealand), Alain Safa (France), Majid Sameti (Iran), Zoha Shawoo (Pakistan/UK), Marcus Taylor (Canada/UK), Mark G.L. Tebboth (UK), Bejoy K. Thomas (India), Kirsten Ulsrud (Norway), Saskia Werners (the Netherlands/Germany), Keren Zhu (China), Monika Zurek (Germany/UK)

Review Editors: Diana Liverman (USA), Nobuo Mimura (Japan)

Chapter Scientists: Ritwika Basu (India/UK), Zoha Shawoo (Pakistan/UK), Yu Mo (China/UK)

This chapter should be cited as:
Schipper, E.L.F., A. Revi, B.L. Preston, E.R. Carr, S.H. Eriksen, L.R. Fernandez-Carril, B.C. Glavovic, N.J.M. Hilmi, D. Ley, R. Mukerji, M.S. Muylaert de Araujo, R. Perez, S.K. Rose, and P.K. Singh, 2022: Climate Resilient Development Pathways. In: *Climate Change 2022: Impacts, Adaptation and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 2655–2807, doi:10.1017/9781009325844.027.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Table of Contents

Executive Summary 2657

18.1 Ways Forward for Climate Resilient Development 2660

18.1.1 Understanding Climate Resilient Development 2660
18.1.2 Pathways for Climate Resilient Development 2661
18.1.3 Policy Context for Climate Resilient Development 2666
18.1.4 Assessing Climate Resilient Development 2667
18.1.5 Chapter Roadmap 2667

Box 18.1 | Transformations in Support of Climate Resilient Development Pathways 2668

Box 18.2 | Visions of Climate Resilient Development in Kenya 2669

18.2 Linking Development and Climate Action 2670

18.2.1 Implications of Current Development Trends 2670
18.2.2 Understanding Development in CRD 2671
18.2.3 Scenarios as a Method for Representing Future Development Trajectories 2673
18.2.4 Climate Change Risks to Development 2675
18.2.5 Options for Managing Future Climate Risks to Climate Resilient Development 2676

Box 18.3 | Climate Resilient Development in Small Islands 2680

Box 18.4 | Adaptation and the Sustainable Development Goals 2681

18.3 Transitions to Climate Resilient Development 2690

18.3.1 System Transitions as a Foundation for Climate Resilient Development 2690

Box 18.5 | The Role of Ecosystems in Climate Resilient Development 2694

18.3.2 Accelerating Transitions 2698

Cross-Chapter Box GENDER | Gender, Climate Justice and Transformative Pathways 2700

18.4 Agency and Empowerment for Climate Resilient Development 2705

18.4.1 Political Economy of Climate Resilient Development 2705
18.4.2 Enabling Conditions for Near-Term System Transitions 2706

Box 18.6 | 'Green' Strategies of Institutional Investors 2710

18.4.3 Arenas of Engagement 2711

Cross-Chapter Box INDIG | The Role of Indigenous Knowledge and Local Knowledge in Understanding and Adapting to Climate Change 2713

Box 18.7 | Macroeconomic Policies in Support of Climate Resilient Development 2718

18.4.4 Frontiers of Climate Action 2720

Box 18.8: The Role of the Private Sector in Climate Resilient Development via Climate Finance, Investments and Innovation 2721

18.5 Sectoral and Regional Synthesis of Climate Resilient Development 2721

18.5.1 Regional Synthesis of Climate Resilient Development 2721
18.5.2 Sectoral Synthesis of Climate Resilient Development 2724
18.5.3 Feasibility and Efficacy of Options for Climate Resilient Development 2724

18.6 Conclusions and Research Needs 2732

18.6.1 Knowledge Gaps 2732
18.6.2 Conclusions 2732

Frequently Asked Questions

FAQ 18.1 | What is a climate resilient development pathway? 2734

FAQ 18.2 | What is climate resilient development and how can climate change adaptation (measures) contribute to achieving this? 2734

FAQ 18.3 | How can different actors across society and levels of government be empowered to pursue climate resilient development? 2736

FAQ 18.4 | What role do transitions and transformations in energy, urban and infrastructure, industrial, land and ocean ecosystems, and in society, play in climate resilient development? 2736

FAQ 18.5 | What are success criteria in climate resilient development and how can actors satisfy those criteria? 2737

References 2738

Cross-Chapter Box FEASIB | Feasibility Assessment of Adaptation Options: An Update of the SR1.5 2769

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Executive Summary

Climate resilient development (CRD) is a process of implementing greenhouse gas mitigation and adaptation options to support sustainable development for all {Section 18.1}. Climate action and sustainable development are interdependent processes and climate resilient development is possible when this interdependence is leveraged. Pursuing these goals in an integrated manner increases their effectiveness in enhancing human and ecological well-being. Climate resilient development can help build capacity for climate action, including contributing to reductions in greenhouse gas emissions, while enabling the implementation of adaptation options that enhance social, economic and ecological resilience to climate change as the prospect of crossing the 1.5°C global warming level in the early 2030s approaches (WGI Table SPM1). For example, incorporating clean energy generation, healthy diets from sustainable food systems, appropriate urban planning and transport, universal health coverage and social protection, can generate substantial health and well-being co-benefits (*very high confidence*[1]) {Section 7.4.4, Cross-Chapter Box HEALTH in Chapter 7}. Similarly, universal water and energy access can help to reduce poverty and improve well-being while making populations less vulnerable and more resilient to adverse climate impacts (*very high confidence*) {Section 18.1, Box 4.7}.

Current development pathways, combined with the observed impacts of climate change, are leading away from, rather than towards, sustainable development, as reported in recent literature (*moderate agreement*, *robust evidence*). While demonstrable progress has been made on some of the Sustainable Development Goals (SDGs), significant gains across a range of targets are still necessary, as is enhancing synergies and balancing and managing trade-offs. Severe risks to natural and human systems are already observed in some places (*high confidence*) and could occur in many more systems worldwide before mid-century (*medium confidence*) and by the end of the century at all scales, from the local to the global, and at all latitudes and altitudes (*high confidence*). The coronavirus disease 2019 (COVID-19) pandemic revealed the vulnerability of development progress to shocks and stresses, potentially delaying the implementation of the 2030 Agenda for all {Section 8.1, Cross-Chapter Box COVID in Chapter 7}. Various global trends, including rising income inequality, continued growth in greenhouse gas emissions, land use change, food and water insecurity, human displacement and reversals of long-term increasing life expectancy trends in some nations, run counter to the SDGs (*very high confidence*), as well as efforts to mitigate greenhouse gas emissions and adapt to a changing climate {Section 18.2}. These development trends contribute to worsening poverty, injustice and inequity, and environmental degradation. Climate change can exacerbate these conditions by undermining human and ecological well-being {Section 18.2}.

Social and economic inequities linked to gender, poverty, race/ethnicity, religion, age or geographic location compound vulnerability to climate change and have created and could further exacerbate injustices, as well as constrain the implementation of CRD for all (*very high confidence*). Climate change intensifies existing vulnerability and inequality, with adverse impacts of climate change on the most vulnerable groups, including women and children in low-income households, Indigenous or other minority groups, small-scale producers and fishing communities, and low-income countries (*high confidence*). Most vulnerable regions and population groups, such as in East, Central and West Africa, South Asia, Micronesia and Melanesia, and Central America, present the most urgent need for adaptation (*high confidence*) {Chapters 10, 12, 15}. Climate justice initiatives explicitly address these multi-dimensional distributional issues as part of climate change adaptation. However, adaptation strategies can worsen social inequities, including gender, unless explicit efforts are made to change those unequal power dynamics, including spaces to foster inclusive decision making. Drawing upon Indigenous knowledge and local knowledge can contribute to overcoming the combined challenges of climate change, food security, biodiversity conservation, and combating desertification and land degradation. {Section 18.2; Cross-Chapter Box GENDER; Cross-Chapter Box INDIG}

Opportunities for climate resilient development vary by location (*very high confidence*). Over 3.3 billion people live in regions that are very high and highly vulnerable to climate change, while 2 billion people live in regions with low and very low vulnerability. Response to global greenhouse gas emissions trajectories, regional and local development pathways, climate risk exposure, socioeconomic and ecological vulnerability, and the local capacity to implement effective adaptation and greenhouse gas mitigation options, differ depending on local contexts and conditions {Table 18.3}. As an example, underlying social and economic vulnerabilities in Australasia exacerbate disadvantage among particular social groups and there is deep under-investment in adaptation, given current and projected risks {Chapter 11}. There is also significant regional heterogeneity in climate change, exposure and vulnerability, indicating different starting points for CRD, as well as mitigation, adaptation and sustainable development opportunities, synergies and trade-offs {Section 18.5}.

There are multiple possible pathways by which communities, nations and the world can pursue CRD. Moving towards different pathways involves confronting complex synergies and trade-offs between development pathways, and the options, contested values and interests that underpin climate mitigation and adaptation choices (*very high confidence*). Climate resilient development pathways (CRDPs) are trajectories for the pursuit of CRD and navigating its complexities. Different actors, the private sector and civil society, influenced by science, local and Indigenous knowledges, and the media are both active and passive in designing and navigating CRDPs {Sections 18.1, 18.4}. Increasing levels of warming may narrow the options and choices available for local survival and sustainable development for human societies and ecosystems. Limiting warming to Paris Agreement goals will reduce the magnitude of climate risks to which people, places the economy and ecosystems will have to adapt. Reconciling the costs, benefits and trade-offs associated with

1 In this Report, the following summary terms are used to describe the available evidence: limited, medium or robust; and for the degree of agreement: low, medium or high. A level of confidence is expressed using five qualifiers: very low, low, medium, high and very high, and typeset in italics, e.g., *medium confidence*. For a given evidence and agreement statement, different confidence levels can be assigned, but increasing levels of evidence and degrees of agreement are correlated with increasing confidence.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

adaptation, mitigation and sustainable development interventions and how they are distributed among different populations and geographies is essential and challenging, but also creates the potential to pursue synergies that benefit human and ecological well-being. For example, in parts of Asia, sustainable development pathways that connect climate change adaptation and disaster risk reduction can reduce climate vulnerability and increase resilience {Table 18.3, Section 10.6.2}. Different actors and stakeholders have different priorities regarding these opportunities, which can exacerbate or diminish existing social, economic and ecological vulnerabilities and inequities. For example, in parts of Africa, intensive irrigation contributes to the development of agriculture but has come at a cost to ecosystem integrity and human well-being {Table 18.3, Section 9.15.2}. Careful and explicit consideration for the ethical and equity dimensions of policies and practices associated with a climate resilient development pathway can help limit these negative externalities.

Prevailing development pathways are not advancing CRD (*very high confidence*). Societal choices in the near term will determine future pathways. Some low-emissions pathways and climate outcomes are *unlikely*[2] to be realised (*very high confidence*). Rapid climate change is affecting every region across the globe and affecting natural and human systems relevant to the pursuit of the SDGs {Sections 18.1, 18.2, Figure 18.1}. Even the most ambitious greenhouse gas mitigation scenarios indicate climate change will continue for decades to centuries {WGI, Section 18.2}. Increasing mitigation effort across multiple sectors exhibits opportunities for synergies with sustainable development, but also trade-offs that increase with mitigation efforts, that need to be balanced and managed (*high confidence*). The uncertainty associated with achieving specific pathways and climate outcomes is a risk factor to consider in planning, with plausibility and transformational challenges, as well as trade-offs and synergies, affected by technology, policy design and societal choices {Section 18.2}. For instance, restrictions on utilisation of individual mitigation options to manage trade-offs (e.g., bioenergy with carbon capture and storage [CCS], afforestation, nuclear power) can also affect the mitigation cost to households (e.g., energy security, commodity prices) and the likelihood of a desired climate outcome being realised. Developing and transitional economies are estimated as low-cost mitigation opportunities but are often at high risk from climate change due to their regional and development context (*high confidence*) {Sections 18.2, 18.5}. For example, in Africa, competing uses for water such as hydropower generation, irrigation and ecosystem requirements can create trade-offs among different management and development objectives {Section 9.7.3}. In Asia, intensive irrigation and other forms of water consumption can have a negative effect on water quality and aquatic ecosystems {Section 10.6.3}. Developed countries also face trade-offs, including in Australasia where adapting to fire risk in peri-urban zones introduces potential trade-offs among ecological values and fuel reduction in treed landscapes {Section 11.3.5}, and in North America where new coastal and alpine developments generate economic activity but enhance local social inequalities {Section 15.4.10}.

Systems transitions can enable CRD when accompanied by appropriate enabling conditions and inclusive arenas of engagement (*very high confidence*). Five systems transitions are considered: energy, industry, urban and infrastructure, land and ecosystems, and societal. Advancing CRD in specific contexts may necessitate simultaneous progress on all five transitions. Collectively, these system transitions can widen the solution space, and accelerate and deepen the implementation of sustainable development, adaptation, and mitigation actions by equipping actors and decision makers with more effective options. For example, urban ecological infrastructure linked to an appropriate land use mix, street connectivity, open and green spaces, and job-housing proximity provides adaptation and mitigation benefits that can aid urban transformation. {Table 18.4, Cross-Working Group Box URBAN in Chapter 6} These system transitions are necessary precursors for more fundamental climate and sustainable-development transformations; but can simultaneously be outcomes of transformative actions. However, the way they are pursued may not necessarily be perceived as ethical or desirable to all actors. Hence, enhancing equity and agency are cross-cutting considerations for all five transitions. Such transitions can generate benefits across different sectors and regions, provided they are facilitated by appropriate enabling conditions, including effective governance, policy implementation, innovation, and climate and development finance, which are currently insufficient {Sections 18.3, 18.4}.

There is a rapidly narrowing window of opportunity to implement system transitions needed to enable CRD. Past choices have already eliminated some development pathways, but other pathways for CRD remain (*very high confidence*). In spite of a growth in national net-zero commitments, the current prospects of surpassing 1.5°C global mean temperatures by the 2030s are high {WGI Table SPM1}. There is strong evidence of the worsening of multiple climate impact drivers in all regions, that will place additional pressures on ecosystem services that support food and water systems, increasing the risks of malnutrition, ill-health and poverty in many regions {WGI Fig SPM9, Table 18.4}. This implies that significant additional adaptation will be needed. Over the near-term, implementing such transformational change could be disruptive to various economic and social systems. Over the long-term, however, they could generate benefits to human well-being and planetary health. Strengthening coordinated adaptation and mitigation actions can enhance the potential of local and regional development pathways to support CRD. Planning for CRD can support both adaptation and decarbonisation via effective land use, promoting resilient and low-carbon infrastructure; protecting biodiversity and integrating ecosystem services {Table 18.4}, assuming advancing just and equitable development processes.

Prospects for transformation towards CRD increase when key governance actors work together in inclusive and constructive ways to create a set of appropriate enabling conditions {Section 18.4.2} (*high confidence*). These enabling conditions include effective governance and information flow, policy frameworks

2 In this Report, the following terms have been used to indicate the assessed likelihood of an outcome or a result: Virtually certain 99–100% probability, very likely 90–100%, likely 66–100%, about as likely as not 33–66%, unlikely 0–33%, very unlikely 0–10% and exceptionally unlikely 0–1%. Additional terms (extremely likely: 95–100%, more likely than not >50–100% and extremely unlikely 0–5%) may also be used when appropriate. Assessed likelihood is typeset in italics, e.g., *very likely*). This Report also uses the term '*likely* range' to indicate that the assessed likelihood of an outcome lies within the 17–83% probability range.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

that incentivise sustainability solutions; adequate financing for adaptation, mitigation and sustainable development; institutional capacity; science, technology and innovation; monitoring and evaluation of climate resilient development policies, programmes and practices; and international cooperation. Investment in social and technological innovation could generate the knowledge and entrepreneurship needed to catalyse system transitions and their transfer. The implementation of policies that incentivise the deployment of low-carbon technologies and practices within specific sectors such as energy, buildings and agriculture could accelerate greenhouse gas mitigation and deployment of climate-resilient infrastructure in urban and rural areas. Civic engagement is an important element of building societal consensus and reducing barriers to action on adaptation, mitigation and sustainable development {Section 18.4}.

CRDPs are determined through engagement in different arenas, the degree to which the emergent pathways foster just and CRD depends on how contending societal interests, values and worldviews are reconciled through inclusive and participatory interactions between governance actors in these arenas of engagement {Section 18.4.3} (*high confidence*). These interactions occur in many different arenas (e.g., governmental, economic and financial, political, knowledge, science and technology, and community) that represent the settings, places and spaces in which societal actors interact to influence the nature and course of development. For instance, the Agenda 2030 highlights the importance of multi-level adaptation governance, including non-state actors from civil society and the private sector. This implies the need for wider arenas and modes of engagement around adaptation that facilitate coordination, convergence and productive contestation among these diverse actors to collectively solve problems and to unlock the synergies between adaptation and mitigation and sustainable development.

Regional and national differences mean different capacities for pursuing CRDPs. Economic sectors and global regions are exposed to different opportunities and challenges in facilitating CRD, suggesting adaptation and mitigation options should be aligned to local and regional context and development pathways (*very high confidence*). Given their current state of development, some regions may prioritise poverty and inequality reduction, and economic development over the near-term as a means of building capacity for climate action and low-carbon development over the long-term. For example, Africa, South Asia, and Central and South America are highly exposed, vulnerable and impacted by climate change, which is amplified by poverty, population growth, land use change and high dependence on natural resources for commodity production. In contrast, developed economies with mature economies and high levels of resilience may prioritise climate action to transition their energy systems and reduce greenhouse gas emissions. Some interventions may be robust in that they are relevant to a broad range of potential development trajectories and could be deployed in a flexible manner. For example, conservation of land and water could be achieved through a variety of means and offer benefits to populations in the Global North and South alike. However, other types of interventions, such as those that are dependent upon emerging technologies, may require a specific set of enhanced enabling conditions or factors including infrastructure, supply chains, international cooperation, and education and training that currently limit their implementation to certain settings {Section 18.5}. Notwithstanding national and regional differences, development practices that are aligned to people, prosperity, partnerships, peace and the planet, as defined in Agenda 2030, could enable more CRD {Figure 18.1}.

People, acting through enabling social, economic and political institutions are the agents of system and societal transformations that facilitate CRD founded on the principles of inclusion, equity, climate justice, ecosystem health and human well-being (*very high confidence*). While much literature on climate action has focused on the role of technology and policy as the factors that drive change, recent literature has focused on the role of specific actors; citizens, civil society, knowledge institutions (including local and Indigenous Peoples and science), governments, investors and businesses. Greater attention to, and transparency of, which actors' benefit, fail to benefit or are impacted by mitigation and adaptation choices actions could better support climate-resilient and sustainable development. For example, grounding adaptation actions in local realities could help to ensure that adaptive actions do not worsen existing gender and other inequities within society (e.g., leading to maladaptation practices) (*high confidence*). Differences in the ability of different actors to effect change ultimately influence which interventions for sustainable development or climate action are implemented and thus what development outcomes are achieved. Recent literature has focused on the social, political and economic arenas of engagement in which these different actors interact. More focused attention on these arenas of engagement could prove beneficial to reconciling divergent views on climate action, integrating Indigenous knowledge and local knowledges, and elevating diverse voices that have historically been marginalised from the policy discourse, thereby reducing vulnerability and deepening adaptive capacity and the ability to implement CRD {Section 18.4; Cross-Chapter Box GENDER; Cross-Chapter Box INDIG}.

Pursuing CRD involves considering a broader range of sustainable development priorities, policies and practices, as well as enabling societal choices to accelerate and deepen their implementation (*very high confidence*). Scientific assessments of climate change have traditionally framed solutions around the implementation of specific adaptation and mitigation options as mechanisms for reducing climate-related risks. They have given less attention to a fuller set of societal priorities and the role of non-climate policies, social norms, lifestyles, power relationships and worldviews in enabling climate action and sustainable development. Because CRD involves different actors pursuing plural development trajectories in diverse contexts, the pursuit of solutions that are equitable for all requires opening the space for engagement and action to a diversity of people, institutions, forms of knowledge and worldviews. Through inclusive modes of engagement that enhance knowledge sharing and realise the productive potential of diverse perspectives and worldviews, societies could alter institutional structures and arrangements, development processes, choices and actions that have precipitated dangerous climate change, constrained the achievement of SDGs and, thus, limited pathways to achieving CRD {Box 18.1, Section 18.4}. Action over the next decade will be critical for charting CRD pathways that catalyse the transformation of prevailing development practices and offer the greatest promise and potential for human well-being and planetary health.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

18.1 Ways Forward for Climate Resilient Development

The links between climate change and development have been long recognized by various research communities (Nagoda, 2015; Winkler et al., 2015; Webber, 2016; Carr, 2019) and have been assessed by Working Group II in every IPCC Assessment Report since AR3 (Smit et al., 2001; Yohe et al., 2007; Denton et al., 2014). For the AR 1-3 reports, these links were largely framed in the context of sustainable development, a concept that has been well described in the literature for decades (Brundtland, 1987). The AR5 introduced the framing of climate-resilient pathways, which narrowed the discussion around sustainable development to specifically address the contributions of mitigation and adaptation actions to the reduction of risk to development and the various institutions, strategies and choices involved in risk management (Denton et al., 2014). That assessment concluded that identifying and implementing appropriate technical and governance options for mitigation and adaptation as well as development strategies and choices that contribute to climate resilience are central to the successful implementation of such strategies. The AR5 also recognised that transformation of current development pathways in terms of wider political, economic and social systems may be necessary (Denton et al., 2014).

The literature presenting research findings on climate resilient development (CRD) and pathways and processes for successfully achieving CRD has expanded significantly in the several years since the AR5 (*very high confidence*). This includes both qualitative studies of development as well as illustrative, quantitative analyses of development trajectories linked to specific scenarios, such as the Shared Socioeconomic Pathways (SSPs) (Section 18.2.2). Furthermore, the literature describing the role of system transitions and societal transformation in enabling climate action (Box 18.1, Section 18.3), compliance with the Paris Agreement (Sections 18.1.3, 18.2.1) and achievement of the SDGs (Section 18.1.3; Box 18.4) has expanded significantly (*very high confidence*). This expansion is comprised of studies spanning a broad range of disciplinary perspectives, some of which have been underrepresented in prior IPCC assessments (*high agreement*, *limited evidence)* (Minx et al., 2017; Pearce et al., 2018b).

This chapter therefore focuses on assessing this more recent literature and the diverse scientific understandings of CRD and the pathways for pursuing it. Notably, this chapter takes off where Chapters 16 and 17 end: recognising the decision-making context to address the representative key risks and their intersections with development, among others. This chapter therefore highlights not only how climate risk undermines CRD, but also how current patterns of development contribute to climate risk, both generally and in different sectoral and regional contexts. In particular, this chapter focuses on achieving CRD through systems transitions, discussing these in relation to societal transformation, and how different actors engage one another in order to pursue policy and practice consistent with CRD.

18.1.1 Understanding Climate Resilient Development

Past IPCC Assessment Reports have consistently examined extensive literature on the links between climate change, adaptation and sustainable development (Smit et al., 2001; Klein et al., 2007; Yohe et al., 2007). However, studies that explicitly refer to CRD as a concept or a guide for policy and practice remain modest (*very high confidence*). The concept of CRD appeared in scholarly literature and development program documents over a decade ago (Kamal Uddin et al., 2006; Garg and Halsnæs, 2007) and has been used in more recent IPCC assessment reports and special reports (e.g., Denton et al., 2014; Roy et al., 2018). Similarly, the use of the term climate resilient development pathways (CRDPs) dates to 2009 (Ayers and Huq, 2009), but its use accelerated after appearing in United Nations Framework Convention on Climate Change (UNFCCC) publications around the launch of the Green Climate Fund (UNFCCC, 2011). While this chapter prioritises the CRD literature, it also recognises that a broad range of literature, disciplinary expertise and development practice is relevant to the concept of CRD.

Much of this literature is assessed in recent IPCC Special Reports (Rogelj et al., 2018; Roy et al., 2018; Bindoff et al., 2019; Hurlbert et al., 2019; Oppenheimer et al., 2019), but new studies have continued to emerge. More specific uses of CRD found in the literature describe development that seeks to achieve poverty reduction and adaptation to climate change simultaneously without explicit mention of mitigation (USAID, 2014), as well as mitigation and poverty reduction, described as 'low-carbon development', without explicit mention of adaptation (Alam et al., 2011; Fankhauser and McDermott, 2016). Other similar terms include 'climate safe', 'climate compatible' and 'climate smart' development (Huxham et al., 2015; Kim et al., 2017b; Ficklin et al., 2018; Mcleod et al., 2018), each with varying nuances. Climate compatible development, coined by Mitchell and Maxwell (2010), specifically describes a 'triple win' of adaptation, mitigation and development (Antwi-Agyei et al., 2017; Favretto et al., 2018) (see also Section 8.6). In this spirit, AR5 specifically referred to CRD as '*development trajectories that combine adaptation and mitigation to realize the goal of sustainable development*' (Denton et al., 2014). This chapter builds on the AR5 and, for the purposes of assessment, formally defines CRD as *a process of implementing greenhouse gas mitigation and adaptation measures to support sustainable development for all.* This extension of the earlier definition reflects the emphasis in recent literature on equity as a core element of sustainable development as well as the objective of the SDGs to '*create conditions for sustainable, inclusive and sustained economic growth, shared prosperity and decent work for all, taking into account different levels of national development and capacities*' (United Nations, 2015: 3/35).

Past, present and future concentrations of greenhouse gases in the atmosphere are the direct result of both natural and anthropogenic greenhouse gas emissions which are, in turn, a function of past and current patterns of human and economic development (*very high confidence*, WGI SPM [IPCC, 2021b]). This includes development processes that drive land use change, extractive industries, manufacturing and trade, energy production, food production, infrastructure development and transportation. These patterns of development are therefore drivers of current and future climate risk to specific sectors, regions and populations (Byers et al., 2018), as

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

well as the demand for both mitigation and adaptation as a means of preventing climate change from undermining development goals. The SDGs represent targets for supporting human and ecological well-being in a sustainable manner. Yet, while progress is being made towards a number of the SDGs, success in achieving all of the SDGs by 2030 across all global regions remains uncertain (*high agreement*, *medium evidence*) (United Nations, 2021). Moreover, current commitments to reduce greenhouse gas emissions are not yet consistent with limiting changes in global mean temperature elevation to well-below 2°C or 1.5°C (*very high confidence*) (IPCC, 2018a) (see also Section 18.2).

Atmospheric concentrations of greenhouse gases are just one of a number of planetary boundaries which define safe operating spaces for humanity and therefore opportunities for achieving sustainable and CRD. Exceeding these boundaries poses increased risk of large-scale abrupt or irreversible environmental changes that would threaten human and ecological well-being (*very high confidence*) (Rockström et al., 2009a; Rockström et al., 2009b; Butler, 2017; Schleussner et al., 2021). Other planetary boundaries reported in the literature such as biodiversity loss, changes in land systems and freshwater use are also directly influenced by patterns of development as well as climate change (Sections 18.2, 18.5). Current rates of species extinction, conversion of land for crop production and exploitation of water resources exceed planetary boundaries, thereby undermining CRD. Moreover, studies indicate that achievement of the SDGs, while consistent with maintaining some planetary boundaries, could undermine others (O'Neill et al., 2018; Hickel, 2019; Randers et al., 2019) (Section 18.2), suggesting significant shifts in current patterns of development are necessary to maintain development within planetary boundaries.

Exceedance of planetary boundaries contributes to human and ecological vulnerability to climate change and other shocks and stressors. People and regions that already face high rates of natural resource use, ecosystem degradation and poverty are more vulnerable to climate change impacts, compounding existing development challenges in regions that are already strained (IPCC, 2014a; Hallegatte et al., 2019). The International Monetary Fund, for example, found that for a medium- and low-income developing country with an annual average temperature of 25°C, the effect of a 1°C increase in temperature is a reduction in economic growth by 1.2% (Acevedo et al., 2018). Countries whose economies are projected to be hard hit by an increase in temperature account for only about 20% of global gross domestic product (GDP) in 2016, but are home to nearly 60% of the global population. This is expected to rise to more than 75% by the end of the century. These economic impacts are a function of the underlying vulnerability of low- and middle-income developing economies to the impacts of climate change (Section 18.5). Such vulnerability was also evidenced and enhanced by the COVID-19 pandemic which slowed progress on the SDGs in multiple nations (Naidoo and Fisher, 2020; Srivastava et al., 2020; Bherwani et al., 2021).

18.1.2 Pathways for Climate Resilient Development

One approach for operationalising the concept of CRD in a decision making context is to link the concept of CRD to that of pathways (Figure 18.1). A pathway can be defined as '*a trajectory in time, reflecting a particular sequence of actions and consequences against a background of autonomous developments, leading to a specific future situation*' (Haasnoot et al., 2013; Bourgeois, 2015). As such, a pathway represents changes over time in response to policies and practices, as well spontaneous and exogenous events. For example, the SR1.5 report suggested that CRD pathways are '*a conceptual and aspirational idea for steering societies towards low-carbon, prosperous and ecologically safe futures*' (Roy et al., 2018: 468), and a way to highlight the complexity of decision making processes at different levels. Here, consistent with the aforementioned definition of CRD, we define CRD pathways as *development trajectories that successfully integrate mitigation, adaptation and sustainable development*.

As illustrated in Figure 18.1, the ultimate aim of CRDPs is to support sustainable development for ensuring planetary health and human well-being. CRD is both an outcome at a point in space and time, as observed through SDG achievement indicators, but also a process consisting of actions and social choices made by multiple actors—government, industry, media, civil society, and science (Section 18.4). These actions and social choices are performed within different dimensions of governance—politics, institutions (norms, rules), and practice, and bounded by ethics, values and worldviews. The development outcomes and processes pertain to political, economic, ecological, socio-cultural, knowledge-technology and community arenas (Figure 18.2). A CRDP will, for example, aspire to achieve ecological outcomes in terms of planetary health and achievement of Paris Agreement goals as well as human well-being, solidarity and social justice, in addition to political, economic and science–technology outcomes. These outcomes are enabled by achieving progress in core system transitions that catalyse broader societal transformations (Figure 18.3).

While there are many possible successful pathways to future development in the context of climate change, history has shown that pathways that are positive for the vast majority often induce notable impacts and costs, especially on marginal and vulnerable people (Hickel, 2017; Ramalho, 2019), placing them in direct contradiction with the commitment to 'leave no one behind' (United Nations, 2015). Similarly, contemporary scenario analyses find that there are plausible development trajectories that lead towards sustainability (Figure 18.1, Section 18.2.2). Yet, a number of plausible trajectories that perpetuate or exacerbate unstainable forms of development also appear in the literature (Figure 18.1, Section 18.2.2). A significant challenge lies in identifying pathways that address current climate variability and change, while allowing for improvements in human well-being. Furthermore, while a given pathway might lead to a set of desired outcomes for one region or set of actors, the process of getting there may come at high environmental, socio- and economic cost to others (*very high confidence*) (Raworth, 2017; Faist, 2018). Frequently, considerations of social difference and equity are not prioritised in the evaluation of different development choices. The assumption that a growing economy lifts opportunity for all could, for example, further marginalise those who are the most vulnerable to climate change (Matin et al., 2018; Diffenbaugh and Burke, 2019; Hickel et al., 2021).

Placing pathways and climate actions within development processes implies a broadening of enablers to include the ethical–political quality of socio-environmental processes that are required to shift such processes in directions that support CRD and the pursuit of

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

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

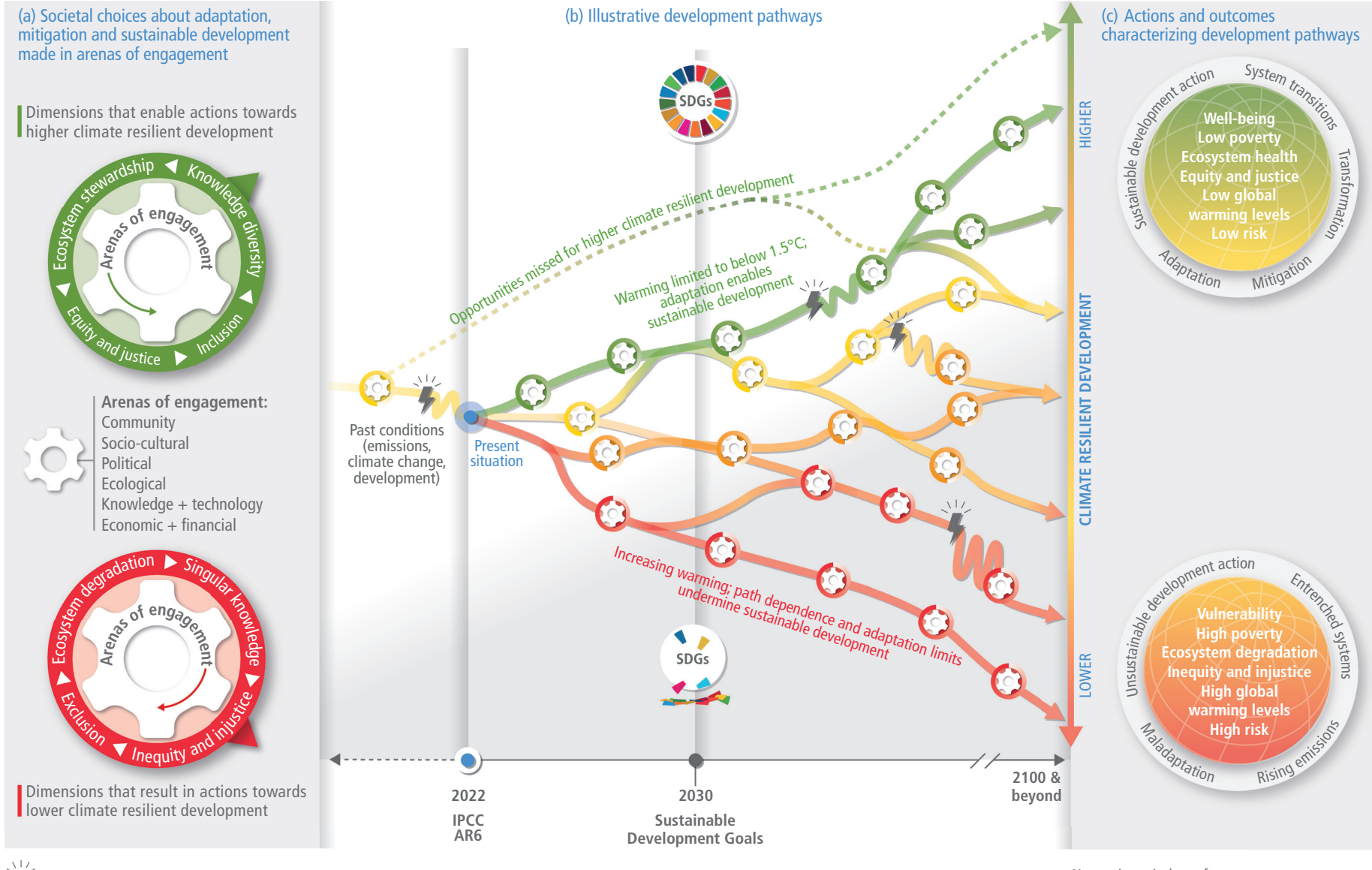


Figure 18.1 | Climate Resilient Development Pathways are development trajectories that successfully integrate GHG mitigation and adaptation efforts to support sustainable development for all.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

(a) Climate resilient development is a process that takes place through continuous societal choices towards higher CRD (illustrative green pathways) or lower CRD (illustrative red pathways).

(b) CRD is described by five development dimensions – people, prosperity, partnership, peace, planet – on which the SDGs build (18.2).

Some societal choices have mixed outcomes for CRD (illustrative orange pathways). This figure builds on figure SPM.9 in AR5 WGII depicting climate resilient pathways by describing how CRDPs emerge from societal choices about adaptation, mitigation and sustainable development within multiple arenas – rather than solely from discrete decision points (18.4). Dimensions of CRD characterize both development outcomes as well as the interactions and societal choices that make up the development process. Societal choices, often contested, are made in arenas of engagement through interactions between key actors in civil society, the private sector and government (see Figure 18.2). The quality of interactions, such as degree of inclusion and empowerment of diverse voices, determine whether societal choices and associated actions shift development towards or away from CRD. The five CRD dimensions underline the close interconnectedness between the biosphere and humans, the two necessarily intertwined in interactions, actions, transitions, and futures (see Figure 18.3). There is a narrow and closing window of opportunity to make transformational changes to move towards and not away from development futures that are more climate-resilient and sustainable (Box 18.1). Pathways not taken (dotted line) illustrate that opportunities have been missed for higher CRD pathways due to past societal choices and increasing temperatures. Present societal choices determine whether we shift towards higher CRD in future or whether pathways will be limited to lower CRD.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Societal choices made in arenas of engagement shape actions and systems

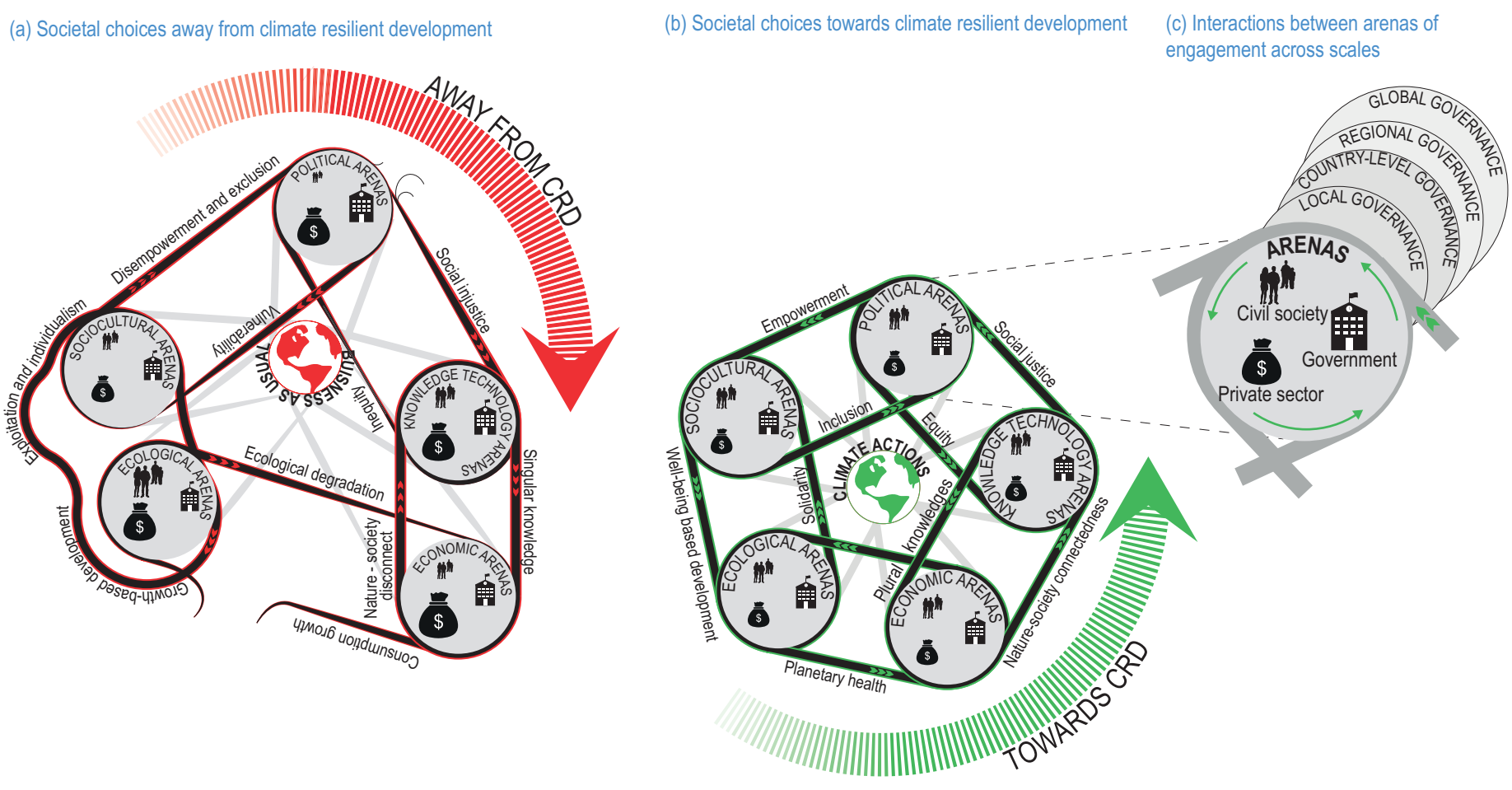


Figure 18.2 | Societal choices made in arenas of engagement shape actions and systems. The settings, places and spaces in which key actors from government, civil society and the private sector interact to influence the nature and course of development can be called arenas of engagement, including political, economic, socio-cultural, ecological, knowledge-technology and community arenas (18.4) For instance, political arenas include formal political settings such as voting procedures to elect local representatives as well as less formal and transparent political arenas. Streets, town squares and post-disaster landscapes can become sites of interaction and political struggle as citizens strive to have their voices heard. Arenas of engagement can take the form of "struggle arenas" – in which power and influence are used to include/exclude, set agendas, and make and implement decisions – with inevitable winners and losers. The quality of interactions in these arenas leads to development outcomes that can be characterized as CRD dimensions that underpin the SDGs – people, prosperity, partnership, peace, planet (see Figure 18.1).

(a) Interactions characterized by inequitable relations and domination of some actors over others may lead to societal choices away from CRD, including mitigation and adaptation actions that exacerbate vulnerability among marginalized groups.

(b) Prospects for moving towards CRD increase when governance actors work together constructively in these different arenas. Interactions and actions that are inclusive and synchronous, as opposed to fragmented or contradictory, enable system transitions and transformational change towards CRD (see Figure 18.3). Most societal choices and associated decisions are characterized by a mix of the dimensions shown in (a) and (b), with mixed outcomes for CRD.

(c) Arenas exist across scales from the local to national level, and beyond. Community arenas of engagement constitute the many interactions between governance actors and the political, economic, socio-cultural, ecological, knowledge-technology arenas, reflecting emergent societal choices across scales. Together, the decisions made by multiple actors within and across these arenas of engagement form societal choices. Unlocking the potential of these societal choices and associated mitigation, adaptation and sustainable development actions is central to advancing human well-being and planetary health.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Transformative actions and system transitions

(a) Societal choices that generate fragmented climate action or inaction and unsustainable development perpetuate business as usual development

(b) Societal choices that support CRD involve transformative actions that drive five systems transitions

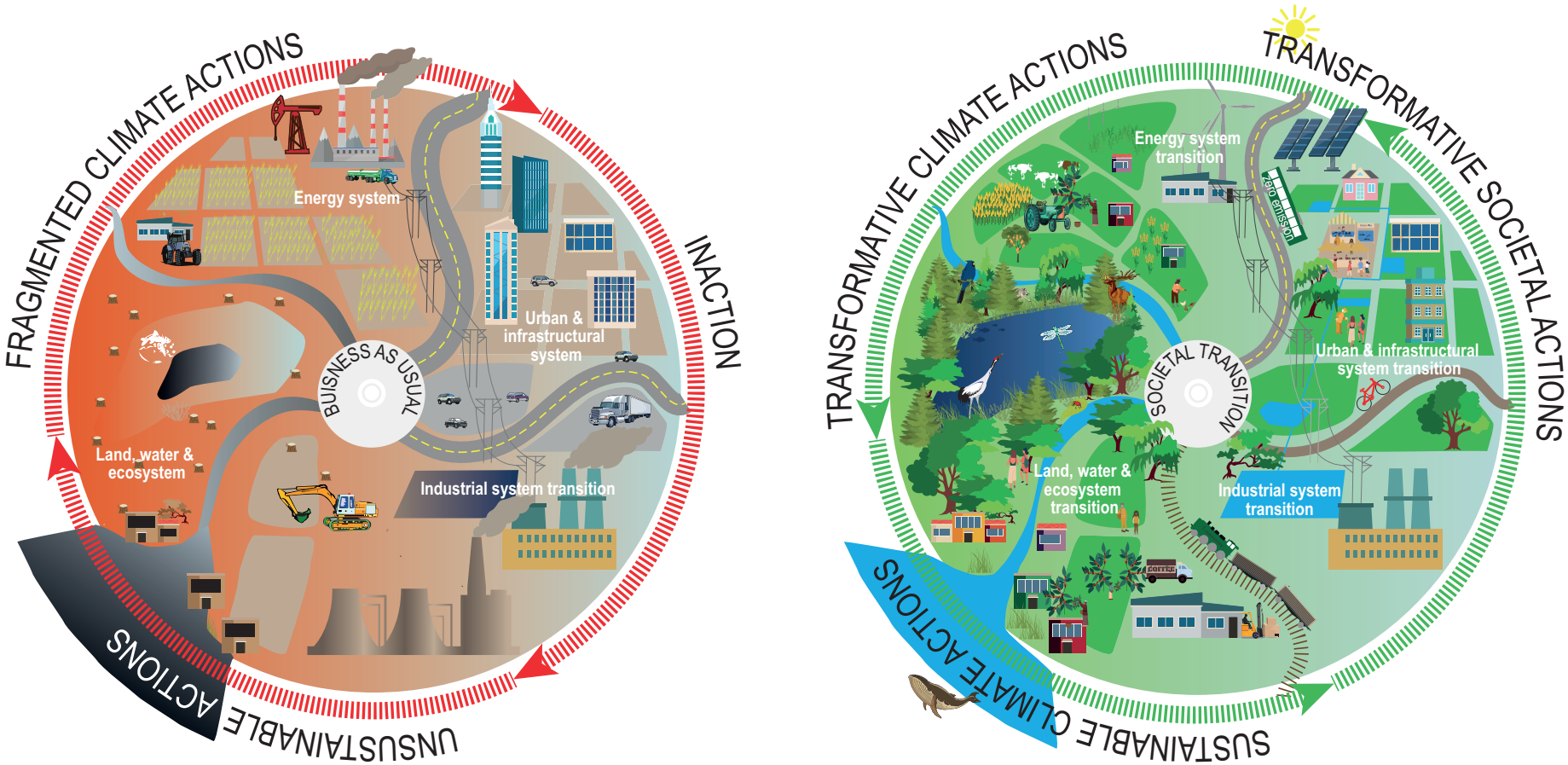


Figure 18.3 | Transformative actions and system transitions characterize Climate Resilient Development Pathways

(a) Societal choices that generate fragmented climate action or inaction and unsustainable development perpetuate business as usual and entrenched systems.

(b) Societal choices that support CRD involve transformative adaptation, mitigation and sustainable development actions that drive five systems transitions (energy, land and other ecosystems, urban and infrastructure, industrial and societal). There is close interdependence between these systems. The system transition framework allows for a comprehensive assessment of the synergies and trade-offs between mitigation, adaptation and sustainable development. For example, land and water use in one system impacts the other systems and their surrounding ecosystems, thus reflecting how agricultural practices can have an impact on energy usage in urban centers. Finally, societal system transitions within each of the other systems enable the transitions to occur (18.3, Box 18.1).

sustainability outcomes. This chapter therefore departs from the AR5s alignment of CRD with adaptation pathways and the emphasis on decision points that enable one to manage (or fail to manage) climate risk, towards a framing that integrates a range of possible futures each offering different opportunities, risks and trade-offs to different actors and stakeholders (see WGII AR5, IPCC, 2014b, Figure SPM.9). Instead, CRD emerges from everyday formal and informal decisions, actions, and adaptation or mitigation policy interventions. This is inclusive of system transitions, increased resilience, environmental integrity, social justice, equity, and reduced poverty and vulnerability, all facets of human well-being and planetary health. Rather than encompassing a formula or blueprint for particular actions, sustainable development is a process that provides a compass for the direction that these multiple actions should take (Anders, 2016). This creates opportunities for actors to apply a diverse toolkit of adaptation, mitigation and sustainable development interventions, thereby opening up the solution space.

This understanding of CRD implies that different actors—governments, businesses and civic organisations—will have to design and navigate their own CRD pathways towards climate-resilient and sustainable development. This includes determining the appropriate balance of adaptation, mitigation and sustainable development actions and investments that are consistent with individual actors' development circumstances and goals, while also ensuring that the collective actions remain consistent with global agreements and goals (such as the SDGs, Sendai Framework and the Paris Agreement; Section 18.1.3), planetary boundaries and other principles of CRD including social justice and equity (Roy et al., 2018). Empowering individual actors to pursue CRD in a context-specific manner while coordinating action among actors and a diversity of scales, local to global, is a key challenge associated with achieving CRD (*high agreement*, *limited evidence*).

18.1.3 Policy Context for Climate Resilient Development

As reflected in Chapter 1 of the AR6 WGII report, CRD is emerging as one of the guiding principles for climate policy, both at the international level (Denton et al., 2014; Segger, 2016), as reflected in the Paris Agreement (Article 2, UNFCCC, 2015), and within specific countries (Simonet and Jobbins, 2016; Kim et al., 2017b; Vincent and Colenbrander, 2018; Yalew, 2020). This framing of development recognises the risks posed by climate change to development objectives (Section 18.2; see also Chapter 16); the opportunities, constraints and limits associated with reducing risk through adaptation; synergies and trade-offs between mitigation, adaptation and sustainable development (Sections 18.2.5, 18.5, Box 18.4); and the role of system transitions in enabling large-scale transformations that limit future global warming to less than 1.5°C, while boosting resilience (IPCC, 2018a) (Section 18.3, Box 18.1).

Since the AR5, the volume of research at the nexus of climate action and sustainable development has changed markedly (*very high confidence*). A rapidly growing, multi-disciplinary literature has emerged on CRD (Mitchell et al., 2015; Clapp and Sillmann, 2019; Hardoy et al., 2019; Yalew, 2020) and associated pathways (Naess et al., 2015; Winkler and Dubash, 2016; Brechin and Espinoza, 2017; Solecki et al., 2017; Ellis and Tschakert, 2019) (Section 18.2.2). Nevertheless, the concept of resilience generally, and CRD specifically, has come under increasing criticism in recent years (*very high confidence*) (Joakim et al., 2015; Schlosberg et al., 2017; Mikulewicz, 2018; Mikulewicz, 2019; Moser et al., 2019), suggesting the need to enhance understanding of how resilience is being operationalised at the programme and project level and the net implications for human and ecological well-being.

This expansion of research has been accompanied by a shift in the policy context for climate action including an increasingly strong link between climate actions and sustainable development. In particular, the SDGs represent a near-term framework linking sustainability and human development in a manner that not only addresses planetary health and human well-being, but also help better plan and implement mitigation and adaptation actions to achieve these linked goals (Conway et al., 2015; Griscom et al., 2017; Allen et al., 2018b; Roy et al., 2018; P.R. Shukla E. Calvo Buendia, 2019). The SDGs explicitly identify climate action (SDG 13) among the goals needed to achieve sustainable development. Meanwhile, the text of the Paris Agreement makes explicit mention of the importance of considering climate 'in the context of sustainable development' (Articles 2, 4, 6) or as 'contributing to sustainable development' (Article 7) (Article 7, UNFCCC, 2015). Similarly, sustainable development appears prominently within the text of the Sendai Framework for Disaster Risk Reduction (UNDRR, 2015) and the Global Assessment Reports on Disaster Risk Reduction (UNDRR, 2019). At the local- or household-level, a growing literature recognises that climate impacts tend to exacerbate existing inequalities within societies, even at the level of gender inequalities within households (Sultana, 2010; Arora-Jonsson, 2011; Carr, 2013). Thus, climate change impacts threaten even short-term gains in sustainable development (18.2, Box 18.4), which could be rolled back over longer adaptation and mitigation horizons. For example, the COVID-19 pandemic is estimated to have reversed gains over the past several years in terms of global poverty reduction (*very high confidence*) (Phillips et al., 2020; Sultana, 2021; Wilhelmi et al., 2021) (Cross-Chapter Box COVID in Chapter 7), reflecting the risks posed by global, systemic threats to development.

The WGII AR5 Report noted that adapting to the risks associated with climate change becomes more challenging at higher levels of global warming (IPCC, 2014a). This was evidenced by contrasting impacts and adaptive capacity for 2°C and 4°C of warming. This relationship between levels of warming, climate risk and reasons for concern (see Chapter 16) is also relevant to the concept of CRD. For example, recent literature on CRD emphasises the urgency of climate action that achieve significant reduction in greenhouse gas emissions, as well as the implementation of adaptation options that result in significant gains in human and natural system resilience (*very high confidence*) (Haines et al., 2017; Shindell et al., 2017; Xu and Ramanathan, 2017; Fuso Nerini et al., 2018). This was explored extensively in the IPCC's SR1.5 report in its comparison of impacts associated with 1.5°C versus 2°C climate objectives and synergies and trade-offs with the SDGs (IPCC, 2018a). However, the SR1.5 report and other literature also identified potential trade-offs between aggressive mitigation and the SDGs (see also Frank et al., 2017; Hasegawa et al., 2018). This indicates that while future magnitudes of warming are a fundamental consideration in CRD, such development involves more than just achieving temperature targets. Rather, CRD considers the possible transitions that enable those targets to be achieved, including the evaluation of different adaptation and

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

mitigation options and how the implementation of these strategies interacts with broader sustainable development efforts and goals. This interdependence between patterns of development, climate risk and the demand for mitigation and adaptation action is fundamental to the concept of CRD (Fankhauser and McDermott, 2016). Therefore, climate change and sustainable development cannot be assessed or planned in isolation of one another.

18.1.4 Assessing Climate Resilient Development

In operationalising the aforementioned definitions of CRD and CRDP, this chapter builds its assessment around five core elements that provide insights relevant to policymakers actively pursuing the integration of climate resilience into development. First, as noted above, climate change poses a potential risk to the achievement of development goals, including global goals such as the SDGs, as well as nationally or locally specific goals. Accordingly, Chapter 16's discussion of key risks, their implications for the SDGs and the options for risk management are fundamental to the pursuit of CRD. This includes the opportunities for implementing adaptation, mitigation or other risk management options. Yet the management of climate risk must be accompanied by interventions that address social and ecological vulnerabilities that enhance climate risk.

Second, CRD is dependent on achieving transitions in key systems including energy, land and ecosystem, urban and infrastructure, and industrial systems (*very high confidence*) (Box 18.1, Figure 18.3). In this context, CRD links to the discussion of system transitions in the SR1.5 report (IPCC, 2018b; IPCC, 2018a). However, in building on the SR1.5, here the assessment of CRD also recognises the importance of transitions in societal systems that drive innovation, preferences for alternative patterns of consumption and development, and the power relationships among different actors that engage in CRD. In particular, the rate at which actors can achieve system transitions has important implications for the pursuit of CRD. Transitions that are slow to evolve or that are more incremental in nature may not be sufficient to enable CRD in comparison with faster transitions that contribute to more fundamental system transformations.

Third, equity and social justice are consistently identified in the literature as being central to CRD (*very high confidence*; Sections 18.1.1, 18.3.1.5, 18.4, 18.5). This includes designing and implementing adaptation, resilience and climate risk management options in a manner that promotes equity in the allocation of the costs and benefits of those options. Similarly, the literature on CRD emphasises equity should be pursued in the implementation of options for greenhouse gas mitigation, transitions in energy systems and low-carbon development. This emphasis on equity is consistent with the SDGs which place an emphasis on reducing inequality and achieving sustainable development for all.

Fourth, success in CRD and alignment of development interventions to CRDPs is contingent on the presence of multiple enabling conditions (*very high confidence*, Section 18.4.2), that operate at different scales ranging from those that provide capacity to implement specific adaptation options to those that enable large-scale transformational change (Box 18.1). The qualities that describe sustainable development processes (e.g., social justice, alternative development models, equity and solidarity, as described above and in Figure 18.1) lead to short-term outcomes and conditions, such as those represented by SDGs, that in an iterative fashion enable or constraint subsequent efforts towards CRD. For example, success or failure in achieving the SDGs or the Paris Agreement would shape future efforts in pursuit of CRD and the options available to different actors.

Fifth, CRD involves processes involving diverse actors, at different scales operating within an environmental, developmental, socioeconomic, cultural and political context, as typified in the SDG and the Paris Agreement negotiations (*very high confidence*) (Kamau et al., 2018) (Section 18.4). The dependence of CRD on processes of negotiation and reconciliation among diverse actors and interests leads to the dismissal of the notion that there is a single, optimal pathway that captures the objectives, values and development contexts of all actors, even for a particular sector, country or region. Rather, preferences for different pathways and specific actions in pursuit of those pathways will be subjected to intense scrutiny and debate among diverse actors within various arenas of engagement (Section 18.4), meaning the settings, places and spaces in which key actors from government, civil society and the private sector interact to influence the nature and course of development.

18.1.5 Chapter Roadmap

This chapter engages with understanding CRD and the pathways to achieving it by building on the concepts introduced in Chapter 1 of this Working Group II report, as well as the regional and sectoral context presented in other chapters (Section 18.5). Notably, this chapter takes off where Chapters 16 and 17 end: recognising the significance of the representative key risks for CRD and the decision making context of different actors who are implementing policies and practices to pursue different CRD pathways and manage climate risk. Therefore, this chapter assesses options for pursuing CRD and the broader system transitions and enabling conditions in support of CRD.

This chapter hosts three Cross-Chapter Boxes, which have their natural home here. The Cross-Chapter Box on Gender, Justice and Transformative Pathways (Cross-Chapter Box GENDER) assesses literature specifically on gender and climate change to uncover the importance of a justice focus to facilitate transformative pathways, both towards CRD, as well as a means to achieving gender equity and social justice. The Cross-Chapter Box on The Role of Indigenous Knowledge in Understanding and Adapting to Climate Change (Cross-Chapter Box INDIG) highlights that achieving CRD requires confronting the uncertainty of a climate change future. There are many perspectives about what future is desired and how to reach it. Integrating multiple forms of knowledge is a strategy to build resilience and develop institutional arrangements that provide temporary solutions able to satisfy competing interests (Grove, 2018). Indigenous knowledge is proven to enhance resilience in multiple contexts (e.g., Chowdhooree, 2019; Inaotombi and Mahanta, 2019). Meanwhile, Cross-Chapter Box FEASIB acts as an appendix to the WGII report, synthesising information on the feasibility associated with different adaptation options for reducing risk.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

In assessing the opportunities and constraints associated with the pursuit of sustainable development, this chapter proceeds in Section 18.2 to assess the links between sustainable development and climate action, including examination of current patterns of development and consideration for synergies and trade-offs among different strategies and options. Then, in Section 18.3, the chapter assesses five systems transitions to identify the shifts in development that would enable CRD. Section 18.4 assesses the role of different actors in the pursuit of CRD as well as the public and private arenas in which they engage. Section 18.5 synthesises CRD assessments from different WGII sectoral and regional chapters to identify commonalities and differences. The chapter concludes in Section 18.6 with a summary of key opportunities for enhancing the knowledge needed to enable different actors to pursue CRD.

Box 18.1 | Transformations in Support of Climate Resilient Development Pathways

Transformational changes in the pursuit of climate resilient development pathways (CRDPs) involve interactions between individual, collective and systems change (Figures 18.1–18.3). There are complex interconnections between transformation and transition (Feola, 2015; Hölscher et al., 2018), and they are sometimes used as synonyms in the literature (Hölscher et al., 2018). Much of the transitions literature focuses on how societal change occurs within existing political and economic systems. Transformations are often considered to involve deeper and more fundamental changes than transitions, including changes to underlying values, worldviews, ideologies, structures and power relationships (Göpel, 2016; O'Brien, 2016; Kuenkel, 2019; Waddock, 2019). Systems transitions alone are insufficient to achieve the rapid, fundamental and comprehensive changes required for humanity and planetary health in the face of climate change (*high confidence*). Transformative action is increasingly urgent across all sectors, systems and scales to avert dangerous climate change and meet the SDGs (Pelling et al., 2015; IPCC, 2018a; IPCC, 2021b; Shi and Moser, 2021; Vogel and O'Brien, 2021) (*high confidence*). The SR1.5 identified transformative change as necessary to achieve transitions within land, water and ecosystems systems; urban and infrastructural systems; energy systems; and industrial systems. This box summarises key points in the transformations literature relevant to CRD.

Transformative actions aimed at 'deliberately and fundamentally changing systems to achieve more just and equitable outcomes', (Shi and Moser, 2021: 2) shift pathways towards climate resilient development (CRD) (*high confidence)*. Transformative action in the context of CRD specifically concerns leveraging change in the five dimensions of development (people, prosperity, partnership, peace, planet) that drive societal choices and climate actions towards sustainability (Section 18.2.2; Figure 18.1). Climate actions that support CRD are embedded in these dimensions of development; for example, social cohesion and equity, individual and collective agency, and democratising knowledge processes have been identified as steps to transform practices and governance systems for increased resilience (Ziervogel et al., 2016b; Nightingale et al., 2020; Colloff et al., 2021; Vogel and O'Brien, 2021) (*high confidence*). Transformative actions towards sustainability and increased well-being, which are dominant components of CRD, include those that explicitly redress social drivers of vulnerability, shift dominant worldviews, decolonialise knowledge systems, activate human agency, contest political arrangements, and insert a plurality of knowledges and ways of knowing (Görg et al., 2017; Fazey et al., 2018a; Brand et al., 2020; Gram-Hanssen et al., 2021; Shi and Moser, 2021). They alter the governance and political economic arrangements through which unsustainable and unjust development logics and knowledges are implemented (Patterson et al., 2017; Shi and Moser, 2021) by shifting the goals of a system or altering the mindset or paradigm from which a system arises, for example, from individualism and nature-society disconnect to solidarity and nature-society connectedness along the CRD dimensions in Figure 18.1, and connecting inner and external dimensions of sustainability (Göpel, 2016; Abson et al., 2017; Wamsler and Brink, 2018; Fischer and Riechers, 2019; Horcea-Milcu et al., 2019; Wamsler, 2019).

There is no blueprint for how transformation is generated. An expanding literature suggests that transformation takes place through diverse modalities and context-dependent actions (O'Brien, 2021). Transformation may require actions that disrupt moral or social boundaries and structures that are perpetuating unsustainable systems and pathways (Vogel and O'Brien, 2021) (*high confidence*). Extreme events and long-term climatic changes can trigger a realigning of practices, politics and knowledge (Carr, 2019; Schipper et al., 2020b) (*high confidence*). While some see opportunities for generating social and political conditions needed for CRD in such actions and events (Beck, 2015; Han, 2015; Shim, 2015; Mythen and Walklate, 2016; Domingo, 2018), this is not guaranteed. Climate shocks, when managed within socio-political systems in ways that safeguard rather than alter practices and structures, can also reinforce rather than shift the status quo (Mosberg et al., 2017; Carr, 2019; Marmot and Allen, 2020; Arifeen and Nyborg, 2021) (*high confidence*). Further, in the absence of equitable and inclusive decision making and planning, realignments resulting from disruptive actions and events can limit inclusiveness and lead to poor or coercive decision-making processes that undermine the equity and justice foundations of sustainable development (Orlove et al., 2020; Shi and Moser, 2021) and lead to adverse socio-environmental outcomes that generate transformations away from CRD (Vogel and O'Brien, 2021) (*high confidence*, see also CROSS-CHAPTER BOX 2).

Evidence for transformative actions largely exists at the community or city level. While identifying how to rapidly and equitably generate transformations at a global scale has remained elusive, there is *high agreement* but *limited evidence* from studies of ecosystem services that suggest facilitating a wide range of locally appropriate management decisions and actions can bring about positive global-scale outcomes (Millennium Ecosystem Assessment, 2005). Diverse local efforts to transform towards sustainability in the face of climate

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Box 18.1 (continued)

change have been observed, such as community mobilisation for equitable and just adaptation actions and alternative visions of societal well-being (Shi, 2020b) and farmer-led shifts in agricultural production systems (Rosenberg, 2021). There has been an increase in transformative actions taking place through city-level resilience building aimed at shifting inequitable relations and opening up space for a plurality of actors (Rosenzweig and Solecki, 2018; Ziervogel et al., 2021) (*high confidence*).

Prospects for transformation towards CRD increase when key governance actors work together in inclusive and constructive ways through engagement in political, knowledge-technology, ecological, economic and socio-cultural arenas (*high confidence*, Section 18.4.3). Yet the interactions between key governance actors involve struggles and negotiations in addition to collaborations (Kakenmaster, 2019; Muok et al., 2021). Transformative actions meet resistance by precisely the political, social, knowledge and technical systems and structures they are attempting to transform (Blythe et al., 2018; Shi and Moser, 2021) (*high confidence*). There is expanding evidence that many adaptation efforts have failed to be transformative, but instead entrenched inequities, exacerbated power imbalances and reinforced vulnerability among marginalised groups and that, instead, marginalised groups and future trends in vulnerability need to be placed at the centre of adaptation planning (Atteridge and Remling, 2018; Mikulewicz, 2019; Owen, 2020; Eriksen et al., 2021a; Eriksen et al., 2021b; Garschagen et al., 2021) (*high confidence*). Beyond the enablers, drivers or modalities, another question tackled in the literature is how to evaluate transformation by establishing criteria for transformation assessments (Ofir, 2021; Patton, 2021; Williams et al., 2021), experience-based lessons on managing transformative adaptation processes (Vermeulen et al., 2018), climate policy integration (Plank et al., 2021), investment criteria (Kasdan et al., 2021) and political economy analysis frameworks for climate governance (Price, 2021).

Box 18.2 | Visions of Climate Resilient Development in Kenya

The government of Kenya's (GoK) ambition through Vision 2030 is to create a globally competitive and prosperous country with a high quality of life by 2030. It aims to transform Kenya into a newly-industrialising, middle-income country providing a high quality of life to all its citizens in a clean and secure environment.

(Government of Kenya, 2008). Dryland regions in Kenya occupy 80–90% of the land mass, are home to 36% of the population (Government of Kenya, 2012) and contribute about 10% of Kenya's gross domestic product (GDP) (Government of Kenya, 2012), which includes half of its agricultural GDP (Kabubo-Mariara, 2009). In dryland regions, pastoralism has long been the predominant form of livelihood and subsistence (Catley et al., 2013; Nyariki and Amwata, 2019). The GoK seeks to improve connectivity and communication infrastructure within the drylands to better exploit and develop livestock, agriculture, tourism, energy and extractive sectors (Government of Kenya, 2018). It argues that the transformation of dryland regions is crucial to enhance the development outcomes for the more than 15 million people who inhabit these areas (Government of Kenya, 2016: 17) and to help the country to realise its wider national ambitions including a 10% year on year growth in GDP (Government of Kenya, 2012). A key element within this vision is the promotion and implementation of the Lamu Port South Sudan Ethiopia (LAPSSET) project. The LAPSSET Corridor consists of two elements: the 500 meter wide Infrastructure Corridor where the road, railway, pipelines, power transmission and other projects will be located and the Economic Corridor of 50 km on either sides of the infrastructure corridor which will be contain other industrial investments (Enns, 2018). Supporters of the LAPSSET project argue that it will help achieve priorities laid out in the Vision 2030 by opening up poorly connected regions, enabling the development of pertinent economic sectors such as agriculture, livestock and energy, and supporting the attainment of a range of social goals made possible as the economy grows (Stein and Kalina, 2019).

However, the development narrative surrounding LAPSSET remains controversial in its assumptions, not least because it is being promoted in the context of a highly complex and dynamic social, economic and biophysical setting (Cervigni and Morris, 2016; Atsiaya et al., 2019; Chome, 2020; Lesutis, 2020). Some of the key trends driving contemporary and likely future change in dryland regions are changing household organisation, evolving customary rules and institutions at local and community levels, and shifting cultures and aspirations (Catley et al., 2013; Washington-Ottombre and Pijanowski, 2013; Tari and Pattison, 2014; Cormack, 2016; Rao, 2019). Dryland regions are also witnessing demographic growth and change in land use patterns linked to shifts in the composition of livestock (for example from grazers to browsers), a decrease in nomadic and increase in semi-nomadic pastoralism, and transition to more urban and sedentary livelihoods (Mganga et al., 2015; Cervigni et al., 2016; Greiner, 2016; Watson et al., 2016). At a landscape level, land is becoming more fragmented and enclosed, often associated with increases in subsistence and commercial agriculture and the establishment of conservancies and other group or private land holdings (Reid et al., 2014; Carabine et al., 2015; Nyberg et al., 2015; Greiner, 2016; Mosley and Watson, 2016). In addition, there are political dynamics associated with Kenya Vision 2030 and decentralisation, the influence of

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Box 18.2 (continued)

international capital, foreign investors and incorporation into global markets (Cormack, 2016; Kochore, 2016; Mosley and Watson, 2016; Enns and Bersaglio, 2020), as well as increasing militarisation and conflict in the drylands (Lind, 2018). Allied to these social and political dynamics are ongoing processes of habitat modification and degradation and biophysical changes linked in part to climate variability (Galvin, 2009; Mganga et al., 2015). The interconnected nature of these drivers will intersect with LAPSSET in myriad ways. For example, the implementation of LAPSSET may accentuate some trends, such as increases in land enclosure and a shift towards more urban and sedentary livelihoods (Lesutis, 2020). Conversely, the perceived threat LAPSSET could pose to pastoral lifestyles may lead to greater visibility, solidarity and strength of pastoralist institutions (Cormack, 2016).

There is a recognised need to adapt and chose development pathways that are resilient to climate change while addressing key developmental challenges within dryland regions, notably, poverty, water and food insecurity, and a highly dispersed population with poor access to services (Government of Kenya, 2012; Bizikova et al., 2015; Herrero et al., 2016). The current vision for development of dryland regions comes with both opportunities and threats to achieve a more climate-resilient future. For example, the growth in and exploitation of renewable energy resources, made possible through increased connectivity, brings climate mitigation gains but also risks. These risks include the uneven distribution of costs in terms of where the industry is sited compared with where benefits primarily accrue, and may exacerbate issues around water and food insecurity as strategic areas of land become harder to access (Opiyo et al., 2016; Cormack and Kurewa, 2018; Enns, 2018; Lind, 2018). While LAPSSET will bring greater freedom of movement for commodities, benefitting investors, improving access to markets and urban centres, supporting trade or ease of movement for tourists supporting economic goals, it can also result in the relocation of people and impede access to certain locations for the resident populations. Mobility is a key adaptation behaviour employed in the short and long term to address issues linked with climatic variability (Opiyo et al., 2014; Muricho et al., 2019). With modelled changes in the climate suggesting decreases in income associated with agricultural staples and livestock-dependent livelihoods, development that constrains mobility of local populations could retard resilience gains (Ochieng et al., 2017; ASSAR, 2018; Enns, 2018; Nkemelang et al., 2018). The likely increase in urban populations and the growth in tourism and agriculture may lead to increases in water demand at a time when water availability could become more constrained owing to the reliance on surface water sources and the modelled increases in evapotranspiration due to rising mean temperature, more heatwave days and greater percentage of precipitation falling as storms (ASSAR, 2018; Nkemelang et al., 2018; USAID, 2018). These pressures could make it harder to meet basic health and sanitation goals for rural and poorer urban populations, issues compounded further by likely increases in child malnutrition and diarrheal deaths linked to climate change (WHO, 2016; ASSAR, 2018; Hirpa et al., 2018; Nkemelang et al., 2018; Lesutis, 2020). Development must pay adequate attention to these interconnections to ensure that costs and benefits of achieving climate mitigation and adaptation goals are distributed fairly within a population.

18.2 Linking Development and Climate Action

The AR5 examined the relationship between climate and sustainable development in Chapter 13 (Olsson et al., 2014) and Chapter 20 (Denton et al., 2014) in Working Group II and Chapter 4 (Fleurbaey et al., 2014) in Working Group III. It concluded that dangerous levels of climate change would limit efforts to reduce poverty (Denton et al., 2014; Fleurbaey et al., 2014). Since the AR5, the adoption of the Paris Agreement and Agenda 2030 have demonstrated increased international consensus regarding the need to pursue climate change as a component of sustainable development. For example, climate change impacts '*undermine the ability of all countries to achieve sustainable development*' (United Nations, 2015) and can reverse or erase improvements in living conditions and decades of development (Hallegatte and Rozenberg, 2017). However, recent analysis shows that actions to meet the goals of the Paris Agreement can undermine progress towards some SDGs (*high agreement*, *medium evidence*) (Pearce et al., 2018b; Liu et al., 2019; Hegre et al., 2020) (Section 18.2.5.3). Meanwhile efforts to achieve the SDGs can contribute to worsening climate change (*high agreement*, *medium evidence*) (Fuso Nerini et al., 2018). These findings in the literature highlight the importance of identifying clear goals and priorities for both climate action and sustainable development as well as mechanisms for capitalising on potential synergies between them and for managing trade-offs. In assessing literature relevant to the intersection between climate action and development, we first explore the implications of different patterns of development and development trajectories followed by more focused assessment of the links between development and climate risk.

18.2.1 Implications of Current Development Trends

Understanding the interactions between climate change, climate action and sustainable development necessitates consideration for the current development context in which different communities, nations and regions find themselves. For example, wealthy economies of the Global North will encounter different opportunities and challenges vis-à-vis climate change and sustainable development than developing economies of the Global South. Moreover, all economies are already following an existing development trajectory that has implications for the type and scale of interventions associated with pursuing CRD and managing climate risk. Some nations may experience particular challenges with reducing greenhouse gas emissions owing to the

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

carbon-intensive nature of their energy systems (*very high confidence*) (Section 18.3.1.1). Others may experience acute challenges with adaptation due to existing vulnerability associated with poverty and social inequality (*very high confidence*) (Section 18.2.5.1). Overcoming such challenges is fundamental to the pursuit of CRD.

While demonstrable progress has been made towards the SDGs and improving human well-being, globally and in specific nations, some observed patterns of development are inconsistent with sustainable development and the principles of CRD (*very high confidence*) (van Dooren et al., 2018; Eisenmenger et al., 2020; Leal Filho et al., 2020). A significant literature, for example, links development to the loss of biodiversity and the extinction crisis (Ceballos et al., 2017; Gonçalves-Souza et al., 2020; Oke et al., 2021). Meanwhile, in human systems, indicators such as the limited convergence in income, life expectancy and other measures of well-being between poor and wealthy countries (with notable outliers such as China) (Bangura, 2019), and the increase in income inequality and the decline in life expectancy and well-being in rich countries (Rougoor and van Marrewijk, 2015; Alvaredo et al., 2017; Goda et al., 2017; Harper et al., 2017; Goldman et al., 2018), suggest limitations of the current development paradigm to successfully deliver universal human and ecological well-being by the 2030s or even mid-century (TWI, 2019).

18.2.2 Understanding Development in CRD

Development in this report is defined as efforts, both formal and informal, to improve standards of human well-being, particularly in places historically disadvantaged by colonialism and other features of early global integration. Development is not limited to the SDGs, however these represent an internationally agreed sub-set of goals. Prior IPCC reports employed development as a typological framing of the current state of a given country or population (IPCC, 2014a) (Section 1.1.4). Such framings frequently rest upon measures of economic activity, using them as proxies for the wider well-being of the population whose activity is measured. For example, the level of GDP is often equated with levels of social welfare, even though as a measure of market output, it can be an inadequate metric for gauging well-being over time, particularly in its environmental and social dimensions (Van den Bergh, 2007; Stiglitz et al., 2009).

The result of this broad framing linking economic growth to human well-being has been decades of policies, programmes and projects aimed at growing economies at scales from the household to regional and global. However, linking development to past and current modes of economic growth creates significant challenges for CRD, as it implies that the very processes that have contributed to current climate challenges, including economic growth and the resource use and energy regimes it relies upon, are also the pathways to improvements in human well-being. This places climate resilience and development in opposition to one another.

While there are many possible successful pathways to future development in the context of climate change, history shows that pathways positive for the vast majority of people typically induce significant impacts and costs, especially on marginal and vulnerable people (*high confidence*) (Hickel, 2017). Frequently, considerations for social difference and equity are side-lined in these processes, for example through the assumption that a growing economy lifts opportunity for all, further marginalising those who are the most vulnerable to climate change (Matin et al., 2018; Diffenbaugh and Burke, 2019).

The Agenda 2030 and its 17 SDGs and 169 targets seeks to 'leave no one behind' through five pillars (5Ps): People, Planet, Prosperity, Peace and Partnership (United Nations, 2015). The five pillars align with the dimensions of development that influence motion towards or away from CRD. The focus on **people** refers to inclusion rather than exclusion, and the extent to which people are empowered or disempowered to make decisions about their well-being, determine their futures and be in a position to assert their rights. This means being able to make decisions that determine whether people are on a pathway towards or away from CRD (Figure 18.1–18.3). The focus on **planet** refers to protecting the planet, ensuring a balance of ecosystems, biodiversity and human activities, and giving equal space and respect for its integrity. The focus on **prosperity** refers to equity in well-being grounded in unanimity over shared goals and resources, rather than individualism, and economic, social and technological progress grounded in stewardship and care, rather than exploitation. The focus on **partnership** refers to mutual respect embedded in solidarity that recognises multiple worldviews and their respective knowledges, rather than singular or hierarchy of knowledge, and acknowledges inherent nature-society connections, rather than posing nature as opposites or competitors. The focus on **peace** emphasises the need for just and equitable societies. These five pillars are inter-related but local and national contexts situate current status differently around the world. Successful achievement of Agenda 2030 is aligned with a safe climate with adequate mitigation and adaptation, and effective and inclusive systems transitions. With these conditions, a high CRD world can be attained, noting that when approached individually, the transformative potential of the SDGs is limited (Veland et al., 2021).

The need for transformational changes across sectors and scales to address the urgency and scope of action needed to enable a climate-resilient future in which goals such as the SDGs might be realised requires attention to the specific ways in which development action is defined and enacted (Box 18.1).

18.2.2.1 Development Perspectives

Development is about 'improvement'. However there have been different and often conflicting viewpoints on the improvement of 'what' and 'how' to improve. The diversity of positions has resulted in a multitude of metrics to track development, some more influential than others on policy. Alternative measures of development, while numerous, generally seek to nuance the connection between economic growth and human well-being. Because they maintain core notions of progress and, in some cases, economic growth seen in more mainstream models of development, they are less vehicles for transformation than continuations of thinking and action fundamentally at odds with the needs of CRD. These include the Measure of Economic Welfare (Nordhaus and Tobin, 1973), the Index of Sustainable Economic Welfare (Cobb and Daly, 1989), the Genuine Progress Indicator (Escobar, 1995), the Adjusted Net Saving Index or the Genuine Savings Index (GSI), The Human Development Index (HDI), the Inequality-Adjusted Human

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Development Index (UNDP, 2016a), the Gender Development Index, the Gender Inequality Index, the Multidimensional Poverty Index, the Index of Sustainable Economic Welfare (ISEW) (Daly and Cobb, 1989), the Genuine Progress Indicator (GPI) (Kubiszewski et al., 2013), Gross National Happiness (GNH) (Ura and Galay, 2004), Measures of Australia's Progress (MAP) (Trewin and Hall, 2004), the OECD Better Life Index (OECD, 2019a) and the Happy Planet Index (NEF, 2016).

In terms of their historical trajectory, different perspectives on development can be broadly divided into five categories.

i) *Development as economic growth (1950s onwards)*: Equating development with economic growth was a natural outcome of the dominance of economics as the major discipline to study problems of newly independent countries in the 1950s (Escobar, 1995), measured through GDP. Environment was not a policy concern in the immediate period after decolonisation. The GDP measure has withstood the test of time, in spite of being an inexact measure of human well-being, and is the widely used metric globally to track development. Recent improvements to GDP have tried to account for environmental factors (Gundimeda et al., 2007; United Nations, 2021).

ii) *Development as distributional improvements (1970s onwards)*: That economic growth does not automatically result in decline in poverty and improved distribution of income became apparent in the 1970s. Welfare measures were thus promoted that involved 'redistribution with growth' (Chenery, 1974). These distributional concerns have re-emerged in the last two decades with the widening gap between the richer and poorer groups of the population (Chancel and Piketty, 2019) and also the increased attention to 'ecological distribution conflicts' (Martinez-Alier, 2021). The political economy perspective, highlighting continued dependencies of countries in the Global South on the Global North, now evolved into political ecology highlighting environmental concerns between and within countries. Environment was not yet a policy priority, despite the links between development and environment becoming clearer.

iii) *Development as participation (1980s onwards)*: Bottom-up responses emphasising sustainable livelihoods and local-level development emerged in the 1980s. The movement, which involved independent and uncoordinated efforts by grassroots activists, social movements and non-governmental organisations (NGOs), became 'mainstreamed' into development in the 1990s (Chambers, 2012). The multi-dimensional nature of poverty was acknowledged at the global policy level (World Bank, 2000) and there was wider acceptance of the role of non-economics social sciences as well as critical approaches in research on development and poverty (Thomas, 2008). Participatory development involved decentralisation and local planning, emphasising protection of local natural resources in addition to improving living standards.

iv) *Development as expansion of human capabilities (1980s onwards)*: The human development and capabilities approach was the first formidable response to the GDP-centric view of development (Sen, 2000; Deneulin and Shahani, 2009). Studies showed that improvements in income did not necessarily improve human well-being in other dimensions such as health and education, or more broadly put, 'freedoms' (Ruggeri Laderchi et al., 2003). The capabilities idea was influential in global policy making through Human Development Reports and metrics such as Human Development Index (HDI) and Multidimensional Poverty Index (MPI). However, environmental sustainability was not a major component in this approach until much later (Alkire and Jahan, 2018). Recent improvements to HDI such as the planetary pressures-adjusted HDI (United Nations, 2020) is a step in this direction.

v) *Development as post-growth (2010 onwards)*: The late 1980s saw a big push towards taking the environment to the centre of the global policy agenda (World Commission on Environment and Development, 1987). However, progress in addressing environmental questions has been slow. As compared with Millennium Development Goals (MDGs), SDGs aim to tackle environmental concerns by explicitly tracking progress on multiple indicators. Nevertheless, the approach in these policy propositions sits largely within the economic growth framework itself. The climate change challenge and the financial crisis of 2008 led many scholars, ecological economists and environmental social scientists in particular, to argue for a post-growth world. Post-growth (Jackson, 2021), degrowth (Kallis, 2018; Hickel et al., 2021) and other environmentalist scholarship takes inspiration from critiques of development such as post-development (Escobar, 1995). The argument here is not for better metrics but for imagining and working towards systemic change in the wake of the climate crisis. The challenge however is how to account for historical differences in economic growth and living standards between the Global North and the Global South and to protect the interests of Global South in the spirit of 'common but differentiated responsibilities' to climate change adaptation and mitigation. As empirical studies in the Global South have demonstrated (Lele et al., 2018), developing countries face multiple stressors, climate change being just one among them, and there are multiple normative concerns in developing country contexts, such as equity and justice, and not merely resilience (*very high confidence*).

Achieving CRD requires framings of development that move away from linear paradigms of development as material progress by focusing on diversity and heterogeneity, well-being and equality, not only in contemporary practices, but also pathways of change over time (Gibson-Graham, 2005; Gibson-Graham, 2006). Such approaches, which are fundamentally aligned with ecological and ecosystem-based environmental assessments that identified heterogeneity of approaches and actions as the most effective path to a sustainable world (Millennium Ecosystem Assessment, 2005), emphasise the importance of cultural, linguistic and religious diversity, not merely as alternative sources of information about the world, but as different paradigms of well-being (Kallis, 2018). These include Indigenous and local knowledge that provide alternatives to these framings of the world (Cross-Chapter Box INDIG). This broad reframing of development includes a focus on visions such as 'buen vivir' (Cubillo-Guevara et al., 2014; Walsh, 2018; Acosta et al., 2019), ecological Swaraj (Kothari et al., 2014; Demaria and Kothari, 2017; Shiva, 2017) and Ubuntu (Dreyer, 2015; Ewuoso and Hall, 2019), among others. All are linked by relationships with nature radically different from the Western mechanistic vision, presenting not only framings of development and the environment that yield locally appropriate CRDPs, but serve as examples of alternative ways of living in balance with nature that might inform similar thinking in other places.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

18.2.2.2. Complexity of Development and Climate Action

Differing perspectives on development are in part determined by the multiple diverse priorities held by different actors and nations. Another reason is that development is not a linear process with a single goal, and active development planning requires simultaneously taking multiple processes and factors into account. This is well illustrated by growing attention to climate security. The AR5 delivered conflicting messages regarding climate change and security (Gleditsch and Nordås, 2014), yet the understanding of climate-related security risks has made substantial progress in recent years (von Uexkull and Buhaug, 2021). Although there remains considerable research gaps in certain regions (Adams et al., 2018), a large body of qualitative and quantitative studies from different disciplines provides new insight into the relationship of climate change and security (Buhaug, 2015; De Juan, 2015; Brzoska and Fröhlich, 2016; Abrahams and Carr, 2017; Sakaguchi et al., 2017; Moran et al, 2018; Scheffran, 2020). Though not the only cause (Sakaguchi et al., 2017; Mach et al., 2019), climate change undermines human livelihoods and security, because it increases the populations vulnerabilities, grievances and political tensions through an array of indirect—at times nonlinear—pathways, thereby increasing human insecurity and the risk of violent conflict (van Baalen and Mobjörk, 2018; Koubi, 2019; von Uexkull and Buhaug, 2021). Indeed, context, as well as timing and spatial distribution, matter and need to be accounted for (Abrahams, 2020).

In line with this better understanding, climate change and security have been reframed in the political space, to focus more on human security. The solutions to climate-related security risks cannot be military, but are linked to development and people's vulnerabilities in complex social and politically fragile settings (Abrahams, 2020). This has resulted in integration of climate-related security risk into institutional and national frameworks (Dellmuth et al., 2018; Scott and Ku, 2018; Aminga and Krampe, 2020), including several Nationally Determined Contributions (NDCs) (Jernnäs and Linnér, 2019; Remling, 2021). One example is the UN Climate Security Mechanism—set up in 2018 between UNDP, UNEP and UN DPPA to help the UN more systematically address climate-related security risks and devise prevention and management strategies. Yet work remains in bridging these concerns with practical responses on the ground (Busby, 2021). Especially since emerging research building on the maladaptation literature shows that this practice cannot just mean adding adaptation and mitigation to the mix of development strategies in a given location, as this may have unintended and unanticipated effects and might even backfire completely (Dabelko et al., 2013; Magnan et al., 2020; Mirumachi et al., 2020; Schipper, 2020; Swatuk et al., 2021). In extremely underdeveloped, fragile contexts such as Afghanistan, the local-level side effects of climate adaptation and mitigation projects might result in different development outcomes and question the potential for sustainable peace (Krampe et al., 2021). Given the clearer understanding of the intertwined nature of climate change, security and development—especially in fragile and conflict affected regions—a rethinking of how to transfer this knowledge into policy solutions is necessary for the formulation of CRD.

18.2.3 Scenarios as a Method for Representing Future Development Trajectories

Sustainable development represents specific development processes and priorities that can affect climate risk. As a result, sustainable development both shapes the context in which different actors experience climate change and represents a potential opportunity, particularly by reducing climate risk by addressing vulnerability, inequity and shifting development towards more sustainable trajectories (IPCC, 2012; Denton et al., 2014; IPCC, 2014b; IPCC, 2014a; IPCC, 2018a; IPCC, 2019b). As assessed in past IPCC special reports and assessment reports, this same literature has also illustrated how different socioeconomic conditions affect mitigation options and costs. For example, variations in future economic growth, population size and composition, technology availability and cost, energy efficiency, resource availability, demand for goods and services, and non-climate-related policies (e.g., air quality, trade), individually and collectively have all been shown to result in different climates and contexts for mitigation and adaptation.

One common approach for exploring the implications of different development trajectories is the use of scenarios of future socioeconomic conditions, such as the SSPs (O'Neill et al., 2017). The SSPs represent sets of future global societal assumptions based on different societal, technological and economic assumptions that result in different development trajectories. Such scenarios often correspond to a small set of scenario archetypes (Harrison et al., 2019; Sitas et al., 2019; Fergnani and Song, 2020) in that they reflect core themes regarding the future of development such as sustainability versus rapid growth. Scenarios with assumptions more closely aligned with sustainability agendas (e.g., SSP1-Sustainability) commonly imply lower greenhouse gas emissions and projected climate change (Riahi et al., 2022), lower mitigation costs for ambitious climate goals (Riahi et al., 2022), lower climate exposure due in large part to the size of society (see Chapter 16) and greater adaptive capacity (Roy et al., 2018) (see also Chapter 16). In contrast, scenarios with rapid global economic and fossil energy growth (e.g., SSP5 Fossil-Fueled Development) imply higher emissions and project climate change and higher mitigation costs, as well as greater social and economic capacity to adapt to climate change impacts (Hunt et al., 2012) (Table 18.1).

The SSPs incorporate various assumptions regarding population, GDP and greenhouse gas emissions, for example, that are relevant to development and climate resilience. In addition, the SSPs have been used to explore a broad range of development outcomes for human and ecological systems (Table 18.1), including multiple studies exploring futures for food systems, water resources, human health and income inequality. Limited, top-down modelling studies have used the SSPs to explore issues such as societal resilience (Schleussner et al., 2021) or gender equity (Andrijevic et al., 2020a). Such studies indicate that different development trajectories have different implications for future development outcomes, but results vary significantly among different climate (e.g., representative concentration pathways [RCPs]) and development contexts, resulting in *limited agreement* among different SSPs (Table 18.1). Nevertheless, for some outcomes, SSPs are associated with generally similar outcomes. Over the near-term (e.g., 2030), those outcomes are strongly influenced by development inertia and path

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Table 18.1 | Implications of different socioeconomic development pathways for CRD indicators. Studies presented in the above table include qualitative storylines and quantitative scenarios for two or more SSPs. Arrows and colour coding reflect the positive or negative impacts on sustainability based on aggregation of results for the 2030–2050 time horizon across the identified studies. Confidence language reflects the number of studies upon which results are based (evidence) and the agreement among studies regarding the direction of change (agreement).

Development indicator	Relevant SDG	Shared Socioeconomic Pathway					Confidence Evidence/ Agreement	References
		Sustainability (SSP1)	Middle of the road (SSP2)	Regional rivalry (SSP3)	Inequality (SSP4)	Fossil-fuelled development (SSP5)		
Agriculture, food and forestry – *Agriculture production* – *Forestry production* – *Food security* – *Hunger*	SDG 2	↗	↔	↘	↘	↘	*Low agreement/ robust evidence*	(Hasegawa et al., 2015; Palazzo et al., 2017; Riahi et al., 2017; Duku et al., 2018; Chen et al., 2019; Daigneault et al., 2019; Mitter et al., 2020; Mora et al., 2020)
Health and well-being – *Excess mortality* – *Air quality* – *Vector-borne disease* – *Life Satisfaction*	SDG 3	↔	↔	↔	↘	↘	*Medium agreement/ robust evidence*	(Chen et al., 2017; Mora et al., 2017; Aleluia Reis et al., 2018; Asefi-Najafabady et al., 2018; Chen et al., 2018; Harrington and Otto, 2018; Marsha et al., 2018; Sellers and Ebi, 2018; Ikeda and Managi, 2019; Rohat et al., 2019; Wang et al., 2019; Chae et al., 2020)
Water and sanitation – *Water use* – *Sanitation access* – *Sewage discharge*	SDG 6	↗	↘	↘	↔	↔	*High agreement/ medium evidence*	(Wada et al., 2016); (van Puijenbroek et al., 2014; Yao et al., 2017); (Mouratiadou et al., 2016; Graham et al., 2018)
Inequality – *Gini coefficient*	SDG 10	↗	↗	↗	↔	↗	*Medium agreement/ limited evidence*	(Rao et al., 2019b; Emmerling and Tavoni, 2021; Gazzotti et al., 2021)
Ecosystems and ecosystem services – *Aquatic resources* – *Urban expansion* – *Habitat provision* – *Carbon sequestration* – *Biodiversity*	SDG 14 SDG 15	↘	↘	↘	↘	↘	*High agreement/ medium evidence*	(Li et al., 2017; Chen et al., 2019; Li et al., 2019b; Chen et al., 2020b; Song et al., 2020b; McManamay et al., 2021; Pinnegar et al., 2021)

Legend

↑ Balance of studies suggest large increasing threat to sustainable development

↗ Balance of studies suggest moderate increasing threat to sustainable development

↔ Studies suggest both threats and benefits to sustainable development

↘ Balance of studies suggest moderate increasing benefit to sustainable development

↓ Balance of studies suggest large increasing benefit to sustainable development

Studies presented in the above table include qualitative storylines and quantitative scenarios for two or more SSPs. Arrows and colour coding reflect the positive or negative impacts on sustainability based on aggregation of results for the 2030–2050 time horizon across the identified studies. Confidence language reflects the number of studies upon which results are based (evidence) and the agreement among studies regarding the direction of change (agreement).

dependence, reducing differences among SSPs. Outcomes diverge later in the century, but fewer studies explore futures beyond 2050. Collectively, the scenarios reflect trade-offs associated with different development trajectories (Roy et al., 2018), with some SSPs foreshadowing outcomes that are positive in some contexts, but negative in others (Table 18.1). For example, pathways that lead to poverty reduction can have synergies with food security, water, gender, terrestrial and ocean ecosystems that support climate risk management, but also poverty alleviation projects with unintended negative consequences that increase vulnerability (e.g., Ley, 2017; Ley et al., 2020).

While the scenarios literature is useful for characterising the potential climate risk implications of different global societal futures, important limitations impact their use in climate risk management planning (*very high confidence*). The first is the often highly geographically aggregated nature of the SSPs and other scenarios, which, in the absence of application of nesting or downscaling methods, often lack regional, national, or sub-national context, particularly regarding social and cultural determinants of vulnerability (van Ruijven et al., 2014). Furthermore, there is limited understanding of the cost and process associated with transforming from today into each

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

assumed socioeconomic future, or the opportunity to shift from one pathway to another (Section 18.3). Furthermore, the characteristics of the pathways suggest that they are not equally likely, there are relationships implied in assumptions that are uncertainties to consider (e.g., land productivity improvements are land saving), it is difficult to identify the role of different development characteristics, and policy implementation is stylised. In general, global assessments are not designed to inform local planning, given that there are many local circumstances consistent with a global future and unique local development context and uncertainties to manage—demographic, economic, technological, cultural and policy.

Overall, pursuing sustainable development in the future is shown to have synergies and trade-offs in its relationships with every element of climate risk: the emissions and mitigation determining hazard; the size, location and composition of development determining exposure; and the adaptive capacity determining vulnerability. Importantly, the scenarios literature overall has found trade-offs such that none of the global societal projections achieve all the SDGs (*very high confidence*) (Roy et al., 2018) (Section 18.2.5.3). Historical evidence supports this as well, for example, finding low-cost energy and food access is historically associated with higher emissions but greater adaptive capacity, and energy efficiency innovation contributing to lower emissions and greater adaptive capacity (e.g., Blanford et al., 2012; Blanco et al., 2014; Mbow et al., 2019; USEPA, 2019). The literature suggests that trade-offs in the pursuit of sustainable development are inevitable. Managing those trade-offs, as well as capitalising on the synergies, will be important for CRD, particularly given trade-offs have distributional implications that could contribute to inequities (Section 18.2.5.3).

18.2.4 Climate Change Risks to Development

In the near-term, additional climate change is expected regardless of the scale of greenhouse gas mitigation efforts (IPCC, 2021a). Across the global scenarios analysed in the AR6, global average temperature changes relative to the reference period 1850–1900 range from 1.2°C to 1.9°C for the period 2021–2040 and 1.2°C to 3.0°C for the period 2041–2060 (WGI AR6 SPM [IPCC, 2021b], *very likely* range). However, the feasibility of emissions pathways (particularly RCP8.5) affect the plausibility of the associated climate projections, potentially lowering the upper end of these ranges because the likelihood of the higher warming levels is a function of the likelihood of the higher emissions scenarios (Riahi et al., 2022) . There is significant overlap between climate scenario ensemble ranges from different emissions scenarios through 2050, more so than through 2100 (Lee et al., 2021). There is also overlap between emissions scenario ensembles consistent with different temperature outcomes (Riahi et al., 2022) . Emissions pathway ranges represent uncertainties for policymakers and organisations to consider and manage (Rose and Scott, 2018, 2020) regarding, among other things, economic growth and structure, available technologies, markets, behavioural dynamics, policies and non-CO_2 climate forcings (Riahi et al., 2022), while climate pathway ranges represent bio-physical climate systems and carbon cycle uncertainties (Lee et al., 2021). For all climate projections and variables, there is significant regional heterogeneity and uncertainty in projected climate change (*very high confidence*) (IPCC, 2021a). Figure 18.4 apresents examples for average and extreme temperature precipitation change (see also Section 18.5 and Tables 18.4–18.5 for more regional detail and ranges of climate outcomes). Higher global warming levels also can affect geographic patterns of change and probability distributions of regional climate outcomes (Ahmad, 2019). Similarly, for all emissions projections, there is significant regional, sectoral and local heterogeneity and uncertainty regarding potential pathways for climate action (Lecocq et al., 2022; Riahi et al., 2022). Not all uncertainties are represented in projected emissions pathway ensembles, such as policy timing and design (e.g., Rose and Scott, 2018) or climate projection ensembles.

The projected ranges for near- and mid-term global average warming levels are estimated to result in increasing key risks and reasons for concern (Chapter 16). Chapter 16 developed aggregate 'Representative Key Risks' (RKRs) as indicators for subsets of approximately 100 sectoral and regional key risks indicators. The RKRs include risks to coastal socio-ecological systems, terrestrial and ocean ecosystems, critical physical infrastructure, networks and services, living standards and equity, human health, food security, water security, and peace and migration. The majority of these risks are directly linked to sustainable development priorities and the SDGs (Chapters 2 to 16; (Roy et al., 2018; IPCC, 2019d; IPCC, 2019b). Therefore, climate risks represent a potential additional challenge to pursuing sustainable development priorities, but also potential opportunities due to geographic variation in climate impacts. In addition, positive synergies have been found between sustainable development and adaptation, but trade-offs are also possible (e.g., Roy et al., 2018).

For all RKRs, additional global average warming is expected to increase risk. However, the increases vary significantly by RKR, and across the underlying key risks represented within each RKR. Geographic variation in key risk implications is only partially assessed in Chapter 16, but evidence can be drawn from the WGII individual regional chapters. Regionally, key risks are found to be potentially greatest in developing and transition economies (Chapter 16 and sectoral chapters), which is also where the least-cost emissions reductions globally are projected to be (Riahi et al., 2022).See Figure 18.4 for an example of key risk geographic heterogeneity (see also Section 18.5 for regional detail). Chapter 16 also maps the RKRs to an updated aggregate 'Reasons for Concern' (RFC) framing. Thus, increasing RKR implies increasing RFC associated with unique and threatened systems, extreme weather events, distribution of impacts, global aggregate impacts and large-scale singular events.

Climate risks are found to vary with future warming levels, the development context and trajectory, as well as by the level of investment in adaptation. Together, these three dimensions define risk—with projected climate changes defining the hazard, development defining the exposure, and development and adaptation defining vulnerability. However, how these different dimensions interact and the level of scientific understanding vary significantly among different types of risk. For human systems, in general, the poor and marginalised are found to have greater vulnerability for a given hazard and exposure level. With some level of global average warming expected regardless of mitigation efforts, human and natural systems will be exposed to new conditions, but some level of adaptation should also be expected.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

18.2.5 Options for Managing Future Climate Risks to Climate Resilient Development

The pursuit of CRD requires not only the implementation of individual adaptation, mitigation and sustainable development initiatives, but also their careful coordination and integration. This section assesses the literature on CRD in the context of key climate change risks (Chapter 16); gaps in adaptation that contribute to risk; potential synergies and trade-offs among mitigation, adaptation and sustainable development; and the mechanisms for managing those trade-offs.

18.2.5.1 Adaptation

18.2.5.1.1 Adaptation and Climate Resilient Development

Given that adaptation is recognised as a key element of addressing climate risk and CRD, the capacity for adaptation implementation is an important consideration for CRD. The AR5 noted a significant overlap between indicators of sustainable development and the determinants of adaptive capacity, and suggested that adaptation presents an opportunity to reduce stresses on development processes and the socio-ecological foundations upon which they depend (Denton et al., 2014). At the same time, it also noted that building adaptive capacity for sustainable development might require transformational changes that shift impacted systems to new patterns, dynamics or places (Denton et al., 2014). Thus, adaptation interventions and pathways can further the achievement of development goals such as food security (Campbell et al., 2016; Douxchamps et al., 2016; Richardson et al., 2018; Bezner Kerr et al., 2019) and improvements in human health (Watts et al., 2019) including in systems where animals and humans live in close proximity (*very high confidence*) (Zinsstag et al., 2018). However, to do so requires not only the avoidance of incremental adaptation actions that extend current unsustainable practices, but also the ability to manage and overcome the barriers which arise when the limits of incremental adaptation are reached (*high agreement*, *medium evidence*) (Few et al., 2017; Vermeulen et al., 2018; Fedele et al., 2019).

Since AR5, the scientific community has deepened its understanding of the relationship between adaptation and sustainable development (*very high confidence*), particularly with regard to the place of resilience at the intersection of these two arenas. The literature has moved forward in its identification of specific overlaps in sustainable development indicators and determinants of adaptive capacity, how adaptation might reduce stress on development processes and their socio-ecological foundation, and how building adaptive capacity might facilitate needed transformative changes. Broadly speaking, work on these topics comes from one of two perspectives. One perspective speaks to adaptation practices that might further sustainable development outcomes, while another perspective draws on deeper understandings of the socio-ecological dynamics of the systems in which we live, and which we may have to transform in the face of climate change impacts. These two literatures are not yet well integrated, leaving gaps in our knowledge of how best to implement adaptation in a manner that achieves sustainable development.

The literature considering adaptation and development in practice since AR5 suggests that efforts to connect adaptation to sustainable development should address proximate and systemic drivers of vulnerability (Wise et al., 2016), while remaining flexible and reversable to avoid the lock-in of undesirable or maladaptive trajectories (Cannon and Müller-Mahn, 2010; Wise et al., 2016). Such goals require critical reflection on processes for decision making and learning. In the AR5, more inclusive, participatory adaptation processes were presumed to benefit development planning by including a wider set of actors in discussions of future goals (Denton et al., 2014). The post-AR5 literature expands on these critical perspectives to provide context regarding when participation is most effective. For example, (Eriksen et al., 2015) emphasise the need to build participatory adaptation processes to avoid subsuming adaptation goals to development-as-usual, while (Kim et al., 2017b) argues that this practice is most effective when it is focused on development efforts and considers how climate change will challenge the goals of those efforts. Adaptation, while presenting an opportunity to foster transformations needed to address the impacts of climate change on human well-being, is also a contested process that is inherently political (*medium agreement*, *medium evidence*) (Eriksen et al., 2015; Mikulewicz, 2019; Nightingale Böhler, 2019; Eriksen et al., 2021b). How adaptation can challenge development and create a situation where CRD effectively becomes transformative adaptation, adaptation that generates transformation of broader aspects of development, remains unclear (*medium agreement*, *limited evidence*) (Few et al., 2017; Schipper et al., 2020c).

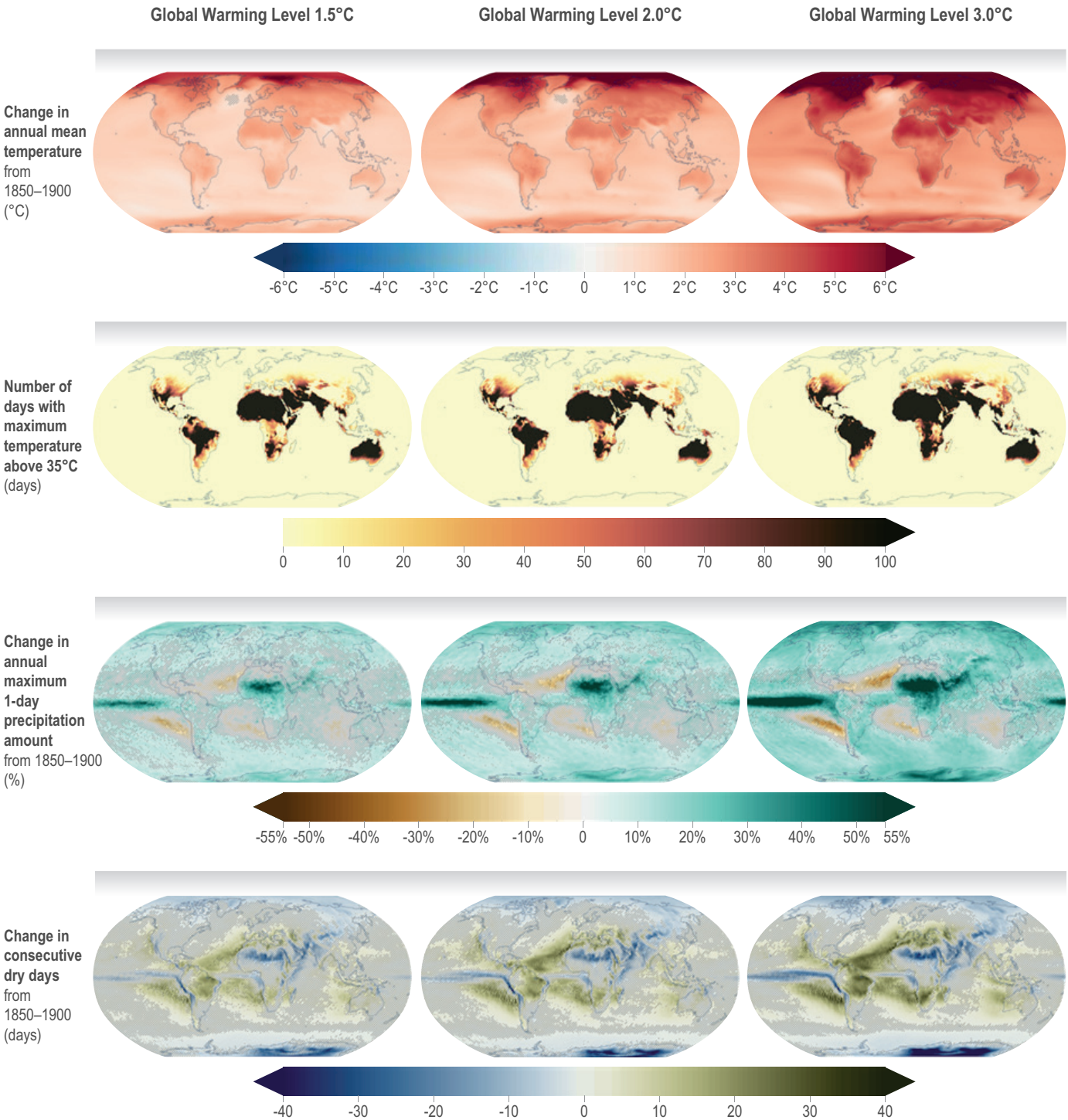
The critical literature on socio-ecological resilience, which has grown substantially since the last AR (*very high confidence*), speaks to some of these questions. Since AR5, the IPCC and the wider literature on socio-ecological resilience have shifted their use of the term to reflect not only the capacity to cope with a hazardous event or trend or disturbance, but also the ability to adapt, learn and transform in ways that maintains socio-ecology's essential function, identity and structure (Chapter 1; Glossary, Annex II). This change in usage is significant in that it shifts resilience from an emergent property of complex socio-ecological systems to a deeply human product of efforts to manage ecology, economy and society to specific ends. This definition of resilience recognises the need to define what is an essential identity, function and structure for a given system, questions rooted not in ecological dynamics, but in politics, agency, difference and power that emerge around the management of ecological dynamics (Cote and Nightingale, 2011; Brown, 2013; Cretney, 2014; Forsyth, 2018; Matin et al., 2018; Carr, 2019).

By connecting this framing of socio-ecological dynamics to the literature on the principles for adaptation efforts that meet development goals, new work has begun to identify 1) how adaptation can reduce stress on development processes, 2) how it might facilitate transformative change and 3) where adaptation interventions might either drive system rigidity and precarity, or otherwise challenge development goals (Castells-Quintana et al., 2018; Carr, 2020). For example, Jordan (2019) draws upon these contemporary framings of resilience to highlight the ways in which coping strategies perpetuate the gendered norms and practices at the heart of women's vulnerability in Bangladesh. Forsyth (2018) draws upon this work to highlight the ways in which the theory of change processes used by development organisations tend to exclude local experiences and sources of risk, and thus foreclose the need for transformative pathways to achieve development goals. Carr

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Regional projected select climate change and sustainable development-related climate impact indicators by global warming level

(a) Physical climate change indicators



https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

(b) Sustainable development related climate impacts indicators

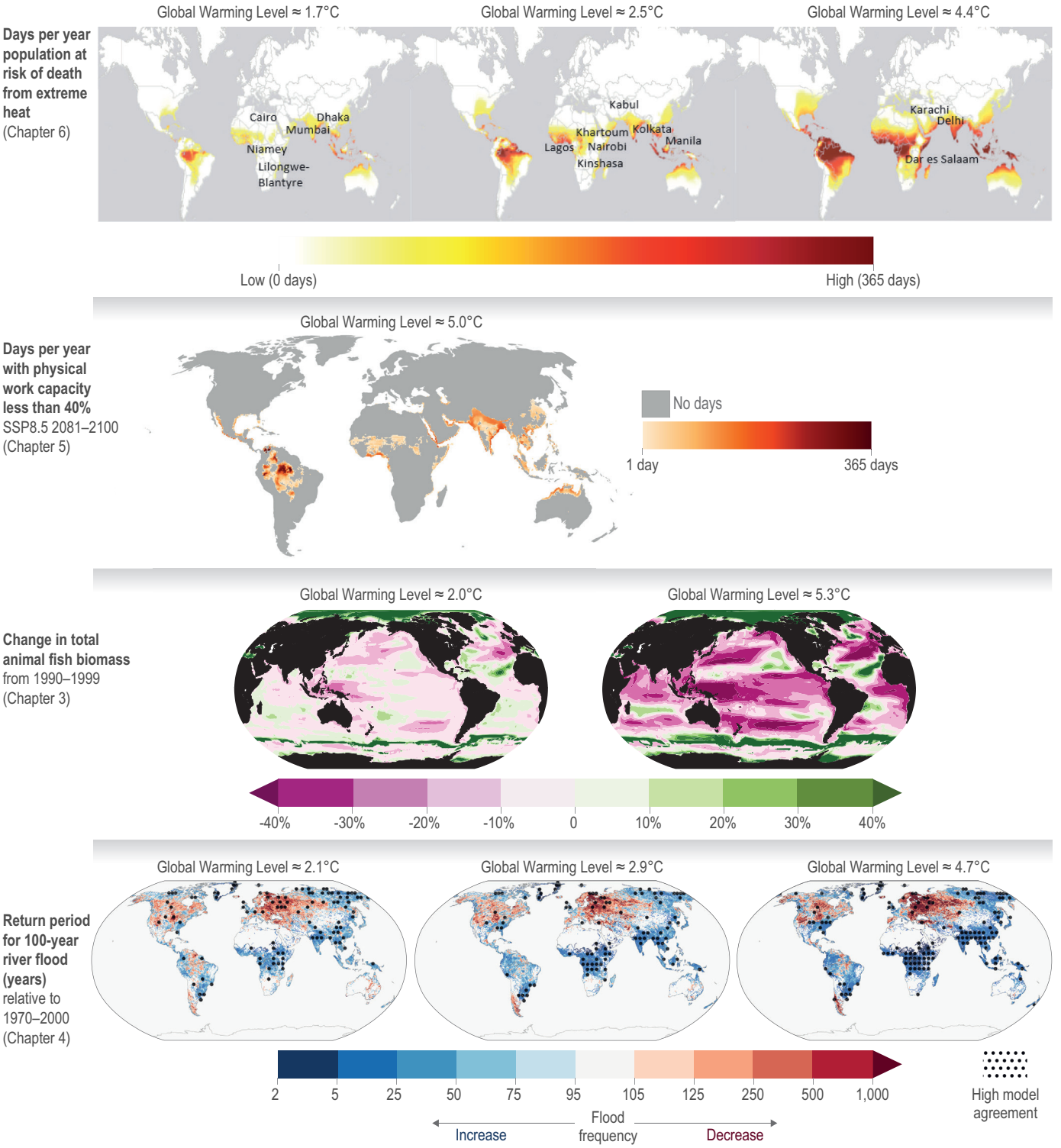


Figure 18.4 | Regional projected select climate change and sustainable-development-related climate impact indicators by global warming level. Sources: WGI AR6 Interactive Atlas (https://interactive-atlas.ipcc.ch/) and WGII Figures 3.21, 4.17, 5.19, and 6.3. The GWLs shown are multi-model means derived from Hauser et al. (2019) for the respective RCP and SSP and time periods associated with each figure.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

(Carr, 2019; 2020) draws upon evidence from sub-Saharan Africa to develop more nuanced understandings of the ways in which different stressors and interventions either facilitate or foreclose transformative pathways, while pointing to the existence of yet poorly understood thresholds for transformation in systems that can be identified and targeted by interventions.

18.2.5.1.2 Adaptation gaps

Adaptation gaps are defined as 'the difference between actually implemented adaptation and a societally set goal, determined largely by preferences related to tolerated climate change impacts and reflecting resource limitations and competing priorities' (UNEP, 2014; UNEP, 2018a). Adaptation deficit is a similar concept, described as an inadequate or insufficient adaptation to current conditions (Chapter 1). Adaptation gaps or deficits arise from a lack of adequate technological, financial, social, and institutional capacities to adapt effectively to climate change and extreme weather events, which are in turn linked to development (*very high confidence*) (Fankhauser and McDermott, 2014; Milman and Arsano, 2014; Chen et al., 2016; Asfaw et al., 2018) (Section 18.2.2).

Currently, there is no consensus around approaches to assess the effectiveness of adaptation actions across contexts and therefore measure adaptation gaps at a global scale (Singh et al., 2021a). UNEP (2021) suggests that comprehensiveness, inclusiveness, implementability, integration and monitoring, and evaluation can be used to assess them (see also Cross-Chapter Box FEASIB). However, limited information is available about future trends in national-level adaptation and the development of monitoring and evaluation mechanisms. Despite the challenges of measurement associated with adaptation gaps, available evidence from smaller scales across several regions, communities and businesses suggest that significant adaptation gaps have existed in historical contexts of climate change, while expectations of extreme heat, increasing storm intensity and rising sea levels will create the context for the emergence of new gaps (*very high confidence*) (Hallegatte et al., 2018; UNEP, 2018a; Dellink et al., 2019; UNEP, 2021). These adaptation gaps create risks to well-being, economic growth, equity, the health of natural systems and other societal goals. The negative impacts of these gaps can be compounded by adaptation efforts that are considered maladaptive or by development actions that are labelled as adaptation (see Chapter 16).

A higher level of adaptation finance is critical to enhance adaptation planning and implementation and reduce adaptation gaps, particularly in developing countries (*very high confidence*) (UNEP, 2021) (Cross-Chapter Box FINANCE in Chapter 17, Section 18.4.2.2). However, adaptation finance is not keeping pace with the rising adaptation costs in the context of increasing and accelerating climate change, as 'annual adaptation costs in developing countries alone are currently estimated to be in the range of US$70 billion, with the expectation of reaching US$140–300 billion in 2030 and US$280–500 billion in 2050' (UNEP, 2021). Investment in attaining SDGs helps bridge adaptation gaps (Birkmann et al., 2021), but care needs to be taken to avoid maladaptation through mislabelling. Integration of the Indigenous and local knowledge systems is anticipated to reduce existing adaptation gaps and secure livelihood transitions.

Analysis of investments by four major climate and development funds (the Global Environment Facility, the Green Climate Fund, the Adaptation Fund and the International Climate Initiative) by UNEP (2021) suggests that support for green and hybrid adaptation solutions has been increasing over the past two decades. These could be effective at reducing climate risks and bridging adaptation gaps while simultaneously bringing important additional benefits for the economy, environment and livelihoods (UNEP, 2021) (see also Cross-Chapter Box NATURAL in Chapter 2).

Lately, the evidence of adaptation activity in the health sector has been increasing (Watts et al., 2019), yet substantial adaptation gaps persist (UNEP, 2018a; UNEP, 2021), including gaps in humanitarian response to climate-related disasters (Watts et al., 2019). It is the under-investment in climate and health research in general and health adaptation in particular that has led to adaptation gaps in the health sector (Ebi et al., 2017).

Costs of implementing efficient adaptation measures and water-related infrastructure in water-deficient regions have received attention at the global and regional level to bridge the 'adaptation gap' (Hallegatte et al., 2018; UNEP, 2018a; Dellink et al., 2019; UNEP, 2021). Livelihood sustainability in the drylands, which cover more than 40% of the land surface area, are home to roughly 2.5 billion people, and support approximately 50% of the livestock and 45% of the food production, is threatened by a complex and inter-related range of social, economic and environmental changes that present significant challenges to rural communities, especially women (Abu-Rabia-Queder and Morris, 2018; Gaur and Squires, 2018). Adaptation deficits in arid and semi-arid regions are of high order (see CROSS-CHAPTER BOX 3). To reduce adaptation deficit in arid and semi-arid regions, comprehensive and efficient adaptation interventions integrating better water management, use of non-traditional water sources, changes in reservoir operations, soil ecosystem rejuvenation and enhanced institutional effectiveness are needed (Section 18.5) (Makuvaro et al., 2017; Mohammed and Scholz, 2017; Morote et al., 2019). Communities facing the lack of adequate technological, financial, human and institutional capacities to adapt effectively to current and future climate change often encounter adaptation deficits. To address current adaptation barriers and adaptation deficits, there is a need to promote efficient adaptation measures, coupled with inclusive and adaptive governance involving marginalised groups such as Indigenous communities and women.

Although unevenly distributed urban adaptation gaps exist in all world regions (see Chapter 6). Such gaps are higher in the urban centres of the poorer nations. Chapter 6 identified that the critical capacity gaps at city and community levels responsible for adaptation gaps are the 'ability to identify social vulnerability and community strengths, and to plan in integrated ways to protect communities, alongside the ability to access innovative funding arrangements and manage finance and commercial insurance; and locally accountable decision making with sufficient access to science, technology and local knowledge to support the application of adaptation solutions at scale'.

Insufficient financial resources are the main reasons for the coastal adaptation gap, particularly in the Global South (see CROSS-CHAPTER

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

BOX 2). Engaging the private sector with a range of financial tools is crucial to address such gaps (see CROSS-CHAPTER BOX 2). An urgent and transformative action to institutionalise locally relevant integrative adaptation pathways is crucial for closing coastal adaptation gaps. Additional efforts are in place for assessing global adaptation progress (see Cross-Chapter Box PROGRESS in Chapter 17).

18.2.5.1.3 Adaptation implementation

As discussed in Chapter 16, adaptation is a key mechanism for managing climate risks, and therefore for pursuing CRD. The lower estimates in Table 18.2 are associated with higher levels of adaptation and more conducive development conditions. Furthermore, additional adaptation demand is associated with greater levels of climate change. Adaptation is a broad term referring to many different levels of response and options for natural and human systems, from individuals, specific locations and specific technologies, to nations, markets, global dynamics and strategies at the system level. Adaptation also includes endogenous reflexive and exogenous policy responses. Perspectives on limits to adaptation, synergies, trade-offs and feasibility therefore depend on where the boundaries are drawn and the objective. Overall, there are a broad range of adaptation options relevant to reducing risks posed by climate change to development. However, current understanding of how such options are implemented in practice, their effectiveness across a range of possible climate futures and their potential limits, is modest.

The IPCC's SR1.5 report evaluated individual adaptation options in terms of economic, technological, institutional, socio-cultural, environmental/ecological and geophysical feasibility (de Coninck et al., 2018). This analysis has been updated for AR6 (Cross-Chapter Box FEASIB). These assessments identify types of barriers that could affect an option's feasibility. Among other things, this work finds that every adaptation option evaluated had at least one feasibility dimension that represented a barrier or obstacle. The barriers also imply that there are trade-offs in these feasibility dimensions to consider. Overall, insights from this work are high-level and difficult to apply to a specific adaptation context. The feasibility and ranking of adaptation opportunities, as well as the list of opportunities themselves, for a given location will vary from location to location, with different criteria and weighting of criteria that reflect the priorities of society and decision-makers as well as differences in markets, technology options and policies for managing risks and trade-offs. Integrated evaluation of criteria and options is needed, that accounts for the relevant geographic context and interactions between options and systems (Section 18.5).

Sustainable development is regarded as generally consistent with climate change adaptation, helping build adaptive capacity by addressing poverty and inequalities and improving inclusion and institutions (Roy et al., 2018). Some sustainable development strategies could facilitate adaptation effectiveness by addressing wider socioeconomic barriers, addressing social inequalities and promoting livelihood security (Roy et al., 2018). With a common goal of reducing risks, sustainable development and adaptation are relatively synergistic. For example, "low-regrets" adaptation strategies have been identified, such as improvements in health systems that reduce climate health impacts in cities (Barata, 2018). However, trade-offs also have been found and are important to consider and potentially address. Synergies have been found between adaptation and poverty reduction, hunger reduction, clean water access and health; while, trade-offs have also been found, particularly when adaptation strategies prioritise one development objective (e.g., food security or heat-stress risk reduction) or promote high-cost solutions with budget allocation and equity implications (Roy et al., 2018) (Sections 18.2.5.3, 18.5, Box 18.4). There are also opportunities for addressing the trade-offs, in particular distributional effects—by recognising that there are trade-offs and considering alternatives and complementary strategies to address those trade-offs (Section 18.2.5.3).

Box 18.3 | Climate Resilient Development in Small Islands

Small islands are particularly vulnerable to climate change and many are already pursuing climate resilient development pathways that enable integrated responses (Allen et al., 2018a; Mycoo, 2018; Hay et al., 2019; Robinson et al., 2021). Countries such as Belize have opted for a systems approach and are working across the sustainable development goals (SDGs) to increase integration (Allen et al., 2018a). This includes rethinking disaster reconstruction mechanisms in the Caribbean and introducing more diversified and sustainable tourism economies that can better withstand external shocks such as disruptions and loss of markets from COVID-19 (Sheller, 2021). In the Seychelles, various government and tourism industry initiatives are focused on the promotion of sustainable tourism ventures that lower emissions, protect and promote biodiversity conservation (e.g., new marine protected areas with mitigation and adaptation benefits), and are climate resilient (Robinson et al., 2021). In 2016, the Seychelles signed the world's first nature-for-debt swap, wherein a non-governmental organisation (NGO; The Nature Conservancy) agreed to pay off Seychelles' public debt to the Paris Club (foreign creditors) in return for the Seychelles government establishing marine conservation areas (Silver and Campbell, 2018).

One key area where enhanced climate risk integration is critical is infrastructure-related decisions, especially on coastal areas (World Bank, 2017). However, despite increasing awareness of climate risks and experienced impacts, decisions on, for example, infrastructure locations still reflect cultural preferences. For example, Hay et al. (2019) report that, despite recommendations to relocate the redevelopment site of the Parliamentary Complex in Samoa away from the coast, multiple cultural and historical factors influenced the decisions to redevelop at the original site. In the Solomon Islands, however, emerging evidence suggests that adaptation efforts to enhance the

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Box 18.3 (continued)

resilience of infrastructure are also serving to help urban areas address problems associated with rapid urbanisation and provide new opportunities for sustainable development (Robinson et al., 2021).

Energy system transitions in small islands can produce synergies with SDG implementation and can lead to transformational outcomes. The Pacific Island territory of Tokelau has demonstrated a nationwide energy transition, sourcing 100% of their energy needs from solar power (Michalena and Hills, 2018), and many other countries such as Fiji, Niue, Tuvalu, Vanuatu, Solomon Islands and Cook Islands also have 100% renewable energy targets. Benefits of small island distributed energy systems (such as solar photovoltaic [PV] systems) include less need for large, centralised infrastructure; reduced reliance on volatile fossil fuel markets; enhanced international climate negotiations power; and enhanced local job markets/skills (Dornan, 2015; Cole and Banks, 2017; Weir, 2018). Additionally, renewable systems can enhance resilience to hydro-meteorological disasters (Weir and Kumar, 2020). For example, well-secured ground-based PV systems withstood cyclones in the Pacific Island of Tonga during cyclone Gita and across the Caribbean during Hurricane Maria, with power restored in days rather than weeks associated with more centralised systems (Weir and Kumar, 2020). Yet a multitude of challenges remain. In the Pacific islands region, these include: the high up front capital investment of renewables; lack of private sector investment; limited renewable energy data for policymaking; land tenure/rent costs; ongoing infrastructure maintenance skills and requirements; political turnover; failed experimentation; difficulty in obtaining and transporting replacement parts; and a highly corrosive environment for equipment (Dornan, 2015; Cole and Banks, 2017; Lucas et al., 2017; Weir, 2018; Weir and Kumar, 2020). The example of Pacific energy transitions demonstrates that a nuanced and context specific analysis of synergies and trade-offs for energy transitions is required to lessen the impact on fragile economies and maximise benefits for remote populations.

Labour migration is increasingly recognised as a significant factor that can contribute to climate resilient development pathways for small islands. In the Pacific islands region, labour mobility schemes are already allowing for climate change adaptation and economic development to occur in labour migrants' countries of origin (Smith and McNamara, 2015; Klepp and Herbeck, 2016; Dun et al., 2020). Dun et al. (2020) demonstrates that temporary or circular migrants from the Solomon Islands, working in Australia under its Seasonal Worker Programme (similar programmes operate in other developed countries), are using the money they earn to invest in adaptation and development activities back home. Similarly, labour migrants from Vanuatu, Kiribati and Samoa contribute to development and *in situ* climate change adaptation (at a household, village and regional level) that enable discussions about more resilient futures for their countries (Barnett and McMichael, 2018; Parsons et al., 2018).

Box 18.4 | Adaptation and the Sustainable Development Goals

The achievement of the Sustainable Development Goals (SDGs) represents near-term positive sustainability as well as indicating the quality of development processes and actions (inclusion and social justice, alternative development models, planetary health, well-being, equity, solidary, different forms of knowledge and human–nature connectivity) that enable climate resilient development (CRD) in the long term (Sections 18.2.2.2, 18.2.5.3). A key question is the extent to which adaptation actions (or non-action) may contribute to (or undermine) SDG achievement and, in particular, shift the quality of development processes and engagement within the political, economic, ecological, socio-ethical and knowledge-technology arenas, and hence contribute to climate resilient development pathways (CRDPs).

Table Box 18.4.1 (below) provides a set of examples of how adaptation actions can either contribute to or undermine SDG achievement for SDGs 2, 3, 6, 11 and 16. In general, formal adaptation policies as well as household and community-based adaptation strategies can generate positive outcomes, particularly if they are responsive to the local context and needs, with real participation and leadership by target populations (Remling and Veitayaki, 2016; Buckwell et al., 2020; McNamara et al., 2020; Owen, 2020). For example, integrated adaptation approaches to the water–energy–food (WEF) nexus aiming to build resilience in those sectors can lead to increased resource use efficiency and coherent strategies for managing the complex interactions and trade-offs among the water, energy and food SDGs (Mpandeli et al., 2018; Nhamo et al., 2020). One such approach could involve cultivating indigenous crops suited to harsh growing conditions, which would allow for agricultural expansion for food and energy without increased water withdrawals (Mpandeli et al., 2018). Overall, adaptation commitments aiming to build resilience of vulnerable populations have typically shown to contribute to SDGs focused on ending extreme poverty (SDG 1), improving food security (SDG 2), improving access to water (SDG 6), ensuring clean energy (SDG 7), tackling climate change (SDG 13) and halting land degradation and deforestation (SDG 15) (Antwi-Agyei et al., 2018).

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Box 18.4 (continued)

However, evidence also suggests limitations of adaptation actions, with the objectives and actions often being too narrow to address social justice and enable CRD. As such, adaptation actions can sometimes undermine SDG achievement through exacerbating social vulnerability, inequity and uneven power relations (Antwi-Agyei et al., 2018; Atteridge and Remling, 2018; Paprocki, 2018; Mikulewicz, 2019; Satyal et al., 2020; Scoville-Simonds et al., 2020). This is due to adaptation practices often not accounting for the differentiated ways in which minority groups are especially vulnerable. For example, designs of emergency shelters should consider the fear of social stigma or abuse faced by women and girls (Pelling and Garschagen, 2019).

Such maladaptive adaptation practices can undermine SDG achievement through increasing vulnerability of marginalised groups by failing to address the underlying root causes of vulnerability and poverty that are related to political economy, power dynamics and vested interests more broadly, instead treating the symptoms as the cause (Magnan et al., 2016; Ajibade and Egge, 2019; Schipper, 2020). For example, evidence exists of flood defence measures through large-scale infrastructure development leading to the violent displacement of poor communities, forcibly resettling people in areas far from their employment or pushing up land and housing costs without providing compensation (Fuso Nerini et al., 2018; Reckien et al., 2018). Moreover, sectoral approaches to adaptation that fail to acknowledge the linkages between SDGs can counter development efforts and generate further trade-offs (Terry, 2009; Rasul and Sharma, 2016; von Stechow et al., 2016; Klinsky et al., 2017; Hallegatte et al., 2019).

The literature recommends a set of strategies for ensuring that adaptation actions are aligned with SDG achievement and do not further perpetuate poverty and inequality. These include ensuring that marginalised voices are central to adaptation decision making, with participatory approaches that empower and compensate affected communities (Moser and Ekstrom, 2011; Broto et al., 2015; Pelling and Garschagen, 2019; Palermo and Hernandez, 2020). Gender mainstreaming and gender transformative approaches within climate policies can also help ensure gender-sensitive design of adaptation projects, with appropriate equity analyses of policy (Klinsky et al., 2017) decisions to identify the actual implications of trade-offs for vulnerable groups (Beuchelt and Badstue, 2013; Alston, 2014; Bowen et al., 2017; Fuso Nerini et al., 2018).

In addition, a substantial literature also argues for policy coherence measures that adopt whole-of-government approaches and mainstream and nationalise SDG targets within national climate policies (Nilsson et al., 2012; Le Blanc, 2015; Ari, 2017; Collste et al., 2017; Dzebo et al., 2017; Nilsson and Weitz, 2019). Institutional coordination mechanisms that aim to break down silos between different agencies and actors at the national level are suggested as beneficial for avoiding trade-offs between adaptation actions and SDGs (Mirzabaev et al., 2015; Howlett and Saguin, 2018; Scherer et al., 2018). However, these need to be paired with an investigation of the deep-seated ideologies and vested interests that are creating goal conflicts and negatively impacting marginalised groups to begin with (Purdon, 2014; Bocquillon, 2018). Ultimately, adaptation measures need to acknowledge and address the underlying drivers that make certain groups particularly vulnerable, such as social disenfranchisement, unequal power dynamics and historical legacies of colonialism and exploitation (Magnan et al., 2016; Schipper, 2020)

Table Box 18.4.1 | Examples of linkages between adaptation and the SDGs. For several key SDGs aligned with the concept of CRD, the table below identifies evidence from the literature where adaptation policies and practices contribute to achievement of the SDG, as well as where they undermine achievement of the SDG.

SDG	*Evidence of adaptation contributing to SDG*	*Evidence of adaptation undermining SDG*
SDG 2: Zero Hunger	Adaptation measures implemented by smallholder farmers (e.g., adjustments in farm operations timing, on-farm diversification, soil–water management) exhibit higher levels of productivity and technical efficiency in food production (Bai et al., 2019; Sloat et al., 2020; Khanal et al., 2021) Some climate smart agriculture measures (e.g., intercropping) can significantly increase yields and contribute to zero hunger (Lipper et al., 2014; Arslan et al., 2015; Saj et al., 2017)	Some adaptation policies can increase land and food prices, negatively impacting smallholder farmers (Fuso Nerini et al., 2018; Zavaleta et al., 2018; Albizua et al., 2019) Potential trade-offs for food production through adaptation actions within the water or energy sector, if integrated approaches not taken (Howells et al., 2013; FAO, 2014; Biswas and Tortajada, 2016)
SDG 3: Good Health and Wellbeing	Increased resilience of societies and reduced vulnerability through investments in public health care and access (Marmot, 2020; Mullins and White, 2020) Adaptation measures that leverage solidarity, equity and nature connectedness contribute to physical and psychological health and well-being (Gambrel and Cafaro, 2009; Capaldi et al., 2015; Soga and Gaston, 2016; Woiwode, 2020)	Societal measures beyond adaptation required to address underlying causes of inequities that drive poor health and well-being, including cuts in public spending and neoliberalisation and commodification of healthcare (Hall, 2020; Walsh and Dillard-Wright, 2020)

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Box 18.4 (continued)

SDG	Evidence of adaptation contributing to SDG	Evidence of adaptation undermining SDG
SDG 6: Clean Water and Sanitation	Integrated water resources management as an adaptation strategy (Tan and Foo, 2018; Sadoff et al., 2020)	Potential trade-offs for water security through adaptation actions within the food or energy sector, if integrated approaches not taken (Howells et al., 2013; Rasul and Sharma, 2016; Mpandeli et al., 2018) Local, regional or national 'grabs' for water from shared resources with poorly defined property rights (Olmstead, 2014)
SDG 11: Sustainable Cities and Communities	Vulnerability reducing adaptation measures that aim to upgrade informal settlements, create affordable housing and protect populations living in disaster prone areas (Major et al., 2018; Sanchez Rodriguez et al., 2018; Ajibade and Egge, 2019)	Need to ensure that adaptation measures understand how power dynamics and cultural norms shape urban form and communities' vulnerability and adaptive capacity (Sanchez Rodriguez et al., 2018) Risk of built infrastructure aiming to increase resilience ignoring local population needs and creating low-skilled jobs that concentrate land, capital and resources in the hands of the elite (Ajibade and Egge, 2019)
SDG 16: Peace, Justice and Strong Institutions	Potential for adaptation projects to support livelihood incomes and resource management, and thereby reduce tensions and the risk of conflicts (Matthew, 2014; Dresse et al., 2018; Barnett, 2019)	Studies from Bangladesh, Cambodia and Nepal found that climate change adaptation-related policies and projects were an underlying cause of natural resource-based conflicts, as well as land dispossession and exclusion, entrenchment of dependency relations, elite capture and inequity (Sovacool, 2018; Sultana et al., 2019) Adaptation projects can reinforce top-down knowledge and decision-making processes, asymmetric power relations and elite capture of adaptation resources (Nightingale, 2017; Eriksen et al., 2021b) Need for conflict-sensitive adaptation approaches that aim to 'do no harm' (Babcicky, 2013; Ide, 2020)

18.2.5.2 Mitigation

Mitigation, including greenhouse gas emissions reductions, avoidance, and removal and sequestration, as well as management of other climate forcing factors (WGIII AR6), is a key element of addressing climate risk and pursuing CRD. There are numerous individual and system mitigation options throughout the economy and within human and natural systems (*very high confidence*) (Chapter 16; Section 18.5). Limiting global average warming has been found to reduce climate risks (IPCC, 2018a; IPCC, 2019b), and limiting global average warming to any temperature level has also been found to be associated with broad ranges of potential global emissions pathways that represent future uncertainty in the evolution of socioeconomic, technological, market and physical systems (*very high confidence*) (Rose and Scott, 2018; Rose and Scott, 2020). Pathways consistent with limiting warming to 2°C and below have been found to require significant deployment of mitigation options spanning energy, land use and societal transformation ((Lecocq et al., 2022; Riahi et al., 2022); Section 18.3). and substantial economic, energy, land use, policy and societal transformation (Lecocq et al., 2022; Riahi et al., 2022). Such emissions pathways would represent deviations from current trends that raise issues about their feasibility and therefore plausibility (Rose and Scott, 2018; Rose and Scott, 2020).

The technical and economic challenge of limiting warming has been found to increase nonlinearly with greater ambition, fewer mitigation options, less than global cooperative policy designs and delayed mitigation action ((Riahi et al., 2022); Table 18.2). Table 18.2 provides a high-level summary of pathway characteristic ranges based on the WGIII AR6 assessment. Global pathways find large regional differences in mitigation potential, as well as the degree of regional nonlinearity with greater mitigation ambition. These represent opportunities for mitigation, but how this effort and cost would be facilitated and distributed respectively is a policy question.

Table 18.2 illustrates that greater climate ambition implies more aggressive emissions reductions in each region, and earlier regional peaking of emissions (if they have not peaked to date). Near-term regional emissions increases are possible, even for 1.5°C compatible pathways, but significantly lower emissions than today are shown in all regions by 2050. Increases in total regional energy consumption and fossil energy are observed for many pathways, even in the most ambitious where energy consumption growth is potentially slower compared with less ambitious pathways. By 2050, regional fossil energy declines, but is not eliminated in any region. Regional growth in electricity use is substantial in all pathways, even the most ambitious, with the growth continuing and accelerating with time and regional dependence on electricity (share of total energy consumption) also growing significantly. The broad ranges are an indication of uncertainty and risk for regional transitions, noting that full uncertainty is likely broader than what is captured by emissions scenario databases (Rose and Scott, 2018; Rose and Scott, 2020). Among other things, pathways commonly assume idealised climate policies with immediate implementation, and model infeasibilities (i.e., models unable to solve) increase with climate ambition and pessimism about mitigation technologies (e.g., Clarke et al., 2014; Bauer et al., 2018; Rogelj et al., 2018; Muratori et al., 2020), highlighting the increasing challenge and potential for actual infeasibility with lower global warming targets. Together, Table 18.2 provides insights into the increasingly demanding system and development transitions associated with lower global warming levels, as well as some of the low-carbon transition uncertainties and risks (see also Figure 18.5).

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Past assessment has evaluated representative mitigation strategies in terms of economic, technological, institutional, socio-cultural, environmental/ecological and geophysical viability, as well as relationships to SDGs (de Coninck et al., 2018). The strategies assessment analysis has been updated for AR6 (Cross-Chapter Box FEASIB). These assessments identify types of barriers that could affect an option's feasibility. Among other things, this work finds that, other than public transport and non-motorised transport, every other mitigation option evaluated had at least one feasibility dimension that represented a barrier or obstacle. The barriers also imply that there are trade-offs in these feasibility dimensions to consider. The assessment of mitigation option-sustainable development relationships identifies related literature and derives aggregate characterisations. Concerns about the potential sustainable development implications of some mitigation technologies may be motivation for precluding the use of some mitigation options. For instance, the potential food security and environmental quality implications of bioenergy have received significant attention in the literature (e.g., Smith et al., 2013). However, constraining or precluding the use of bioenergy without or with CCS could have significant implications for the cost of pursuing ambitious climate goals, and potentially the attainability of those goals (e.g., Clarke et al., 2014; Bauer et al., 2018; Rogelj et al., 2018; Muratori et al., 2020). Bioenergy is not unique in this regard. Social, environmental, and sustainability concerns have also been raised about the large-scale deployment of many low-carbon technologies, for example, REDD+, wind, solar, nuclear, fossil with CCS and batteries. See WGIII Chapter 3 (Riahi et al., 2022) for examples of the potential implications of limiting or precluding different low-carbon technologies.

Overall, as with adaptation options, insights from this aggregate feasibility and sustainable development mapping work are high level and difficult to apply to a specific mitigation context. The feasibility, ranking and sustainable development implications of mitigation options, as well as the list of options themselves, for a given location will vary from location to location, with different criteria and weighting of criteria that reflect the relevant social priorities and differences in markets, technology options and policies for managing risks and trade-offs. Integrated evaluation of criteria and options is needed here as well, that accounts for the relevant geographic context and interactions between options, systems and implications.

Analyses of the potential implications of mitigation on sustainable development has various strands of literature—studies exploring general greenhouse gas mitigation feedbacks to society, assessments of mitigation implications on specific societal objectives other than climate and literature evaluating mitigation implications specifically for sustainable development objectives (Denton et al., 2022; Lecocq et al., 2022; Riahi et al., 2022). In general, mitigation alters development opportunities by constraining the emissions future society can produce, which affects markets, resource allocation, economic structure, income distribution, consumers and the environment (besides climate) (*very high confidence*). Examples of general development feedbacks from mitigation include estimated price changes, macroeconomic costs, and low carbon energy and land system transformations (Fisher et al., 2007; Clarke et al., 2014; Popp et al., 2014; Rose et al., 2014; Weyant and Kriegler, 2014; Bauer et al., 2018; Rogelj et al., 2018). Examples of mitigation implications for other specific variables of societal interest include evaluating potential effects on air pollutant emissions, crop prices, water and land use change (e.g., McCollum et al., 2018b; Roy et al., 2018), while the literature evaluating mitigation implications specifically for sustainable development objectives includes evaluations on energy access, food security and income equality (e.g., Roy et al., 2018; Arneth et al., 2019; Mbow et al., 2019). Proxy indicators are frequently used to represent whether there might be implications for a sustainable development objective. For example, changes in energy prices are used as a proxy for effects on energy security (e.g., Roy et al., 2018). This is common with aggregate modelling studies, such as those associated with global or regional emissions scenarios and energy systems.

Figure 18.5, derived from WGIII scenarios data, illustrates estimated relationships between mitigation and various sustainable development proxy variables for different global regions. Figure 18.5 illustrates synergies and trade-offs with mitigation, as well as regional heterogeneity, that can intensify with the level of climate ambition—synergies in air pollutants, such as black carbon, NOx and SO_2; and trade-offs in overall economic development, household consumption, food crop prices and energy prices for electricity and natural gas. For comparison, recent IPCC assessments also observed similar synergies and trade-offs but did not directly make comparisons regarding overall development nor evaluate potential climates above 2°C (Rogelj et al., 2018; Roy et al., 2018; Mbow et al., 2019). Regional nonlinearity in the economic costs of mitigation with greater climate ambition (i.e., costs rising at an increasing rate with lower warming goals) can be significant within individual models (Rose and Scott, 2018; Rose and Scott, 2020). Figure 18.5 also illustrates transition risks in the potential for significant synergistic and trade-off implications with, for instance, potentially large regional commodity price implications and household consumption losses, as well as more significant air pollution benefits. Note that the 1.5°C results in Figure 18.5 (and Table 18.2) are biased by model infeasibilities. Many models are unable to solve, especially with less optimistic assumptions, resulting in small sample sizes and a different representation of models compared to the 2°C and higher results.

Results such as those in Figure 18.5 illustrate that mitigation–development trade-offs are inevitable and need to be considered and addressed. For instance, Roy (2018) found that although limiting warming to 1.5°C would make it markedly easier to achieve most of the UN's SDGs, none of the 1.5°C pathways assessed achieved all of the SDGs. A similar conclusion follows from the results in Figure 18.5 based on WGIII AR6 scenarios.. A newer literature is developing, evaluating the potential for managing SDG trade-offs. Results like those in Figure 18.5 provide insights regarding some of the types of strategy sets to consider. Roy et al. (2018) discuss the potential for policies that address distributional implications, such as payments, food support and revenue recycling, as well as education, retraining and technology outreach, subsidies or prioritisation. Recent studies have begun to estimate potential payments to offset trade-offs, such as related to food, water and energy access (e.g., McCollum et al., 2018a). These analyses estimate investments to address specific trade-offs; however, with mitigation redirecting resources away from other productive activities, there is a need to also evaluate the aggregate economy-wide, distributional and welfare effects, including the redistribution effects of managing sustainable development trade-offs.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Table 18.2 | Emissions pathway regional characteristics from WGIII scenarios database for pathways associated with different global warming levels (1.5°C, 2°C, 3°C and 4°C). Sample sizes: *n* = 2, 120–126, 56, and 26 emissions pathways for 1.5°C, 2°C, 3°C and 4°C global warming levels, respectively. Sample size ranges indicate that the sample size varies by variable due to differences in model reporting. Sample size varies by warming level due to model infeasibilities and differences in model reporting.

Variable	Peak global warming to 2100	Asia		Latin America		Middle East/Africa		OECD		Reforming economies		*n*
Peak CO_2 emissions year	1.5°C	2020		2010		2020		2010		2015		2
	2°C	2015 to 2030		2010 to 2035		2010 to 2030		2010 to 2020		2015 to 2030		126
	3°C	2020 to 2080		2010 to 2100		2030 to 2100		2010 to 2020		2015 to 2100		56
	4°C	2025 to 2100		2010 to 2100		2070 to 2100		2010 to 2100		2040 to 2100		26
Variable	**Peak global warming to 2100**	**Asia**		**Latin America**		**Middle East/Africa**		**OECD**		**Reforming economies**		
		2030	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**	***n***
Net CO_2 emissions (% change from 2010)	1.5°C	–18 to –24%	–73 to –69%	–61 to –57%	–94 to –92%	–26 to –1%	–65 to –50%	–50 to –46%	–91 to –90%	–42 to –41%	–92 to –91%	2
	2°C	–31 to 38%	–89 to –33%	–62 to 31%	–98 to –3%	–30 to 67%	–73 to –1%	–51 to –13%	–97 to –59%	–52 to 32%	–105 to –30%	126
	3°C	10 to 50%	–5 to 49%	–58 to 16%	–132 to 50%	7 to 84%	33 to 101%	–44 to 2%	–67 to –12%	–18 to 33%	–37 to 41%	56
	4°C	26 to 76%	37 to 103%	–49 to 5%	–41 to 22%	19 to 121%	78 to 225%	–34 to –8%	–53 to –7%	–13 to 38%	0 to 53%	26
Energy consumption growth (% change from 2010)	1.5°C	48 to 48%	49 to 62%	23 to 27%	26 to 39%	40 to 46%	55 to 62%	–15 to –12%	–43 to –28	–21 to –15%	–41 to –34%	2
	2°C	17 to 90%	16 to 130%	3 to 72%	12 to 160%	18 to 82%	43 to 145%	–16 to 10%	–35 to 11%	–15 to 37%	–33 to 29%	125
	3°C	43 to 80%	70 to 129%	–9 to 74%	17 to 170%	21 to 82%	79 to 174%	–16 to 13%	–29 to 21%	–3 to 37%	–15 to 86%	56
	4°C	47 to 91%	73 to 175%	19 to 65%	34 to 137%	46 to 95%	91 to 197%	–9 to 3%	–21 to 18%	–8 to 18%	–4 to 27%	26
Fossil energy use growth (% change from 2010	1.5°C	7 to 8%	–34 to 34%	–9 to –6%	–53 to –46%	15 to 25%	–23 to –20%	–42 to –38%	–81 to –76%	–38 to –34%	–81 to –80%	2
	2°C	–33 to 64%	–73 to 14%	–20 to 65%	–78 to 61%	–6 to 71%	–78 to 61%	–47 to –8%	–81 to –32%	–51 to 31%	–85 to –5%	121
	3°C	15 to 70%	29 to 89%	–20 to 65%	3 to 124%	7 to 79%	31 to 158%	–37 to 3%	–57 to 3%	–24 to 32%	–30 to 43%	56
	4°C	38 to 88%	59 to 149%	10 to 63%	21 to 149%	41 to 115%	103 to 247%	–26 to –5%	–45 to –1%	14 to 18%	–5 to 32%	26
Electricity consumption growth (% change from 2010)	1.5°C	159 to 165%	330 to 417%	91 to 93%	275 to 338%	119 to 132%	500 to 588%	3 to 12%	32 to 86%	28 to 30%	67 to 116%	2
	2°C	41 to 231%	120 to 580%	34 to 127%	140 to 489%	64 to 172%	177 to 801%	–2 to 33%	18 to 143%	–1 to 112%	36 to 187%	120
	3°C	57 to 198%	126 to 472%	34 to 129%	140 to 348%	75 to 175%	260 to 600%	–3 to 39%	10 to 128%	3 to 112%	38 to 221%	56
	4°C	107 to 208%	203 to 478%	47 to 123%	156 to 320%	84 to 200%	332 to 586%	1 to 33%	20 to 88%	36 to 83%	78 to 143%	26
Growth in electricity share of energy consumption (% change from 2010)	1.5°C	76 to '79%	188 to 219%	53 to 56%	198 to 215%	56 to 60%	288 to 324%	22 to 27%	132 to 160%	54 to 61%	182 to228%	2
	2°C	–6 to 79%	13 to 240%	9 to 85%	43 to 238%	13 to 94%	77 to 386%	–7 to 42%	22 to 182%	–8 to 75%	7 to 262%	120
	3°C	–2 to 76%	6 to 158%	7 to 85%	37 to 180%	13 to 94%	70 to 204%	14 to 39%	8 to 112%	–4 to 57%	7 to 127%	56
	4°C	29 to 72%	41 to 150%	20 to 46%	37 to 103%	26 to 57%	70 to 149%	9 to 33%	22 to 79%	26 to 58%	43 to 102%	26

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Regional implications of climate mitigation pathways in 2050

for various development and sustainable development proxy variables for different global mean peak temperature outcomes (during the century)



Figure 18.5 | Regional implications of climate mitigation pathways in 2050 for different global mean peak temperature outcomes (during the century) for various development and sustainable development proxy variables. Each row reports results for a different variable for each of the five global regions (columns) used by WGIII, and SDG associated with each variable is noted. Blue dots represent individual emissions scenario results from each of the respective WGIII climate outcome scenario categories, with red bars the median results. All results are changes (percentage or fraction) relative to each WGIII scenario's reference scenario. In some circumstances the reference case emissions are below those from the scenario consistent with a global warming level, which can produce results that appear counter-intuitive (e.g., increases in GDP or consumption). Data sample sizes vary substantially across temperature levels for a given variable and across variables due to model infeasibilities and model differences in reporting. Model infeasibilities, in particular, result in significantly fewer data points for 1.5°C compatible emissions pathways compared to 2°C pathways (i.e., models are more often unable to solve for a 1.5°C consistent pathway, than a 2°C pathway, with a given set of assumptions). Food/feed crop price results were not available for 1.5°C and 4°C warming levels. Sample sizes for each variable and warming level respectively—1.5°C, 2°C, 3°C, and 4°C—are as follows (and apply to all regions): GDP (n = 2, 93, 29, 12); Consumption (2, 93, 30, 13); Black Carbon (2, 100, 39, 16), NOx (2, 100, 39, 15), SO2 (2, 100, 39, 16), price food/feed crops (0, 44, 23, 0); price electricity (2, 94, 38, 15); price

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

natural gas (10, 86, 44, 10). The sample sizes are very small for the 1.5°C and 4°C results; therefore, the medians for these warming levels are statistically unreliable, which should be considered in comparing across warming levels. Individual values in the samples exceed y-axis' ranges in a few cases: black carbon 2°C Latin America minimum equals 0.08, food/feed price change 3°C minimums in Asia, Latin America, Middle East/Africa, OECD, and Reforming Economies equal respectively -33%, -28%, -28%, -29%, and -29%, natural gas price change 2°C maximums in Asia, Latin America, Middle East/Africa, OECD, and Reforming Economies equal respectively 962%, 1240%, 2768%, 917%, and 3588%. Figure developed from the WGIII AR6 scenarios database, with scenarios filtered according to WGIII exclusions and regional vetting.

There are a wide range of mitigation options and systems to consider, with assessment suggesting that a diverse portfolio is practical for pursing climate policy ambitions. However, local context will impact mitigation choices, with unique sustainable development priorities, available mitigation options, sustainable development synergies and trade-offs, and policy design and implementation possibilities.

18.2.5.3 Combining Adaptation, Mitigation and Sustainable Development Options

In practice, adaptation, mitigation and sustainable development interventions are likely to be implemented in portfolio packages rather than as individual discrete options in isolation (*high agreement*, *limited evidence*). However, there is a dearth of literature estimating optimal portfolios of global adaptation and mitigation strategies. This is not surprising given the geographic-specific nature of climate impacts and adaptation and the information and computational complexity of representing that detail, as well as mitigation options and interactions. There are, however, different literatures relevant to considering potential combinations of adaptation, mitigation and sustainable development.

At the most aggregate level, there is a long-standing literature exploring economically optimal global trade-offs between climate risks and mitigation (e.g., Manne and Richels, 1992; Nordhaus, 2017; Rose, 2017), as well as global stochastic analysis exploring global risk hedging for a small number of uncertainties (e.g., (Lemoine and Traeger, 2014). Recent work has found optimal global emissions and climate pathways to be highly sensitive to uncertainties and plausible alternative assumptions, with uncertainties throughout the causal chain from society to emissions to climate to climate damages shown to imply a wide range of different possible economically optimal pathways (Rose, 2017). Among other things, this work identifies assumptions consistent with limiting warming to different temperature levels. For example, the combination of potential annual climate damages of 15% of global GDP at 4°C of warming and a less sensitive climate system were consistent with an economically efficient global pathway limiting warming to 2°C. In addition, this work highlights the importance of characterising and managing uncertainties. These types of global aggregate analyses inform discussions regarding long-run global pathways and goals but are not designed to inform local planning.

As discussed in Section 18.2.5.3.1, there are synergies and trade-offs in mitigation, adaptation and sustainable development. For instance, the literature on the global cost-effectiveness of mitigation pathways provides insights regarding aggregate synergies and trade-offs between mitigation and sustainable development (e.g., Figure 18.5). Furthermore, linkages between mitigation and adaptation options have been shown, such as expected changes in energy demand due to climate change interacting with energy system development and mitigation options, changes in future agricultural production practices to manage the risks of potential changes in weather patterns affecting land-based emissions and mitigation strategies, or mitigation strategies placing additional demands on resources and markets. This increases pressure on and costs for adaptation, or ecosystem restoration that provides carbon sequestration and natural and managed ecosystem resiliency benefits, but also could constrain mitigation and impact consumer welfare (WGIII AR6).

Nonlinearities are an important consideration in evaluating risk management combinations. Nonlinearities have been estimated in global and regional mitigation costs and potential economic damages from climate change *(very high confidence*) ((Riahi et al., 2022); (Clarke et al., 2014; Burke et al., 2015; Rose, 2017). Nonlinear mitigation costs mean increasingly higher costs for each additional incremental reduction in emissions (or incremental reduction in global average temperature). Nonlinear increases in estimated economic climate damage means increasingly higher damages for each additional incremental increase in climate change (e.g., global average temperature). However, the evidence on whether damages increase at an increasing or decreasing rate is mixed (Chapter 16 CWGB: ECONOMIC). Nonlinearities are also suggested in estimated changes in key risks and adaptation costs (Chapters 2 to 16). However, to date, they have not been as explicitly characterised. These nonlinearities imply nonlinearities in climate risk management synergies and trade-offs with sustainable development. Not only do trade-offs vary by climate level, as do synergies, but they increase at an increasing rate and their relative importance can shift across climate levels (*very high confidence*). Some of this is evident in results such as those shown in Figure 18.5 for mitigation (keeping in mind differences in sample sizes across temperature levels). Uncertainty about the degree of nonlinearity in mitigation, climate damages, key risks and adaptation costs creates uncertainties in the strength of the trade-offs and synergies, but also represents opportunities. For instance, additional mitigation options and more economically efficient policy designs have been shown to reduce mitigation costs and the nonlinearities in mitigation costs (*very high confidence*) (Riahi et al., 2022). The same is true for adaptation options and adaptation costs.

Infeasibilities of mitigation and adaptation options (Sections 18.4.2.2.1, 18.4.2.2.2), as well as global pathways (Riahi et al., 2022) , are also relevant to consideration of combinations of risk management options. Infeasibility of options implies higher costs and greater cost nonlinearity due to fewer and/or more expensive options, while infeasibility of pathways bounds some of the uncertainty about the pathways relevant to decision making and planning.

18.2.5.3.1 Trade-offs and synergies in adaptation, mitigation and climate resilient development

Since AR5, a growing body of literature has emerged that frames adaptation processes as endogenous socioeconomic dynamics, exogenous driving forces and explicit decisions (Barnett et al., 2014; Maru et al., 2014; Butler et al., 2016; Kingsborough et al., 2016;

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Werners et al., 2018). Central to this framing is a shift away from viewing adaptation as discrete sets of options that are selected and implemented to manage risk, to thinking about adaptation as a social process that evolves over time, includes multiple decision points, and requires dynamic adjustments in response to new information about climate risk, socioeconomic conditions and the value of potential adaptation responses (*very high confidence*) (Haasnoot et al., 2013; Wise et al., 2016). This aligns adaptation with aspects of development thinking, including questions around the capacity and agency of different actors to effect change, the governance of adaptation, and the contingent nature of adaptation needs and effectiveness on the future evolution of society and climate change risk.

While ensuring development and adaptation produce synergies that allow for the achievement of sustainable development is challenging, modelling exercises suggest that there are pathways where synergies among the SDGs are realised (*very high confidence*) (Roy et al., 2018; Van Vuuren et al., 2019) (Section 18.5), particularly if longer time horizons are used. These pathways require progress on multiple social, economic, technological, institutional and governance aspects of development, including building human capacity, managing consumption behaviour, decarbonisation of the global economy, improving food and water security, modernising cities and infrastructure, and innovations in science and technology (Van Vuuren et al., 2019) (Section 18.3). In addition, Olsson et al, (Olsson et al., 2014) and Roy et al. (2018) emphasise the importance of integrating considerations for social justice and equity in the pursuit of sustainable development (Gupta and Pouw, 2017).

The significant overlaps and linkages between development and adaptation practice and a lack of conceptual clarity about adaptation pose a conundrum for scholars (e.g., Bassett and Fogelman, 2013; Webber, 2016), who raise concerns that this potentially leads to trade-offs or mislabelling (Few et al., 2017). This framing of adaptation and development can result in competition between attainment of sustainable development and policies to reduce the impacts of climate change (Ribot, 2011). Such trade-offs are illustrated by (Moyer and Bohl, 2019) who use a baseline development trajectory based on current trends to project progress on SDGs by 2030. This work concluded that only marginal gains are likely to be achieved under that pathway over the next decade (Barnes et al., 2019).

Emerging evidence also suggests that many adaptation-labelled strategies may exacerbate existing poverty and vulnerability or introduce new inequalities, for example by affecting certain disadvantaged groups more than others, even to the point of protecting the wealthy elite at the expense of the most vulnerable (Eriksen et al., 2019). Pelling et al. (2016) find that adaptation has been conceived and implemented in such a manner that most projects preserve rather than challenge the status quo. Specifically, the potential for knowledge and the goals of adaptation to be contested by different actors and stakeholders and the need to sustain progress over extended periods of time can constrain the ability to effectively implement actions that lead to sustainable development outcomes that are protected from the impacts of climate change while also delivering climate mitigation outcomes, that is, for CRD (Bosomworth et al., 2017; Bloemen et al., 2019). This creates the possibility for specific adaptation actions to result in outcomes that undermine greenhouse gas mitigation and/or broader development goals (Fazey et al., 2016; Wise et al., 2016; Magnan et al., 2020). For example, a study in Bangladesh revealed how local elites and donors used adaptation projects as a lever to push vulnerable populations away from their agrarian livelihoods and into uncertain urban wage labour (Paprocki, 2018). These types of outcomes are categorised as maladaptation, interventions that increase rather than decrease vulnerability, and/or undermine or eradicate future opportunities for adaptation and development (Barnett and O'Neill, 2010; Juhola et al., 2015; Magnan et al., 2016; Antwi-Agyei et al., 2017; Schipper, 2020). This inadvertent impact on equity appears to fundamentally contradict a benevolent understanding of transformative adaptation that also champions social justice (Patterson et al., 2018), thus posing long-term maladaptation in opposition to transformative adaptation (Magnan et al., 2020).

Similarly, mitigation efforts, while reducing emissions, can also increase climate impacts vulnerability and undermine adaptation efforts. The same can be said for some poverty alleviation and sustainable development efforts that increase vulnerability for specific segments of the population. For example, in Central America, an evaluation of 12 rural renewable energy projects (either forthe clean development mechanism, early warning systems or rural electrification goals) found that some mitigation and poverty alleviation projects increased vulnerability to families—by excluding them, not adhering to local safety and quality codes and standards, or significantly altering community power dynamics and contributing to conflict (Ley, 2017; Ley et al., 2020).

Synergies between adaptation, mitigation and sustainable development might be promoted by prioritising those CRD strategies most likely to generate synergies (*very high confidence*) (Roy et al., 2018; Karlsson et al., 2020). This could include focusing on poverty alleviation that improves adaptive capacity (e.g., Kaya and Chinsamy, 2016; Kuper et al., 2017; Ley, 2017; Sánchez and Izzo, 2017; Stańczuk-Gałwiaczek et al., 2018; Ley et al., 2020); renewable energy systems that improve water management and preservation of river ecological integrity (e.g., Berga, 2016; Rasul and Sharma, 2016); or internalising positive externalities, such as subsidies for mitigation options thought to also improve water use efficiency (e.g., Roy et al., 2018). Similarly, trade-offs might be managed by prioritising strategies such as disqualifying mitigation options thought to have negative social implications (Section 18.2.5.3.1), internalising externalities, such as placing a fee or constraint on a negative externality or related activity (Dubash et al., 2022) (Bistline and Rose, 2018), or using complementary policies, such as transfer payments to offset negative mitigation, adaptation or sustainable development strategy implications (*very high confidence*) (e.g., McCollum et al., 2018b). Roy et al. (2018) discusses the latter, noting, for instance, the possibility of complementary sustainable development payments to avoid global energy access, food security and clean water trade-offs (Box 4.7).

SR1.5 and AR6 assessments of system transitions also find opportunities for synergies and managing trade-offs (Section 18.3; Cross-Chapter Box FEASIB). Within each system, mitigation and adaptation options are assessed for their specific benefits and the impacts they can have on one another, as well as with sustainable development. For example, within energy system transitions, the three adaptation options (power infrastructure resilience, reliability of power systems, efficient water use management) have strong synergies with mitigation. While not

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

all mitigation options have strong synergies, the trade-offs can be managed when adaptation and SDGs are also considered. Under land and other ecosystems system transitions, the main trade-off is the competition for land use between potential alternative uses, for example, sustainable agriculture, afforestation/reforestation, purpose-grown biomass for energy. On the other hand, assessment of urban and infrastructure system transitions finds mainly synergies between mitigation and adaptation options with trade-offs that are considered manageable, and there is growing evidence of rural landscape infrastructure benefits to adaptation.

Overall, this literature is relatively new and still developing. It highlights the importance of societal priorities and policy design for realizing synergies. However, the literature is not well developed in terms of how to optimize mitigation, adaptation and sustainable development interventions to achieve multiple priorities.

18.2.5.3.2 Risk management combinations with lower to higher climate change

Given the global climate system is committed to additional future warming, different portfolios of adaptation, mitigation, and sustainable development interventions are relevant for climate risk management. The different strands of literature discussed above can be integrated to help inform thinking about combinations of approaches to climate risk management. Globally, low climate change projections, versus higher climate change projections, imply greater mitigation, lower climate risks and less adaptation. This implies greater mitigation trade-offs in terms of overall economic development, food crop prices, energy prices and overall household consumption, but lower climate risk, with sustainable development synergies such as human health and lower adaptation trade-offs, and an uneven distribution of effects (*very high confidence*) (Roy et al., 2018).

Sustainable development considerations could be used to prioritise mitigation options, but as noted earlier, there are trade-offs, with a potentially significant impact on the economic cost of mitigation, as well as a potential trade-off in terms of the climate outcomes that are still viable (Riahi et al., 2022). For instance, all of the 1.5°C scenarios used in IPCC (2018a) deploy carbon dioxide removal technologies (Rogelj et al., 2018). Without these technologies, most models cannot generate pathways that limit warming to 1.5°C, and those that are able to adopt strong assumptions about global policy development and socioeconomic changes. Sustainable development might also affect the design of policies by prioritising specific sustainable development objectives. However, there are trade-offs here as well, with costs and the distribution of costs varying with alternative policy designs. For instance, prioritising air quality has climate co-benefits but does not ensure the lowest cost climate strategy (Arneth et al., 2009; Kandlikar et al., 2009). Similarly, prioritising land protection has a variety of co-benefits but could increase food prices significantly, as well as the overall cost of climate mitigation (IPCC, 2019b). In this context, with lower climate risk and adaptation levels and larger mitigation effort, managing mitigation trade-offs could be a sustainable development priority. Furthermore, sustainable development could also be tailored to facilitate adaptation and manage mitigation costs.

Globally, high climate change projections imply lower mitigation effort, higher climate risks and greater adaptation. This implies lower mitigation trade-offs, but greater climate risk with greater demand of adaptation and potential for trade-offs in terms of competing sustainable development priorities. Sustainable development considerations could affect adaptation options. For instance, constraining options such as relocation or facilitating adaptation capacity and community resilience. Sustainable development might also be tailored to affect the climate outcome by shaping the development of emissions. In this context, with greater climate risk and adaptation levels and less mitigation effort, facilitating adaptation addressing adaptation costs and trade-offs could be a sustainable development priority.

Locally, there are many qualitative similarities to the global perspective in thinking about risk management combinations across lower versus higher levels of warming. However, there is one very important difference. Local decision makers are confronted with uncertainty about what others will do beyond their local jurisdiction. With future climate a function of the sum of global decisions, sustainable development planning needs to consider the possibility of more and less emissions reduction action globally and the potential associated climates. This implies the need for sustainable development to manage for the possibility of higher levels of warming by further facilitating adaptation and managing adaptation trade-offs. Prioritising sustainable development locally is also supported by the insight that the impacts on poverty depend at least as much or more on development than on the level of climate change (*very high confidence*) (Wiebe et al., 2015; Hallegatte and Rozenberg, 2017).

With surpassing 1.5°C a distinct possibility, considering higher levels of warming is a necessity. CRD could be pursued with additional adaptation, recognizing increasing challenges for adaptation and sustainable development with higher warming, just as there are increasing challenges for mitigation and sustainable development with limiting warming to lower levels. There are many possible pathways for pursuing climate resilient development, though our understanding of the possibilities with different levels of warming is currently limited (e.g., David Tàbara et al., 2018; O'Brien, 2018). The current literature suggests that different mixes of adaptation and mitigation strategies, and sustainable development and trade-off management priorities, measures and reallocations (Section 18.5.3.1), will be appropriate for different expected climates and locations (Section 18.1.2); while trade-offs between climates will be dictated by relative nonlinearities, feasibilities, shifts in priorities, and trade-off and reallocation options across future climates.

Finally, it is important to note that there is currently limited information available regarding the following: (1) local implications of 1.5°C versus warmer futures with respect to local climate outcomes, avoided impacts and sustainable development implications and interactions, given that applying global conclusions to local, national and regional settings can be misleading; (2) local context-specific synergies and trade-offs with respect to adaptation, mitigation and sustainable development for 1.5°C futures; and (3) standard indicators for monitoring factors related to CRD (Roy et al., 2018).

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

18.3 Transitions to Climate Resilient Development

A key finding emerging from the IPCC SR1.5 is the critical role that system transitions play in enabling mitigation pathways consistent with a 1.5°C or less world (IPCC, 2018a; IPCC, 2019b).Such transitions are similarly critical for the broader pursuit of CRD, and the various AR6 special reports as well as subsequent literature provide new evidence of why such transitions are needed for CRD, as well as both the opportunities for accelerating system transitions and their limitations for delivering on the goals of CRD.

18.3.1 System Transitions as a Foundation for Climate Resilient Development

In the AR6, system transitions are defined as '*the process of changing (the system in focus) from one state or condition to another in a given period of time*' (IPCC, 2018a; IPCC, 2019b). In the climate change solution space, system transitions represent an important mechanism for linking and enabling mitigation, adaptation and sustainable development options and actions (*very high confidence*). SR1.5C identified the need for rapid and far-reaching transitions in four systems—energy, land and terrestrial ecosystems, urban and infrastructure, and industrial systems (IPCC, 2018b; IPCC, 2018a) (Sections 1.5.1 and 18.1). The SRCCL expanded on this with a focus on terrestrial systems, while SROCC added additional evidence from ocean and cryosphere systems. This section assesses the four system transitions discussed in the SR1.5C assessment in the context of CRD, while also extending the assessment to consider societal transitions as a cross-cutting, fifth transition important for CRD. Literature to support this assessment is also drawn from AR6 regional and sectoral chapters, which is synthesised later in this chapter (Section 18.5).

As discussed in Box 18.3 (Hölscher et al., 2018), system transitions are linked to system transformation, which is defined as '*a change in the fundamental attributes of a system including altered goals or values*' (Figure 18.1) (IPCC, 2018a). In a systems context, transitions focus on 'complex adaptive systems; social, institutional and technological change in societal sub-systems', while transformations are '*large scale societal change processes … involving social-ecological interactions*' (IPCC, 2018a) (Box 18.1). Although system transitions are often identified in the literature as being necessary processes for large-scale transformations (Roggema et al., 2012; Hölscher et al., 2018), thereby making them a core enabler of CRD, they are not necessarily transformative in themselves.

18.3.1.1 Energy Systems

Recent observed changes in global energy systems include continued growth in energy demand, led by increased demand for electricity by industry and buildings (*very high confidence*)(Dhakal et al., 2022) . Growth in energy demand has also been driven by increased demand for industrial products, materials, building energy services, floor space and all modes of transportation. This growth in demand, however, has been moderated by improvements in energy efficiency in industry, buildings and transportation sectors (*very high confidence*) (Dhakal et al., 2022). There is also a trend of moving away from coal towards cleaner fuels, owing to lower natural gas prices and lower cost renewable technologies, and structural changes away from more energy-intensive industry.

Features of sustainable development, such as enhanced energy access, energy security, reductions in air pollution and economic growth, continue to be the dominant influence on the evolution of energy systems and decision making regarding energy investments and portfolios (*very high confidence*) (Clarke et al., 2022) . To date, climate policy has been comparatively less influential in driving energy transitions globally. Yet there are examples at the local, regional and national level of policy incentivising rapid changes in energy systems (*very high confidence*) (Clarke et al., 2022) . Many sustainable development priorities have co-benefits in terms of climate mitigation, such as air pollution and conservation policies reducing short-lived climate forcers and sequestering carbon respectively, as well adaptation benefits, such as improved energy access and environmental quality enhancing adaptive capacity (*very high confidence*) (Clarke et al., 2022) (de Coninck et al., 2018). Alternatively, sustainable development projects can have negative climate implications with, for instance, hydroelectric projects shut down by droughts or floods resulting in greater use of bunker and fuel oil, as well as natural gas.

In addition to sustainable development priorities driving change in energy systems, observed energy system trends have implications for sustainable development (e.g., IEA et al., 2019). Observed changes in energy system size, rate of growth, composition and operations impact energy access, equity, environmental quality and well-being, with both synergies and trade-offs, including recent improvements in global access to affordable, reliable and modern energy services. For instance, in some countries, such as the USA, there has been a significant shift away from coal as a fuel source for electricity generation in favour of natural gas. More recently, however, renewables have emerged as the dominant form of new electricity generation (Gielen et al., 2019). Similarly, for energy access in developing countries, renewable energy or hybrid distributed generation systems are increasingly being prioritised because of challenges associated with access, costs and environmental impacts from traditional fossil fuel-based energy technologies (Mulugetta et al., 2019).

Energy systems have been a historical driver of climate change, but are also adversely affected by climate change impacts, including short-term shocks and stressors from extreme weather as well as long-term shifts in climatic conditions (*very high confidence*). The potential for such factors is often incorporated into local system designs, operations and response strategies. There have been changes in observed weather and extreme event hazards for the energy system, but to date, many are not attributable solely to anthropogenic climate change (USGCRP, 2017; IPCC, 2021a). Nevertheless, with observed extremes shifting outside of what has been observed historically, existing design criteria and operations may not be optimal for future climate conditions and contingencies (Chapters 2 to 16). Overall, there is limited historical evidence on the efficacy of adaptation responses in reducing vulnerability of energy systems (*high agreement*, *limited evidence*). However, sustainable development trends, such as improving incomes, reducing poverty, and improving health and education have reduced vulnerability (Chapter 16), and improvements in system resiliency

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

to extreme weather events and more efficient water management have occurred that have synergies with adaptation and sustainable development in general.

Available literature indicates that greenhouse gas emissions reductions have been achieved in response to climate actions including financial incentives to promote renewable energy, carbon taxes and emissions trading, removal of fossil fuel subsidies, and promotion of energy efficiency standards (*very high confidence*) (Clarke et al., 2022). Such policies tend to lead to a lower carbon intensity of GDP, due to structural changes in the use of energy and the adoption of new energy technologies. However, other drivers of change are also present and thus ongoing energy transitions and their future evolution are a response to both climatic and non-climatic considerations, with broader sustainable development priorities being a significant driver of change {Clarke, 2022 #4316.

18.3.1.2 Urban and Infrastructure Systems

Urban areas and their associated infrastructure are critical targets for CRD processes. This is a function of urban areas being the dominant settlement pattern, with over 55% of the global population living in cities (World Bank, 2021). As a consequence, urban areas are also the focal point for energy use, land use change and consumption of natural resources, thereby making them responsible for an estimated 70% of global CO_2 emissions (Johansson et al., 2012; Ribeiro et al., 2019). The trend towards increasing urbanisation is anticipated to create both challenges and opportunities for sustainable development, as well as climate action (Güneralp et al., 2017; Li et al., 2019a).

The built environment is increasingly exposed to climate stresses and more frequent co-occurrences of climate shocks than in the past. This has the potential to increase rates of building and infrastructure degradation and increase damage from extreme weather events. The existing adaptation gaps and everyday risks within many cities, particularly those of the Global South, combined with escalating risk from climate change, makes rapid progress in enhancing urban resilience a high priority for CRD (Pelling et al., 2018; Davidson et al., 2019; Lenzholzer et al., 2020). Strategic investments in disaster risk reduction, including climate-resilient green infrastructure, updated building codes and land use planning can provide significant long-term cost savings and social benefits. Moreover, evaluating the relative merits of 'fail safe' versus 'safe to fail' approaches to infrastructure planning can help to identify more design principles that are more robust to the uncertainties of climate change and urbanisation (Kim et al., 2017a; Kim et al., 2019).

Much of the literature on urban resilience and sustainability focuses on addressing discrete challenges for urban infrastructure subsystems. Climate change has the potential to enhance stress on lifeline infrastructure services such as the provision of electricity, water and wastewater, communications and transportation—subsystems which are often underdeveloped in many regions of the world (Arku and Marais, 2021; Sitas et al., 2021). For example, a warming and more variable climate can increase stress on electricity grids by reducing transmission efficiency, increasing cooling demand requirements, and by increasing exposure to climate shocks such as heatwaves, floods and storms (Bartos and Chester, 2015; Auffhammer et al., 2017; Perera et al., 2020). Accordingly, a significant focus on the energy transition is on achieving the dual goals of reducing the carbon footprint of energy while also increasing resilience of energy supply to current and future threats. For example, renewable energy generation and storage technologies that are modular and distributed and provide enhanced resilience to shocks and stresses from climate change (Venema and Temmer, 2017a).

Similarly, building and maintaining urban water systems that are resilient to climate shocks requires significant changes in water demand, infrastructure and management. Enhancing redundancy in water supply and the flexibility to shift between surface and groundwater options aids adaptation. Decentralised water supply and sanitation options are now feasible and can provide greater resilience than most centralised systems (Parry, 2017), provided they have adequate supply (Leigh and Lee, 2019; Rabaey et al., 2020). Water conservation and green infrastructure options for stormwater management are proven approaches for reducing climate risks (Venema and Temmer, 2017b), with adaptation and mitigation co-benefits. Water demand management and rainwater harvesting contribute to climate change mitigation and increase adaptive capacity by increasing resilience to climate change impacts such as drought and flooding (Paton et al., 2014; Berry et al., 2015). In addition, they can contribute to restoring urban ecosystems that offer multiple ecosystem services to citizens (Berry et al., 2015) {Lwasa, 2022 #4317}. The context-appropriate development of green spaces, protecting ecosystem services and developing nature-based solutions, can increase the set of available urban adaptation options (IPCC, 2018b), while creating opportunities for more complex and dynamic approaches to urban water management (Franco-Torres et al., 2020). For example, the Netherlands' 'Room for the River' policy focuses on not only achieving higher flood resilience, but also improving the quality of riverine areas for human and ecological well-being (Busscher et al., 2019).

An overarching focus of urban sustainability is the reversal of long-standing trends of ecosystem fragmentation and degradation that have resulted in growing separation between human and natural systems within urban environments (IPBES, 2019) (Lwasa et al., 2022). Urban ecosystems and the integration of nature-based solutions and green infrastructure into urban areas can yield benefits that facilitate achievement of the SDGs. There has been growing recognition of urban ecosystems as social, cultural and economic assets that can support economic development while also enhancing resilience to extreme weather events and improving air and water quality (Shaneyfelt et al., 2017; Matos et al., 2019). Investing in urban ecosystems and green infrastructure can provide lower-cost solutions to multiple urban development challenges when compared with traditional infrastructure systems (Terton, 2017). Relatedly, agriculture, while largely a rural system, is increasingly expanding within urban areas. Urban agriculture enables citizens to fulfil some of their food needs, improving urban resilience to food shortages, enhancing biodiversity and increasing coping capacity during disasters (Demuzere et al., 2014; Clucas et al., 2018) (Lwasa et al., 2022). Strengthening urban agroecosystems therefore increases resilience to supply shocks from climate change impacts and can contribute to community cohesion (Temmer, 2017a).

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Overall, the discourse in the literature regarding the future of cities emphasises the importance of viewing cities as more than just their physical infrastructure that can be made more resilient through engineering solutions (Davidson et al., 2019). Rather, urban areas are increasingly conceptualised as complex socio-ecological or socio-technical systems (*very high confidence*) (Patorniti et al., 2017; Patorniti et al., 2018; Visvizi et al., 2018; Savaget et al., 2019). Such frameworks integrate physical, cyber, social and ecological elements of cities in pursuit of resilience and sustainability transitions, and they recognise the role of governance and engagement processes as being central to system change (Temmer, 2017b). Nevertheless, some authors have cautioned that urban transitions will be associated with synergies as well as trade-offs with respect to sustainable development (*very high confidence*) (Maes et al., 2019; Sharifi, 2020).

18.3.1.3 Land, Oceans and Ecosystems

Land, oceans and terrestrial ecosystems are in transition globally, with anthropogenic factors including climate change being a major driving force (*very high confidence*) (IPBES, 2019) (Box 6). Seventy-five percent of the land surface has been significantly altered, 66% of the ocean area is experiencing increasing cumulative impacts and over 85% of wetland areas have been lost (IPBES, 2019). Since 1970, only four out of eighteen recognised ecosystem services assessed have improved in their functioning: agricultural production, fish harvest, bioenergy production and material harvests. The other 14 ecosystem services have declined (IPBES, 2019), raising concerns about the capacity of ecosystems and their services to support sustainable and CRD.

Given the pressures on land, oceans and ecosystems, enhancing resilience to climate change and other pressures of human development is a core priority of transition in these systems. Yet there are a few recorded initiatives that provide evidence of successful improvement in ecosystem resilience (*high agreement*, *limited evidence*). Similarly, although there is significant evidence that a broad range of adaptation initiatives have been pursued across global regions and sectors, including a rapid expansion of nature- or ecosystem-based solutions (Mainali et al., 2020), there is *limited evidence* of how these planned climate adaptation efforts have contributed to enhanced ecosystem resilience. Additional research is necessary to evaluate these efforts in terms of their performance and also to identify mechanisms for scaling them up in different contexts. As an example, Paik et al. (Paik et al., 2020) record the increased diffusion of salt tolerant rice varieties in the Mekong River Delta, which is at risk of sea level rise and an associated saline intrusion. This is a low-cost adaption to saline ingress, that increases food productivity and reduces the risk of outmigration for this vulnerable agricultural region.

Evidence of the interactions between ecosystems and resilience come from a range of sources including both regional and sectoral examples (Box 18.2; Tables 18.7–18.8. For example, regional examples suggest that the use of land to produce biofuels could increase the resilience of production systems and address mitigation needs (Box 2.2). Nevertheless, the potential of bioenergy with carbon capture and storage (BECCS) to induce maladaptation needs deeper analysis (Hoegh-Guldberg et al., 2019). Climate Smart Forestry (CSF) in Europe provides an example of the use of sustainable forest management to unlock the EU's forest sector potential (Nabuurs et al., 2017). This is in response to diverse climate impacts ranging from pressure on spruce stocks in Norway and the Baltics, on regional biodiversity in the Mediterranean region, and the opportunity to use afforestation and reforestation to store carbon in forests (Nabuurs et al., 2019). CSF considers the full value chain from forest to wood products and energy and uses a wide range of measures to provide positive incentives to firmly integrate climate objectives into the forestry sector. CSF has three main objectives; (i) reducing and/or removing greenhouse gas emissions; (ii) adapting and building forest resilience to climate change; and (iii) sustainably increasing forest productivity and incomes (Verkerk et al., 2020).

Other solutions focus on specific subsectors. Mutually supportive climate and land policies have the potential to save resources, amplify social resilience, support ecological restoration, and foster engagement and collaboration between multiple stakeholders (IPCC, 2019 f, C.1). Land-based solutions can combat desertification in specific contexts: water harvesting and micro-irrigation, restoring degraded lands using drought-resilient ecologically appropriate plants, agroforestry and other agroecological and ecosystem-based adaptation practices (IPCC, 2019 f, B.4.1). Reducing dust, sandstorms and sand dune movement can lessen the negative effects of wind erosion and improve air quality and health. Depending on water availability and soil conditions, afforestation, tree planting and ecosystem restoration programmes using native and other climate-resilient tree species with low water needs, can reduce sand storms, avert wind erosion and contribute to carbon sinks, while improving micro-climates, soil nutrients and water retention (IPCC, 2019 f, B.4.2).

Coastal blue carbon ecosystems, such as mangroves, salt marshes and seagrasses, can help reduce the risks and impacts of climate change, with multiple co-benefits. Over 150 countries contain at least one of these coastal blue carbon ecosystems and over 70 contain all three. Successful implementation of measures of carbon storage in coastal ecosystems could assist several countries in achieving a balance between emissions and removal of greenhouse gases. Carbon storage in marine habitats can be up to 1,000 tC ha^{-1}, higher than most terrestrial ecosystems. Conservation of these habitats would also sustain a wide range of ecosystem services, assist with climate adaptation by improving critical habitats for biodiversity, enhance local fishery production and protect coastal communities from sea level rise (SLR) and storm events (IPCC, 2019b). Ecosystem-based adaptation is a cost-effective coastal protection tool that can have many co-benefits, including supporting livelihoods, contributing to carbon sequestration and the provision of a range of other valuable ecosystem services (IPCC, 2019b).

Diversification of food systems is another component of land, ocean and ecosystem transitions that are consistent with CRD. Balanced diets, featuring plant-based foods such as those based on coarse grains, legumes, fruits and vegetables, nuts and seeds, and animal-sourced food produced in a resilient, sustainable and low-greenhouse gas (GHG) emission manner, are major opportunities for adaptation and mitigation and improving human health. By 2050, dietary changes could free several million km^2 of land and provide a mitigation potential of 0.7–8.0 Gt CO_2-eq yr^{-1}, relative to Business-As-Usual projections.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

For coastal systems, many frameworks for climate resilience and adaptation have been developed since the AR5 (Hoegh-Guldberg et al., 2014; Settele et al., 2014) with substantial variations in approach between and within countries and across development status. Few studies have assessed the success of implementing these frameworks owing to the time-lag between implementation, monitoring, evaluation and reporting (IPCC, 2019g). As an example, the Nature-Based Climate Solutions for Oceans initiative has the potential to restore, protect and manage coastal and marine ecosystems, adapt to climate change, improve coastal resilience, and enhance their ability to sequester and store carbon (Hoegh-Guldberg et al., 2019).

Polar regions will be profoundly different in the future. The degree and nature of that difference will depend strongly on the rate and magnitude of global climate change, which will influence adaptation responses regionally and worldwide. Future climate-induced changes in the polar oceans, sea ice, snow and permafrost will drive habitat and biome shifts, with associated changes in the ranges and abundance of ecologically important species (IPCC, 2019g). Innovative tools and practices in polar resource management and planning show strong potential in improving society's capacity to respond to climate change. Networks of protected areas, participatory scenario analysis, decision support systems and community-based ecological monitoring that draws on local and Indigenous knowledge and self-assessments of community resilience contribute to strategic plans for sustaining biodiversity and limit risk to human livelihoods and well-being. Experimenting, assessing and continually refining practices while strengthening links with decision making has the potential to ready society for the expected and unexpected impacts of climate change (IPCC, 2019g).

18.3.1.4 Industrial Systems

Industrial emissions have been growing faster since 2000 compared with emissions in any other sector, driven by increased extraction and production of basic materials (Crippa et al., 2019; IEA, 2019) (*very high confidence*). About one-third of the total emissions are contributed by the industry sector, if indirect emissions from energy use are considered (Crippa et al., 2019). The COVID-19 pandemic has caused a significant decrease in demand for fuels, oil, coal, gas and nuclear energy (IEA, 2020). However, there is concern that the rebound in the crisis will reverse this trend (IEA, 2020). Accordingly, the literature suggests a combined set of measures is beneficial for facilitation a transition of industrial systems in support of CRD. This includes (i) dematerialisation and decarbonisation of industrial systems, (ii) establishment of supportive governance, policies and regulations, and (iii) implementation of enabling corporate strategies.

Decarbonisation and dematerialisation strategies have been proposed as key drivers for the transition of industrial systems (Fischedick et al., 2014; Worrell et al., 2016). The former involves limiting carbon emissions from industrial processes (IEA, 2017; Hildingsson et al., 2019), while the latter involves improving material efficiency, developing circular economies, raw material demand management, environmentally friendly product and process innovations, and environmentally friendly supply chain management (Worrell et al., 2016; Petrides et al., 2018).

Recent modelling suggests that stocks of manufactured capital, including buildings, infrastructure, machinery and equipment, stabilise as countries develop and decouple from GDP (*high agreement*, *medium evidence*). For instance, Bleischwitz et al. (2018) confirmed the occurrence of a saturation effect for materials in four energy-intensive sectors (steel, cement, aluminum and copper) in five industrialised countries (Germany, Japan, the UK, the USA and China). High growth in the supply of materials may still drive global demand for new products in the coming years for developing countries that are still far from saturation levels. Therefore, accelerating industrial transitions to drive the decoupling of industrial emissions from economic growth and facilitate broader transformation in industrial systems can be one component of CRD.

Continued transitions in the industrial sector will be contingent on technological innovation. Although technologies exist to drive emissions in industrial sectors to very low or zero emissions, they require 5–15 years of innovation, commercialisation and intensive policies to ensure uptake (Åhman et al., 2017) (*high agreement*, *medium evidence*). For instance, several options exist to reduce GHG emissions related to steel production process including increasing the share of the secondary route (Pauliuk et al., 2013), hydrogen-based direct reduced iron (Vogl et al., 2018), aqueous electrolysis rout (Cavaliere, 2019) and plasma process (Quader et al., 2016).

Industrial transitions are also contingent upon consumer behaviour in terms of preferences for, and rates of, consumption of industrial products. Sustainable consumption can play an important role in sustainable production (Allwood et al., 2013; Allwood et al., 2019). This suggests feedbacks between industrial production and consumption in driving industrial transitions. For example, sustainable consumption could be triggered and/or enabled through sustainable production processes that provide more sustainable options to consumers as well as public or private promotional campaigns that promote those options. Meanwhile, demand from consumers for more sustainable options could help to drive the expansion of markets and innovation among industrial producers to meet that demand. However, some have argued that such promotional campaigns that target consumers do little to incentivize sustainable development and climate action (Farrell, 2015; Grydehøj and Kelman, 2017).

18.3.1.5 Societal Systems

This chapter contributes a fifth system transition in addition to the four which have already been introduced by SR1.5: the societal systems transition. While society and people also feature in the other systems transitions, the purpose of defining a fifth transition is to explicitly highlight the challenges associated with changes in behaviour, attitudes, values and consciousness required to achieve CRD. One caveat of considering transitions in societal systems is the limit to which the nature of change is known: transitions accomplish reconfigurations towards a relatively known destination. Historical and current differences between and within nations translate to a multitude of equally valid but diverse priorities for development, for example the understanding of development towards progress as linear has been challenged as being a Western concept by scholars of colonialisation (Sultana et al., 2019). Thus, societal transitions are understood as being intrinsically diverse for the purpose of achieving CRD.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Box 18.5 | The Role of Ecosystems in Climate Resilient Development

Ecosystems and their services closely relate to climate resilient development (CRD). Climate change has impacted ecosystems across a range of scales, and those impacts have been exacerbated by other ecological impacts associated with human activities. Ecosystem-based adaptation strategies have been developed and are crucial to CRD. However, knowledge and evidence still missing, and cultural services—in contrast to provision and regulation services as main benefits and supporting services as co-benefits—are less well addressed in the literature.

Ecosystems Play a Key Role in CRD

A key element of CRD is ensuring that actions taken to mitigate climate change do not compromise adaptation, biodiversity and human needs. Maintaining ecosystem health, linked to planetary health, is an integral part of the goals of CRD. The 2005 Millennium Ecosystem Assessment (MEA) defined ecosystem services as '*the benefits people obtain from ecosystems*', and categorised the services in to provisioning, regulating, supporting and cultural services (Millennium Ecosystem Assessment, 2005; IPBES, 2019). The 2019 Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) broadened the definition to '*the contributions, both positive and negative, of living nature to the quality of life for people*', and developed a classification of 18 categories (IPBES, 2019).

Table Box 18.5.1 demonstrates how ecosystem services connect to sustainable development goals (SDGs) and CRD. MEA's provisioning service generally connects to the IPBES' material services, mostly contributing to the SDG cluster associated with nature's contribution to people (NCP) (Millennium Ecosystem Assessment, 2005; IPBES, 2019) and to '**D**evelopment' in CRD. MEA's regulating and supporting services connect to IPBES' non-material services, contributing to SDG clusters of Nature and Driver of change in nature and NCP and to '**R**esilience' in CRD. MEA's cultural services connect to IPBES' non-material services, contributing to SDG clusters of good quality of lift (GQL) and to **E**nabling conditions for CRD.

Table Box 18.5.1 | Ecosystem services (based on the Millennium Ecosystem Assessment [MEA] and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES] classifications) and their connections to sustainable development goals (SDGs) and climate resilient development (CRD) (Millennium Ecosystem Assessment, 2005; IPBES, 2019).

Ecosystem services		SDGs	CRD
MEA	IPBES		
Provisioning services	11 Energy 12 Food and feed 13 Materials and assistance 14 Medicinal, biochemical and genetic resources	1 No poverty 2 Zero hunger 3 Good health and well-being 11 Sustainable cities communities 7 Affordable clean energy 8 Decent work and economic growth 9 Industry, innovation and infrastructure 12 Responsible consumption and production	**D**evelopment
Regulating services	3 Regulation of air quality 4 Regulation of climate 5 Regulation of ocean acidification 6 Regulation of freshwater quantity, location and timing 7 Regulation of freshwater and coastal water quality 9 Regulation of hazards and extreme events 10 Regulation of organisms detrimental to humans	6 Clean water and sanitation 13 Climate action	**C**limate adaptation and mitigation
Supporting services	1 Habitat creation and maintenance 2 Pollination and dispersal of seeds 8 Formation, protection and decontamination of soils and sediments 18 Maintenance of options	14 Life below water 15 Life on land	
Cultural services	15 Learning and inspiration 16 Physical and psychological experiences 17 Supporting identities	4 Quality education 5 Gender equality 10 Reduce inequality 16 Peace, justice and strong institutions 17 Partnerships for the goals	**E**nabling conditions

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Box 18.5 (continued)

Climate Change Impacts on Ecosystems and their Services

Climate change connects to ecosystem services through two links: climate change and its influence on ecosystems as well as its influence on services (Section 2.2). The key climatic drivers are changes in temperature, precipitation and extreme events, which are unprecedented over millennia and highly variable by regions (Sections 2.3, 3.2; Cross-Chapter Box EXTREMES in Chapter 2). These climatic drivers influence physical and chemical conditions of the environment and worsen the impacts of non-climate anthropogenic drivers including eutrophication, hypoxia and sedimentation (Section 3.4). Such changes have led to changes in terrestrial, freshwater, oceanic and coastal ecosystems at all different levels, from species shifts and extinctions, to biome migration, and to ecosystem structure and processes changes (Sections 2.4, 2.5, 3.4, Cross-Chapter Box MOVING PLATE in Chapter 5). Changes in ecosystems leads to changes in ecosystem services including food and limber prevision, air and water quality regulation, biodiversity and habitat conservation, and cultural and mental support (Sections 2.4, 3.5). Table Box 18.5.2 presents examples of climate change's impact on ecosystems and their services from other chapters in the WGII report. The degradation of ecosystem services is felt disproportionately by people who are already vulnerable because of historical and systemic injustices, including women and children in low-income households, Indigenous or other minority groups, small-scale producers and fishing communities, and low-income countries (Sections 3.5, 4.3, 5.13).

Table Box 18.5.2 | Examples of key risks to ecosystems from climate change and their connections to ecosystem services (ES) in the WGII report and cross-chapter papers (CCPs). (See Table 1 for the description of the categories of ES)

Climate factors	Key risk	ES			
		P	R	S	C
Terrestrial and freshwater ecosystems **(Chapters 2, 4, 5; CCP 1; CCP 7; CCP 3; CCP 5)**					
– Increase in average and extreme temperatures – Changes in precipitation amount and timing – Increase in aridity – Increase in frequency and severity of drought – Increased atmospheric CO_2	Species extinction and range shifts	X		X	X
	Ecosystem structure and process change	X	X		
	Ecosystem carbon loss	X	X		
	Wildfire		X	X	
	Water cycle and scarcity	X	X		
Ocean and coastal **(Chapter 3; CCP 1; CCP 6)**					
– Ocean warming – Marine heatwaves – Ocean acidification – Loss of oxygen – Sea level rise – Increased atmospheric CO_2 – Extreme events	Species extinction and range shifts	X		X	X
	Ecosystem structure and process change	X	X		
	Habitat loss	X		X	
	Ocean carbon sink less effective		X		
	Erosion and land loss	X	X		
Food, fibre and other ecosystem products **(Chapter 5)**					
– Global warming – Water stress – Extreme events – Ocean acidification – Salt intrusion	Species distribution	X			
	Timing of key biological events change	X			
	Corp productivity and quality decrease	X			
	Diseases and insect	X			

Adaptation Practices and Enabling Conditions for CRD

Ecosystem protection and restoration, ecosystem-based adaptation (EBA), and nature-based solutions (NBS) can lower climate risk to people and achieve multiple benefits including food and material provision, climate mitigation and social benefits (Sections 2.6, 3.6, 4.6, 5.13, 6.3, 8.6). Table Box 18.5.3 presents some examples of ecosystem adaptation practices reported in WGII sectoral and regional chapters and CCPs, as well as their co-benefits, potential for maladaptation and enabling conditions. Many of the strategies focus on integrated systems (managing for multiple objectives and trade-offs) as well as the fair use of resources. However, there is *limited evidence* of the extent to which adaptation is taking place and virtually no evaluation of the effectiveness of adaptation in the scientific literature (Sections 2.6, 3.5). Enabling conditions for the successful implementation ecosystem-based practice include regional and community-based based approaches, multi-stakeholder and multi-level governance approaches, Integration of local knowledge and Indigenous knowledge, finance and social equity (Sections 2.6, 3.6).

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Box 18.5 (continued)

Table Box 18.5.3 | Examples of adaptation practices and their connections to ecosystem services (ES) and climate resilient development pathways (CRDP) in the WGII sectoral and regional chapters and cross-chapter papers (CCPs). (See Table 1 for the description of the categories of ES and CRDP)

Adaptation practices (and – *examples*)	Main benefit (and & co-benefit; – trade off; + enabling conditions; X barrier and potential maladaptation)	ES			
		P	R	S	C
Agroforestry (Table 2.7; Table 5 ES; Section 5.10.4; Section 5.12.5.2; Box 5.10; Table 16.2) – *Climate Adaptation and Maladaptation in Cocoa and Coffee Production* (Box 5.7)	Food provision & Fuel (wood) provision, carbon sequestration, biodiversity and ecosystem conservation, diversification and improved economic incomes, water and soil conservation, and aesthetics + Secure tenure arrangements, supporting Indigenous knowledge, inclusive networks and socio-cultural values, access to information and management skill X Higher water demand; disruption of hydrology; loss of native biodiversity; reduced resilience of certain plants; degraded soil and water quality; improper and increased use of agrochemicals, pesticides and fertilizers	***	**		**
Forest maintenance and restoration (Box 2.2; Table 16.2; Table Cross-Chapter Box NATURAL.1 in Chapter 2) – *Protected Area Planning in Thailand* (Section 2.6.5.3) – *Conserving Joshua trees in* the *Joshua National Park* (Section 2.6.5.6) – *Addressing Vulnerability of Peat Swamp Forests in Southeast Asia* (Section 2.6.5.10) – *Reduce Emissions from Deforestation and Forest Degradation (REDD+)* (Section 5.6.3.3; Table 16.2)	Ecosystem conservation & Food provision, fuel provision, job creation, carbon sequestration, biodiversity conservation, air quality regulation, water and soil conservation, vector-borne disease control, improved mental health, cultural benefits, natural resources relative conflict prevention + Cooperation of Indigenous peoples and other local communities X Planting large-scale non-native monocultures leads to loss of biodiversity and poor climate change resilience, increased vulnerability to landslide, increased sensitivity of new tree species, reduced resilience of certain plants, high water demand, trees planted damaged buildings during heavy storms, lack of carbon rights in national legislations	**	**	***	**
Traditional practices/Indigenous knowledge and local knowledge (IKLK) (Table 2.7; Section 5.6.3; Section 5.14.2.2; Table 16.2) – *Crop and Livestock Farmers on Observed Changes in Climate in the* Sahel (Box 5.6) – *Karuk Tribe in Northern California* (Section 5.6.3.2)	Food and material provision & Carbon sequestration + Partnerships between key stakeholders such as researchers, forest managers and local actors, Indigenous and local knowledge	***	**		
Restoring natural fire regimes (Table 2.7) – *Protecting Gondwanan wildfire refugia in Tasmania, Australia* (Section 2.6.5.8)	Fire regulation & Biodiversity conservation		***		
Natural flood risk management (Table 2.7) – *Natural Flood Management (NFM) in England, UK* (Section 2.6.5.2)	Water security, flood regulation, sediment retention & Biodiversity and ecosystem conservation		***	**	
Coastal ecosystem conservation (Table Cross-Chapter Box NATURAL.1 in Chapter 2) (Tables 16.2, 2.7) – *African Penguin On-Site Adaptation* (Section 2.6.5.5)	Coastal protection against sea level rise and storm surges & Fisheries, carbon sequestration, biodiversity and ecosystem conservation, flood regulation, water purification, recreation and cultural benefits X NH_4 emissions, digging channels and sand walls around homes, loss of recreational value of beaches, shifted the flood impacts to poor informal urban settlers, erosion and degraded coastal lands		**	***	**
Eco-tourism within protected areas (Table 2.7)	Tourism & Habitat protection	***		**	
Aquaculture (Section 5.9.4; Table 16.2; Table Cross-Chapter Box NATURAL.1 in Chapter 2)	Food provision & Biodiversity conservation + Farmer incentives, participatory adaptation to context X Lack of financial, technical or institutional capacity; short value chains; productivity varies by system; over-fertilising; deforestation of mangroves; salt intrusion; increased flood vulnerability	***		*	
Water–energy–food (WEF) nexus (Box 4.7) – *Food Water Energy Nexus in Asia* (Section 10.6.3) – *New Zealand's Land, Water and People Nexus under a Changing Climate* (Box 11.7)	Water, energy and food provision X Insufficient data, information, and knowledge in understanding the WEF inter-linkages; lack of systematic tools to address trade-offs involved in the nexus	***			

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Box 18.5 (continued)

Adaptation practices (and – *examples*)	Main benefit (and & co-benefit; – trade off; + enabling conditions; X barrier and potential maladaptation)	ES			
		P	R	S	C
Urban greening (Tables 2.7, 16.2; Table Cross-Chapter Box NATURAL.1 in Chapter 2) – *Ecosystem-Based Adaptation in Durban, South Africa* (Section 2.6.5.7)	Urban flood management, water savings, urban heat island mitigation & Reduced carbon emissions, air and noise regulation, improved mental health, energy savings, recreation and aesthetics + Meaningful partnerships, long-term financial commitments and significant political and administrative X Storage of large quantities of water in the home; water contamination; increased breeding sites for mosquitoes and flies; vectors and diseases; intensified cultivation of marginal lands; clearing of virgin forests for farmland; frequent weeding; increased competition for water and nutrients; reduced soil fertility, invasive species		***		**

The four systems transitions identified in SR1.5 already include a component of societal change—for example, attitude change is part of public acceptance that facilitates shifts in energy including changing electricity to renewables (Chapter 4 SR1.5, Section 4.3.1.1) and developing nuclear power (Section 4.3.1.3), and behavioural change is a part of shifting irrigation practices to drive required land and ecosystems transitions (Section 4.3.2.1). Extracting societal transitions also allows for a detailed examination of other societal dimensions that facilitate systems transitions, for example justice issues relating to water and energy access and distribution, and land use. Societal transition, sometimes known as 'societal transformation', is an established concept in different literatures, as described below. Transformation and transition are terms often used as synonyms (Hölscher et al., 2018), although different schools of thought understand them as sub-components of each other, for example transition driving transformation, or transformation driving transition. For a more detailed discussion on the differences between transition and transformation represented in the literature, see Box 18.1.

Societal transitions for the purpose of this report are understood as the collection of shifts in attitudes, values, consciousness and behaviour required to move towards CRD. This builds on the SR1.5 (IPCC, 2018a: 599) definition of societal (social) transformation: 'A profound and often deliberate shift initiated by communities towards sustainability, facilitated by changes in individual and collective values and behaviours, and a fairer balance of political, cultural, and institutional power in society'. This includes accepting Indigenous knowledge and local knowledge (IKLK) as an equally valid form of knowledge as compared with Western, scientific knowledge (see Cross-Chapter Box INDIG) and recognition of the role of shifting gender norms to achieve climate resilience (see Cross-Chapter Box GENDER). Changes associated with societal transitions are not specific to defined systems (e.g., energy, industry, land/ecosystems or urban/infrastructure). Rather, these sectoral systems are embedded within broader societal systems, including for example political systems, economic systems, knowledge systems and cultural systems (Davelaar, 2021; Turnhout et al., 2021; Visseren-Hamakers et al., 2021). Changes that happen in these broader social systems can therefore prompt changes in all systems embedded within them, meaning that societal transition is key to transforming across a range of sectors and topics (Leventon et al., 2021). Furthermore, societal transition requires changes in individual behaviours, but also in the broader conditions that shape these behaviours. These broader conditions are largely related to questions of power, in enforcing dominant political economies and social-technological mindsets (Stoddard et al., 2021). This section also briefly describes the various trains of research on societal transitions and transformation.

Because of the multiple sectors, interests and scales that are involved in societal transitions, understanding and creating evidence on transitions requires shifting across system boundaries and finding ways to transcend disciplinary silos. Relevant research includes work within the topic of transformation and transitions (Hölscher et al., 2018). Transformations literature can be split into multiple sub-concepts and requires engagement with multiple schools of thought (Feola, 2015; Feola et al., 2021). Much focus within transformations research is currently related to biodiversity conservation (Massarella et al., 2021), and transitions work tends towards a focus in urban areas (Loorbach et al., 2017). Though there is also work in both that is more broadly labelled as sustainability transformations or transitions (Luederitz et al., 2017). Furthermore, there is likely to be much relevant literature that does not explicitly label itself as transformations or transitions (Feola et al., 2021). For example, we could look to political science theories on policy change (Leventon et al., 2021) and historical perspectives on social change. Bridging these divides will require a deeper rethinking in the research community to undo power structures that marginalise diverse knowledge (Caniglia et al., 2021; Lahsen and Turnhout, 2021).

There are a number of concepts proposed as pathways to creating societal transitions; usually centred around the idea of working with individuals and communities to change their mindsets as a way to change the way they manage their local environments or behave. Transformations work explores how values are pathways towards sustainability, for example by changing values, through making values explicit, through negotiation and by eliciting values (Horcea-Milcu et al., 2019). Human nature connections is a further concept that is identified as a way to shift values and behaviours across a range of disciplines (Ives et al., 2017). The role of learning and Indigenous knowledge is also explored (Lam et al., 2020). These three concepts have had particular salience in discussions around transformations for biodiversity conservation and restoration, related to the IPBES assessment on Values (Pascual et al.,

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

2017; Peterson et al., 2018). They largely focus on the need to engage with people's values, connections and knowledge to better manage the social–ecological system they are in.

Focusing on bottom-up and community-led transformations, there is emphasis on the role of grassroots organisations in transformations. Community actions around specific locations or topics have parallels to the idea of transformative spaces. They are sites of innovative activity (Seyfang and Smith, 2007). Grassroots organisations can bridge the local and the political scales by politicising actors and creating new interactions between individuals and political processes (Novák, 2021). They are a collective approach to pushing for both individual and societal change (Sage et al., 2021).

Despite a current lack of empirical evidence, there are numerous frameworks emerging for exploring societal transitions across levels. There is focus on pathways for sustainability transitions, which tends to look at projected, normative scenarios for the future, and explore or back-cast the institutional and societal changes that are required to get there (Westley et al., 2011; Sharpe et al., 2016). There is also work that looks at scaling up of smaller sustainability initiatives, through processes of scaling up, scaling out and scaling deep (Moore et al., 2015; Lam et al., 2020). In particular, systems thinking provides an organising framework for bringing together multiple disciplines and perspectives, to understand problem framings, and normative and design aspects of social systems and behaviours (Foster-Fishman et al., 2007). Within this, Meadows (1999) framework of leverage points for systems transformation has been operationalised within the sustainability transformations debate (Abson et al., 2017). Here, system properties relating to system paradigms and design are leverage points where interventions can create greatest system change; shallower leverage points relate to materials and processes. This framework is increasingly being used across a range of sustainability problems as boundary objects for cross-disciplinary, critical research (Fischer and Riechers, 2019; Leventon et al., 2021; Riechers et al., 2021).

Analyses of societal transitions have had limited engagement with adaptation questions. The focus of the sub-field of sustainability transitions on a few industrialised nations, mostly in North America and Europe, limited the field's development to assumptions born from the experiences in those areas. More recent studies have sought to understand sustainability transitions in other countries, especially emerging economies (Wieczorek, 2018; Köhler et al., 2019). In particular, China has received attention from scholars on sustainability transitions (Huang et al., 2018; Lo and Castán Broto, 2019; Castán Broto et al., 2020; Huang and Sun, 2020). As a result, some pressing issues related to societal transitions for adaptation have received limited attention compared with that paid to other system transitions. However, more recently, scholarship has begun examining transitions that have turned to nature and nature-based solutions. Adaptive transitions are an intermediary step towards sustainability transitions, whereby multiple actions at material and institutional levels are combined towards improving adaptation outcomes (Pant et al., 2015; Scarano, 2017).

18.3.2 Accelerating Transitions

Successfully implementing climate actions and managing trade-offs between mitigation, adaptation and sustainable development (Section 18.2.4) has important time considerations that imply significant urgency, making substantive progress in system transitions critical for CRD. Both the SDGs and the Sendai Framework, for example, have target dates of 2030. Meanwhile, the Paris Agreement sets specific time horizons for NDCs and the SR1.5 indicated that limiting warming to 1.5°C would similarly require substantial climate action by 2030 (IPCC, 2018a). While the literature is unambiguous regarding the need for significant system transitions to achieve CRD (Section 18.1.3), the current pace of global emissions reductions, poverty alleviation and development of equitable systems of governance is incommensurate with these policy time tables (Rogelj et al., 2010; Burke et al., 2016; Oleribe and Taylor-Robinson, 2016; Kriegler et al., 2018; Frank et al., 2019; Sadoff et al., 2020). As noted previously in the AR5, '*delaying action in the present may reduce options for climate-resilient pathways in the future*' (Denton et al., 2014: 1123). Accordingly, significant acceleration in the pace of system transitions is necessary to enable the implementation of mitigation, adaptation and sustainable development initiatives consistent with CRD (*very high confidence*).

Studies since the AR5 directly address the issue of how to accelerate transitions within the broader system transitions, sustainability transitions and socio-technical transitions literature (Frantzeskaki et al., 2017; Gliedt et al., 2018; Gorissen et al., 2018; Johnstone and Newell, 2018; Kuokkanen et al., 2019; Markard et al., 2020). Such literature explores several core themes to facilitate acceleration, which are aligned with the discussion later in this chapter on arenas of engagement for CRD (Section 18.4.3). One dominant theme is accelerating the implementation of sustainability or low-carbon policies that target specific sectors or industries (Bhamidipati et al., 2019). For example, Altenburg and Rodrik (Altenburg and Rodrik, 2017) discuss green industrial polices including taxes, mandated technology phase outs and the removal of subsidies as means of constraining polluting industries. Kivimaa et al. (Kivimaa and Martiskainen, 2018; Kivimaa et al., 2019a; Kivimaa et al., 2019b; Kivimaa et al., 2020) and Vihemäki et al. (2020) discuss low-carbon transitions in buildings, noting the important role that intermediaries play in facilitating policy reform. Nikulina et al. (2019) identify mechanisms for facilitating policy change in personal mobility including political leadership, combining carrots and sticks to incentivise behavioural change and challenging current policy frameworks. These various examples reflect a fragmented approach to system transitions, suggesting a large portfolio of such transition initiatives would be required to accelerate change or more fundamental and cross-cutting policy drivers are needed (*high agreement*, *limited evidence*). Policies that seek to promote social justice and equity, for example, could ultimately catalyse a broader range of sustainability and climate actions than policies designed to address a specific sector or class of technology (Delina and Sovacool, 2018; White, 2020).

In contrast with formal government policies, a second theme in accelerating transitions is that of civic engagement (see also Section 18.4.3), which is reported to be an important opportunity for

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Table 18.3 | Specific options for facilitating the five system transitions that can support CRD

Transition	Examples	Reference
Energy systems	Fuel switching from coal to natural gas Expansion of renewable energy technologies Financial incentives to promote renewable energy Reduced energy intensity of industry Improvements in power system resilience and reliability Increased water use efficiency in electricity generation Energy demand management strategies	(Gielen et al., 2019); (Mulugetta et al., 2019); (IEA et al., 2019); AR6 WGIII Chapter 2
Urban and infrastructure systems	Increased investment in physical and social infrastructure Enhance urban and regional planning Enhanced governance and institutional capacity supports post-disaster recovery and reconstruction (Kull, 2016)	(IPCC, 2018b): D3.1)
Land, oceans and ecosystems	Expanding access to agricultural and climate services Strengthening land tenure security and access to land Empowering women farmers Improved access to markets Facilitating payments for ecosystem services Promotion of healthy and sustainable diets Enhancing multi-level governance by supporting local management of natural resources Strengthening cooperation between institutions and actors Building on local, indigenous and scientific knowledge funding, and institutional support Monitoring and forecasting Education and climate literacy and social learning and participation	(IPCC, 2019 f): C2.1; (IPCC, 2019 f): C4.5; (IPCC, 2019 f): C4
Industrial systems	Promote material efficiency and high-quality circularity Materials demand management (IEA 2019, 2020) Application of new processes and technologies for GHG emission reduction Carbon pricing or regulations with provisions on competitiveness to drive innovation and systemic carbon efficiency Low-cost, long-term financing mechanisms to enable investment and reduce risk Better planning of transport infrastructure Labour market training and transition support Electricity market reform Regulations—standards and labelling, material efficiency Mandating technologies and targets Green taxes and carbon pricing, preferential loans and subsidies Voluntary action agreements, expanded producer responsibilities Information programmes: monitoring, evaluation, partnerships, and research and development Government provisioning of services—government procurements, technology push and market-pull	(Åhman et al., 2017; Bataille et al., 2018; Material, 2019); (Tanaka, 2011; Schwarz et al., 2020); (Ciwmb, 2003); (Romero Mosquera, 2019); (Tanaka, 2011); (Ryan et al., 2011; Boyce, 2018); (Taylor, 2008); (UNEP, 2018b); (Kaza et al., 2018); (Söderholm and Tilton, 2012); (Bataille et al., 2018); (Ghisetti et al., 2017); (Taylor, 2008; Fischedick et al., 2014; Hansen and Lema, 2019); (Crippa et al., 2019; IEA, 2019); (Cavaliere, 2019; IEA, 2020); Vogl et al. (2018); (Pauliuk et al., 2013; Quader et al., 2016)
Societal systems	Inclusive governance Empowerment of excluded stakeholders, especially women and youth Transforming economies Finance and technology aligned with local needs Overcoming uneven consumption and production patterns Allowing people to live a life in dignity and enhancing their capabilities Involving local governments, enterprises and civil society organisations across different scales Reconceptualising development around well-being rather than economic growth (Gupta and Pouw, 2017), Rethinking, prevailing values, ethics and behaviour Improving decision making processes that incorporate diverse values and world views Creating space for negotiating diverse interests and preferences	(Fazey et al., 2018b; O'Brien, 2018; Patterson et al., 2018); (MRFCJ, 2015; Dumont et al., 2019); (Popescu et al., 2017; David Tàbara et al., 2018); (de Coninck and Sagar, 2015; IEA, 2015; Parikh et al., 2018); (Dearing et al., 2014; Häyhä et al., 2016; Raworth, 2017); (Klinsky and Winkler, 2018); (Hajer et al., 2015; Labriet et al., 2015; Hale, 2016; Pelling et al., 2016; Kalafatis, 2017; Lyon, 2018); (Holden et al., 2017); (Cundill et al., 2014; Butler et al., 2016; Ensor, 2016; Fazey et al., 2016; Gorddard et al., 2016; Aipira et al., 2017; Chung Tiam Fook, 2017; Maor et al., 2017); (O'Brien and Selboe, 2015; Gillard et al., 2016; DeCaro et al., 2017; Harris et al., 2018; Lahn, 2018; Roy et al., 2018); Sections 5.6.1 and 5.5.3.1

driving transitions forward (*high agreement*, *medium evidence*). Ehnert et al. (2018) describe local organisations and civic engagement in policy processes as an important engine for sustainability activities in European states. Similarly, Ruggiero et al. (2021) note the potential to use civic organisations to appeal to local identities in order to mobilise citizens to pursue energy transition initiatives among communities in the Baltic Sea region. Gernert et al. (2018) attribute such influence to the ability of grassroots movements to bypass traditional social and political norms and thereby experiment with new behaviours and processes. Moreover, civic engagement is also the foundation for collective action including protest and civil disobedience (Welch and Yates, 2018, Section 18.5.3.7). However, Haukkala (2018) observes that while green-transition coalitions in Finland could be an agent of change driving energy transitions, the diversity of views among the various grassroots actors could make consensus building difficult, thereby slowing transition initiatives.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box GENDER | Gender, Climate Justice and Transformative Pathways

Authors: Anjal Prakash (India), Cecilia Conde (Mexico), Ayansina Ayanlade (Nigeria), Rachel Bezner Kerr (Canada/USA), Emily Boyd (Sweden), Martina A Caretta (Sweden), Susan Clayton (USA), Marta G. Rivera Ferre (Spain), Laura Ramajo Gallardo (Chile), Sharina Abdul Halim (Malaysia), Nina Lansbury (Australia), Oksana Lipka (Russia), Ruth Morgan (Australia), Joyashree Roy (India), Diana Reckien (the Netherlands/Germany), E. Lisa F. Schipper (Sweden/UK), Chandni Singh (India), Maria Cristina Tirado von der Pahlen (Spain/USA), Edmond Totin (Benin), Kripa Vasant (India), Morgan Wairiu (Solomon Islands), Zelina Zaiton Ibrahim (Malaysia).

Contributing Authors: Seema Arora-Jonsson (Sweden/India), Emily Baker (USA), Graeme Dean (Ireland), Emily Hillenbrand (USA), Alison Irvine (Canada), Farjana Islam (Bangladesh/ UK), Katriona McGlade (UK/Germany), Hanson Nyantakyi-Frimpong (Ghana), Nitya Rao (UK/India), Federica Ravera (Italy), Emilia Reyes (Mexico), Diana Hinge Salili (Fiji), Corinne Schuster-Wallace (Canada), Alcade C. Segnon (Benin), Divya Solomon (India), Shreya Some (India), Indrakshi Tandon (India), Sumit Vij (India), Katharine Vincent (UK/South Africa), Margreet Zwarteveen (the Netherlands)

Key Messages

- Gender and other social inequities (e.g., racial, ethnic, age, income, geographic location) compound vulnerability to climate change impacts (*high confidence*). Climate justice initiatives explicitly address these multi-dimensional inequalities as part of a climate change adaptation strategy (Box 9.2: Vulnerability Synthesis: Differential Vulnerability by Gender and Age in Chapter 9).
- Addressing inequities in access to resources, assets and services, as well as participation in decision making and leadership is essential to achieving gender and climate justice (*high confidence*).
- Intentional long-term policy and programme measures and investments to support shifts in social rules, norms and behaviours are essential to address structural inequalities and support an enabling environment for marginalised groups to effectively adapt to climate change (*very high confidence*) (Equity and Justice box in Chapter 17).
- Climate adaptation actions are grounded in local realities so understanding links with Sustainable Development Goal (SDG) 5 is important to ensure that adaptive actions do not worsen existing gender and other inequities within society (e.g., leading to maladaptation practices) (*high confidence*). [Section 17.5.1]
- Adaptation actions do not automatically have positive outcomes for gender equality. Understanding the positive and negative links of adaptation actions with gender equality goals, (i.e., SDG 5), is important to ensure that adaptive actions do not exacerbate existing gender-based and other social inequalities [Section 16.1.4.4]. Efforts are needed to change unequal power dynamics and to foster inclusive decision making for climate adaptation to have a positive impact for gender equality (*high confidence*).
- There are very few examples of successful integration of gender and other social inequities in climate policies to address climate change vulnerabilities and questions of social justice (*very high confidence*).

Gender, Climate Justice and Climate Change

This Cross-Chapter Box highlights the intersecting issues of gender, climate change adaptation, climate justice and transformative pathways. A gender perspective does not centre only on women or men but examines structures, processes and relationships of power between and among groups of men and women and how gender, particularly in its non-binary form, intersects with other social categories such as race, class, socioeconomic status, nationality or education to create multi-dimensional inequalities (Hopkins, 2019). A gender transformative approach aims to change structural inequalities. Attention to gender in climate change adaptation is thus central to questions of climate justice that aim for a radically different future (Bhavnani et al., 2019). As a normative concept highlighting the unequal distribution of climate change impacts and opportunities for adaptation and mitigation, climate justice (Wood, 2017; Jafry et al., 2018; Chu and Michael, 2019; Shi, 2020a) calls for transformative pathways for human and ecological well-being. These address the concentration of wealth, unsustainable extraction and distribution of resources (Schipper et al., 2020a; Vander Stichele, 2020) as well as the importance of equitable participation in environmental decision making for climate justice (Arora-Jonsson, 2019).

Research on gender and climate change demonstrates that an understanding of gendered relations is central to addressing the issue of climate change. This is because gender relations mediate experiences with climate change, whether in relation to water (Köhler et al., 2019) (see also Sections 4.7, 4.3.3, 4.6.4, 5.3), forests (Arora-Jonsson, 2019), agriculture (Carr and Thompson, 2014; Balehey et al., 2018; Garcia et al., 2020) (see also Chapter 4, Section 5.4), marine systems (Mcleod et al., 2018; Garcia et al., 2020) (see also Section 5.9) or urban environments (Reckien et al., 2018; Susan Solomon et al., 2021) (see also Chapter 6). Climate change has direct negative impacts on women's livelihoods due to their unequal control over and access to resources (e.g., land, credit) and because they are often the ones with the least formal protection (Eastin, 2018) (see also Box 9.2 in Chapter 9). Women represent 43% of the agricultural labour force globally, but only 15% of agricultural landholders (OECD, 2019b). Gendered and other social inequities also exist with non-land assets and financial services (OECD, 2019b) often due to social norms, local institutions and inadequate social protection (Collins et al., 2019b). Men may experience different adverse impacts due to gender roles and expectations (Bryant and Garnham, 2015; Gonda, 2017). These impacts can lead to irreversible losses and damages from climate change across vulnerability hotspots (Section 8.3).

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box GENDER (continued)

Participation in environmental decision making tends to favour certain social groups of men, whether in local environmental committees, international climate negotiations (Gay-Antaki and Liverman, 2018) or the IPCC (Nhamo and Nhamo, 2018). Addressing climate justice reinforces the importance of considering the legacy of colonialism on developing regional and local adaptation strategies. Scholars have criticised climate programmes for setting aside forestland that poor people rely on and appropriating the labour of women in the Global South without compensatory social policy or rights; where women are expected to work with non-timber forest products to compensate for the lack of logging and for global climate goals, but where their work of social reproduction and care is paid little attention (Westholm and Arora-Jonsson, 2015; Arora-Jonsson et al., 2016). A global ecologically unequal exchange, biopiracy, damage from toxic exports or the disproportionate use of carbon sinks and reservoirs by high-income countries enhance the negative impacts of climate change. Women in Least Developed Countries (LDCs) and Small Island Developing States (SIDS) also endure the harshest impacts of the debt crisis due to imposed debt measures in their countries (Appiah and Gbeddy, 2018; Fresnillo Sallan, 2020). The austerity measures derived as conditionalities for fiscal consolidation in public services increases gender-based violence (Castañeda Carney et al., 2020) and brings additional burdens for women in the form of increasing unpaid care and domestic work (Bohoslavsky, 2019).

Gendered Vulnerability

Land, ecosystem and urban transitions to climate resilient development need to address gender and other social inequities to meet sustainability and equity goals, otherwise, marginalised groups may continue to be excluded from climate change adaptation. In the water sector, increasing floods and droughts and diminishing groundwater and runoff have gendered effects on both production systems and domestic use (Sections 4.3.1, 4.3.3, 4.5.3). Climate change is reducing the quantity and quality of safe water available in many regions of the world and increasing domestic water management responsibilities (*high confidence*). In regions with poor drinking water infrastructure, it is forcing, primarily women and girls, to walk long distances to access water, and limiting time available for other activities, including education and income generation (Eakin et al., 2014; Kookana et al., 2016; Yadav and Lal, 2018). Water insecurity and the lack of water, sanitation and hygiene (WASH) infrastructure have resulted in psychosocial distress and gender-based violence, as well as poor maternal and child health and nutrition (Collins et al., 2019a; Wilson et al., 2019; Geere and Hunter, 2020; Islam et al., 2020; Mainali et al., 2020) (Sections 4.3.3 and 4.6.4.4) (*high confidence*). Climate-related extreme events also affect women's health—by increasing the risk of maternal and infant mortality, disrupting access to family planning and prevention of mother to child transmission regimens for human immunodeficiency virus (HIV) positive pregnant women (UNDRR, 2019) (see also Section 7.2). Women and the elderly are also disproportionately affected by heat events (Sections 7.1.7.2.1, 7.1.7.2.3, 13.7.1).

Extreme events impact food prices and reduce food availability and quality, especially affecting vulnerable groups, including low-income urban consumers, wage labourers and low-income rural households who are net food buyers (Green et al., 2013; Fao, 2016) (Section 5.12). Low-income women, ethnic minorities and Indigenous communities are often more vulnerable to food insecurity and malnutrition from climate change impacts, as poverty, discrimination and marginalisation intersect in their cases (Vinyeta et al., 2016; Clay et al., 2018) (Section 5.12). Increased domestic responsibilities of women and youth, due to migration of men, can increase their vulnerability due to their reduced capacity for investment in off-farm activities and reduced access to information (Sugden et al., 2014; O'Neil et al., 2017) (Sections 4.3, 4.6) (*high confidence*).

In the forest sector, the increased frequency and severity of drought, fires, pests and diseases, and changes to growing seasons, has led to reduced harvest revenues, fluctuations in timber supply and availability of wood (Lamsal et al., 2017; Fadrique et al., 2018; Esquivel-Muelbert et al., 2019). Climate programmes in the Global South such as REDD+ have led to greater social insecurity and the conservation of the forests have led to more pressure on women to contribute to household incomes, but without enough supporting market access mechanisms or social policy (Westholm and Arora-Jonsson, 2015; Arora-Jonsson et al., 2016). In countries in the Global North, reduced harvestable wood and revenues have led to employment restructuring that has important gendered effects and negatively affects community transition opportunities (Reed et al., 2014).

Integrating Gender in Climate Policy and Practice

Climate change policies and programmes across regions reveal wide variation in the degree and approach to addressing gender inequities (see Table SMCCB GENDER.2). In most regions where there are climate change policies that consider gender, they inadequately address structural inequalities resulting from climate change impacts, or how gender and other social inequalities can compound risk (*high confidence*). Experiences show that it is more frequent to address specific gender inequality gaps in access to resources. Regionally, Central and South American countries (Section 12.5.8) have a range of gender-sensitive or gender-specific policies such as the intersectoral coordination initiative Gender and Climate Change Action Plans (PAGcc), adopted in Perú, Cuba, Costa Rica and Panamá (Casas Varez, 2017), or the Gender Environmental policy in Guatemala that has a focus on climate change (Bárcena-Martín et al., 2021). However, countries often have limited commitment and capacity to evaluate the impact of such policies (Tramutola, 2019). In North and South America, policies have failed to address how climate change vulnerability is compounded by the intersection of race, ethnicity and gender (Radcliffe, 2014; Vinyeta et al.,

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box GENDER (continued)

2016) (see also Section 14.6.3). Gender is rarely discussed in African national policies or programmes beyond the initial consultation stage (Holvoet and Inberg, 2014; Mersha and van Laerhoven, 2019), although there are gender and climate change action strategies in countries such as Liberia, Mozambique, Tanzania and Zambia (Mozambique and IUCN, 2014; Zambia and IUCN, 2017). European climate change adaptation strategies and policies are weak on gender and other social equity issues (Allwood, 2014; Boeckmann and Zeeb, 2014; Allwood, 2020), while in Australasia, there is a lack of gender-responsive climate change policies. In Asia, there are several countries that recognise gendered vulnerability to climate change (Jafry, 2016; Singh et al., 2021b), but policies tend to be gender-specific, with a focus on targeting women, for example in the national action plan on climate change as in India (Roy et al., 2018) or in national climate change plan as in Malaysia (Susskind et al., 2020).

Potential for Change and Solutions

The sexual division of labour, systemic racism and other social structural inequities lead to increased vulnerabilities and climate change impacts for social groups such as women, youth, Indigenous peoples and ethnic minorities. Their marginal positions not only affect their lives negatively but their work in maintaining healthy environments is ignored and invisible in policy affecting their ability to work towards sustainable adaptation and aspirations in the SDGs (Arora-Jonsson, 2019). However, attention to the following has the potential to bring about change:

Creation of new, deliberative policymaking spaces that support inclusive decision making processes and opportunities to (re)negotiate pervasive gender and other social inequalities in the context of climate change for transformation (Tschakert et al., 2016; Harris et al., 2018; Ziervogel, 2019; Garcia et al., 2020) (*high confidence*).

Increased access to reproductive health and family planning services, which contributes to climate change resilience and socioeconomic development through improved health and well-being of women and their children, including increased access to education, gender equity and economic status (Onarheim et al., 2016; Starbird et al., 2016; Lopez-Carr, 2017; Hardee et al., 2018) (Section 7.4) (*high confidence*).

Engagement with women's collectives is important for sustainable environments and better climate decision making whether at the global, national or local levels (Westholm and Arora-Jonsson, 2018; Agarwal, 2020). The work of such collectives in maintaining their societies and environments and in resisting gendered and community violence is unacknowledged (Jenkins, 2017; Arora-Jonsson, 2019) but is indispensable especially when combined with good leadership, community acceptance and long-term economic sustainability (Chu, 2018; Singh, 2019) (Section 4.6.4). Networking by gender experts in environmental organisations and bureaucracies has also been important for ensuring questions of social justice (Arora-Jonsson and Sijapati, 2018).

Investment in appropriate reliable water supplies, storage techniques and climate-proofed WASH infrastructure as key adaptation strategies that reduce both burdens and impacts on women and girls (Alam et al., 2011; Woroniecki, 2019) (Sections 4.3.3, 4.6.44).

Improved gender-sensitive early warning system design and vulnerability assessments to reduce vulnerabilities, prioritising effective adaptation pathways to women and marginalised groups (Mustafa et al., 2019; Tanner et al., 2019; Werners et al., 2021).

Established effective social protection, including both cash and food transfers, such as the universal public distribution system (PDS) for cereals in India, or pensions and social grants in Namibia, that have been demonstrated to contribute towards relieving immediate pressures on survival and support processes at the community level, including climate effects (Kattumuri et al., 2017; Lindoso et al., 2018; Rao et al., 2019a; Carr, 2020).

Strengthened adaptive capacity and resilience through integrated approaches to adaptation that include social protection measures, disaster risk management and ecosystem-based climate change adaptation (*high confidence*), particularly when undertaken within a gender-transformative framework (Gumucio et al., 2018; Bezner Kerr et al., 2019; Deaconu et al., 2019) (Cross-Chapter Box NATURAL in Chapter 2, Sections 5.12, 5.14).

For example, gender-transformative and nutrition-sensitive agroecological approaches strengthen adaptive capacities and enable more resilient food systems by increasing leadership for women and their participation in decision making and a gender-equitable domestic work (*high confidence*) (Gumucio et al., 2018; Bezner Kerr et al., 2019; Deaconu et al., 2019) (Cross-Chapter Box NATURAL in Chapter 2, Sections 5.12, 5.14)

New initiatives, such as the Sahel Adaptive Social Protection Program, represent an integrated approach to resilience that promotes coordination among social protection, disaster risk management and climate change adaptation. Accompanying measures include health, education, nutrition and family planning, among others (Daron et al., 2021).

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

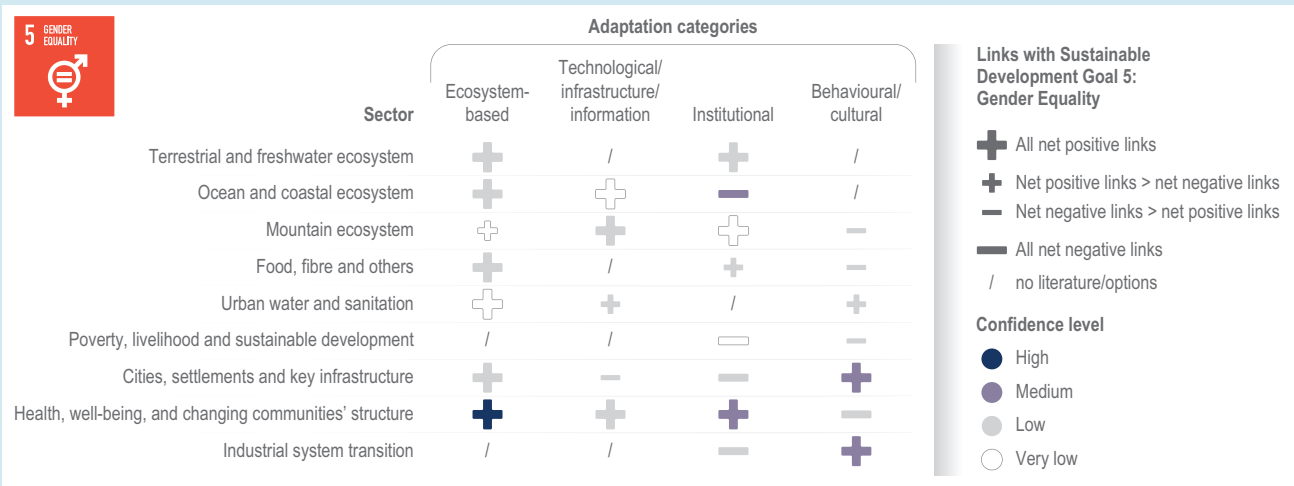
Cross-Chapter Box GENDER (continued)

Climate Change Adaptation and SDG 5

Adaptation actions may reinforce social inequities, including gender, unless explicit efforts are made to change (Nagoda and Nightingale, 2017; Garcia et al., 2020) (*robust evidence*, *high agreement*). Participation in climate action increases if it is inclusive and fair (Huntjens and Zhang, 2016). Roy et al. (2018) assessed links among various SDGs and mitigation options. Adaptation actions are grounded in local realities, especially in terms of their impacts, so understanding links with the goals of SDG 5 becomes more important to make sure that adaptive actions do not worsen prevalent gender and other social inequities within society (*robust evidence*, *high agreement)*. In the IPCC 1.5°C Special Report, Roy et al. (2018) assessed links between various SDGs and mitigation options, adaptation options were not considered. The current SDG 13 climate action targets do not specifically mention gender as a component for action, which makes it even more imperative to link SDG 5 targets and other gender-related targets to adaptive actions under SDG 13 to ensure that adaptation projects are synergistic rather than maladaptive (Section 16.3.2.6, Table 16.6) (Susan Solomon et al., 2021; Roy et al., Submitted).

This assessment is based on a systematic rapid review of scientific publications (McCartney et al., 2017; Liem et al., 2020) published on adaptation actions in nine sectors from 2014 to 2020 (see Table SMCCB GENDER.1) (Roy et al., Submitted)(Roy et al., Submitted)(Roy et al., Submitted)and how they integrated gender perspectives impacting gender equity. The assessment is based on over 17,000 titles and abstracts that were initially found through keyword search and were reviewed. Finally, 319 relevant papers on case studies, regional assessments and meta-reviews were assessed. Gender impact was classified by various targets under SDG 5. Following the approach taken in Roy et al. (2018) and (Hoegh-Guldberg et al., 2019), the linkages were classified into synergies (positive impacts or co-benefits) and trade-offs (negative impacts) based on the evidence obtained from the literature review which is finally used to develop net impact (positive or negative) scores (see Table Cross-Chapter Box GENDER.1 and Supplementary Material).

Table Cross-Chapter Box GENDER.1 | Inter-relations between SDG5 (gender equality) and adaptation initiatives in nine major sectors



Potential net synergies and trade-offs between a sectoral portfolio of adaptation actions and SDG 5 are shown. Colour codes showing the relative strength of net positive and net negative impacts and confidence levels. The strength of net positive and net negative connections across all adaptation actions within a sector are aggregated to show sector-specific links. The links are only one-sided on how adaptation action is linked to gender equality (SDG 5) targets and not vice versa. 22 adaptation options were assessed in ecosystem-based actions, 10 options in technological/infrastructure/information, 17 in institutional and 13 in behavioural/cultural. The assessment presented here is based on literature presenting impacts on gender equality and equity of various adaptation actions implemented in various local contexts and in regional climate change policies (Table SMCCB GENDER.2).

Adaptation actions being implemented in each sector in different local contexts can have positive (synergies) or negative (trade-offs) effects with SDG 5. This can potentially lead to net positive or net negative connections at an aggregate level. How they are finally realised depends on how they are implemented, managed and combined with various other interventions, in particular, place-based circumstances. Ecosystem-based adaptation actions and terrestrial and freshwater ecosystems have higher potential for net positive connections (Roy et al., 2018) (Table Cross-Chapter Box GENDER.1 and Supplementary Material). Adaptation in terrestrial and freshwater ecosystems has the strongest net positive links with all SDG 5 targets (*medium evidence*, *low agreement*). For example, community-based natural resource management increases the participation of women, especially when they are organised into women's groups (Pineda-López

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box GENDER (continued)

et al., 2015; de la Torre-Castro et al., 2017) (Supplementary Material). For poverty, livelihood and sustainable development sectors, adaptation actions have generated more net negative scores (*limited evidence*, *low agreement*) (Table Cross-Chapter Box GENDER.1). For example, patriarchal institutions and structural discriminations curtail access to services or economic resources as compared with men, including less control over income, fewer productive assets and lack of property rights, as well as less access to credit, irrigation, climate information and seeds which devaluate women's farm-related adaptation options (Adzawla et al., 2019; Friedman et al., 2019; Ullah et al., 2019) (Supplementary Material).

Among the adaptation actions, ecosystem-based actions have the strongest net positive links with SDG 5 targets (Table Cross-Chapter Box GENDER.1, Table SMCCB GENDER.1). In the health, well-being and changing communities' sector, this is with *robust evidence* and *medium agreement*, while in all other sectors there is *medium evidence* and *low agreement*. Net negative links are most prominent in institutional adaptation actions (Table Cross-Chapter Box GENDER.1). For example, in mountain ecosystems, changes in gender roles in response to climatic and socioeconomic stressors is not supported by institutional practices, mechanisms and policies that remain patriarchal (Goodrich et al., 2019). Additionally, women often have less access to credit for climate change adaptation practices, including post-disaster relief, for example, to deal with salinisation of water or flooding impacts (Hossain and Zaman 2018). Lack of coordination among different city authorities can also limit women's contribution in informal settlements towards adaptation. Women are typically under-represented in decision making on home construction and planning and home-design decisions in informal settlements, but examples from Bangladesh show they play a significant role in adopting climate-resilient measures (e.g., the use of corrugated metal roofs and partitions which is important in protection from heat) (Jabeen, 2014; Jabeen and Guy, 2015; Araos et al., 2017; Susan Solomon et al., 2021).

Towards Climate-Resilient, Gender-Responsive Transformative Pathways

The climate change adaptation and gender literature call for research and adaptation interventions that are 'gender-sensitive' (Jost et al., 2016; Thompson-Hall et al., 2016; Kristjanson et al., 2017; Pearce et al., 2018a) and 'gender-responsive', as established in Article 7 of the Paris Agreement (UNFCCC, 2015). In addition, attention is drawn to the importance of 'mainstreaming' gender in climate/development policy (Alston, 2014; Rochette, 2016; Mcleod et al., 2018; Westholm and Arora-Jonsson, 2018). Many calls have been made to consider gender in policy and practice (Ford et al., 2015; Jost et al., 2016; Rochette, 2016; Thompson-Hall et al., 2016; Kristjanson et al., 2017; Mcleod et al., 2018; Lau et al., 2021; Singh et al., 2021b). Rather than merely emphasising the inclusion of women in patriarchal systems, transforming systems that perpetuate inequality can help to address broader structural inequalities not only in relation to gender, but also other dimensions such as race and ethnicity (Djoudi et al., 2016; Pearse, 2017; Gay-Antaki, 2020). Adaptation researchers and practitioners play a critical role here and can enable gender-transformative processes by creating new, deliberative spaces that foster inclusive decision making and opportunities for renegotiating inequitable power relations (Tschakert et al., 2016; Ziervogel, 2019; Garcia et al., 2020).

To date, empirical evidence on such transformational change is sparse, although there is some evidence of incremental change (e.g., increasing women's participation in specific adaptation projects, mainstreaming gender in national climate policies). Even when national policies attempt to be more gendered, there is criticism that they use gender-neutral language or include gender analysis without proposing how to alter differential vulnerability (Mersha and van Laerhoven, 2019; Singh et al., 2021b). More importantly, the mere inclusion of women and men in planning does not necessarily translate to substantial gender-transformative action, for example in National Adaptation Programmes of Action across sub-Saharan Africa (Holvoet and Inberg, 2014; Nyasimi et al., 2018) and national and sub-national climate action plans in India (Singh et al., 2021b). Importantly, there is often an overemphasis on the gender binary (and household headship as an entry point), which masks complex ways in which marginalisation and oppression can be augmented due to the interaction of gender with other social factors and intra-household dynamics (Djoudi et al., 2016; Thompson-Hall et al., 2016; Rao et al., 2019a; Lau et al., 2021; Singh et al., 2021b).

Climate justice and gender transformative adaptation can provide multiple beneficial impacts that align with sustainable development. Addressing poverty (SDG 1), energy poverty (SDG 7), WaSH (SDG 6), health (SDG 3), education (SDG 4) and hunger (SDG 2)—along with inequalities (SDG 5 and SDG 10)—improves resilience to climate impacts for those groups that are disproportionately affected (women, low-income and marginalised groups). Inclusive and fair decision making can enhance resilience (SDG 16; Section 13.4.4), although adaptation measures may also lead to resource conflicts (SDG 16; Section 13.7). Nature-based solutions attentive to gender equity also support ecosystem health (SDGs 14 and 15) (Dzebo et al., 2019). Gender and climate justice will be achieved when the root causes of global and structural issues are addressed, challenging unethical and unacceptable use of power for the benefit of the powerful and elites (MacGregor, 2014; Wijsman and Feagan, 2019; Vander Stichele, 2020). Justice and equality need to be at the centre of climate adaptation decision-making processes. A transformative pathway needs to include the voice of the disenfranchised (MacGregor, 2020; Schipper et al., 2020a).

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

A third theme is that of innovation, generally, and sustainability-oriented innovation, specifically (de Vries et al., 2016; Geradts and Bocken, 2019; Loorbach et al., 2020), which creates opportunities for overcoming existing transition barriers (*very high confidence*). For example, Valta (2020) describes the role of innovation ecosystems—partnerships among companies, investors, governments and academics—in accelerating innovation (see also World Economic Forum, 2019). Burch et al. (Burch et al., 2016) describe the role of small- and medium-sized business entrepreneurship in promoting rapid innovation. Innovation extends beyond pure technology considerations to consider innovation in practices and social organisation (Li et al., 2018; Psaltoglou and Calle, 2018; Repo and Matschoss, 2020). Zivkovic (2018), for example, discusses 'innovation labs' as accelerators for addressing so-called wicked problems such as climate change through multi-stakeholder groups. Meanwhile, Chaminade and Randelli (2020) describe a case study where structural preconditions and place-based agency were important drivers of transitions to organic viticulture in Tuscany, Italy.

The fourth theme is that of transition management (Goddard and Farrelly, 2018), particularly vis-à-vis, disruptive technologies (Iñigo and Albareda, 2016; Kuokkanen et al., 2019) or broader societal disruptions (Brundiers, 2020; Davidsson, 2020; Hepburn et al., 2020; Schipper et al., 2020b). Recent literature has given attention to how actors can use disruptive events, such as disasters, as a window of opportunity for accelerating changes in policies, practices and behaviours (*high agreement*, *medium evidence*) (Brundiers, 2018; Brundiers and Eakin, 2018). This is consistent with concepts in resilience thinking around 'building back better' after disasters (Fernandez and Ahmed, 2019). For example, Hepburn et al. discuss fiscal recovery packages for COVID-19 as a means of accelerating climate action, with a particular influence on clean physical infrastructure, building efficiency retrofits, investment in education and training, natural capital investment, and clean research and development (Andrijevic et al., 2020b).

18.4 Agency and Empowerment for Climate Resilient Development

As reflected in the discussion of societal transitions (Section 18.3), people and their values and choices play an instrumental role in CRD. The agency of people to act on CRD is grounded in their worldviews, beliefs, values and consciousness (Woiwode, 2020), and is shaped through social and political processes including how policies and decision making recognise the voices, knowledges and rights of particular actors over others (*very high confidence*) (Harris and Clarke, 2017; Nightingale, 2017; Bond and Barth, 2020; Muok et al., 2021). Since the AR5, evidence on diverse forms of engagement by and among social, political and economic actors to support CRD and sustainability outcomes, has increased. New forms of decision making and engagement are emerging within the formal policymaking and planning sphere, including co-production of knowledge, interventions grounded in the arts and humanities, civil participation and partnerships with business (Ziervogel et al., 2016a; Roberts et al., 2020). In addition, the set of actors that drive climate and development actions are recognised to extend beyond government and formal policy actors to include civil society, education, industry, media, science and art (Ojwang et al., 2017; Solecki et al., 2018; Heinrichs, 2020; Omukuti, 2020). This makes the power dynamics among actors and institutions critical for understanding the role of actors in CRD (Buggy and McNamara, 2016; Camargo and Ojeda, 2017; Silva Rodríguez de San Miguel, 2018).

The formal space for national, sub-national and international adaptation governance emerged at COP 16 (UNFCCC, 2010) when adaptation was recognised as a similar level of priority as GHG mitigation. The Paris Agreement (UNFCCC, 2015) built on this and the 2030 Sustainable Development Agenda (United Nations, 2015) to link adaptation to development and climate justice. It also highlighted the importance of multi-level adaptation governance, including new non-state voices and climate actors that widen the scope of adaptation governance beyond formal government institutions. For example, individuals can act as agents of changes in their own behaviour, such as via change in their consumption patterns, but also generate change within organisations, fields of practice and the political landscape of governance. Accordingly, these interactions among actors across different scales implies the need for wider modes of, and arena for, engagement around adaptation to accommodate a diversity of perspectives (*high agreement*, *medium evidence*) (Chung Tiam Fook, 2017; Lesnikowski et al., 2017; IPCC, 2018a).

In most regions, such new institutional and informal arrangements are at an early stage of development (*high agreement*, *limited evidence*). Further clarification and strengthening are needed to enable the fair sharing of resources, responsibilities and authorities to enable climate action to enable CRD (Wood et al., 2017; IPCC, 2018a; Reckien et al., 2018). These are strongly linked to contested and complementary worldviews of climate change and the actors that use these worldviews to justify, direct, accelerate and deepen transformational adaptation and climate action.

18.4.1 Political Economy of Climate Resilient Development

Political economy studies (i.e., the origins, nature and distribution of wealth, and the ideologies, interests and institutions that shape it) explicitly addressing CRD are quite limited. Yet there is an extensive post-AR5 literature on political economy associated with various elements relevant to CRD including climate change and development (Naess et al., 2015); vulnerability, adaptation, and climate risk (Sovacool et al., 2015; Sovacool et al., 2017; Barnett, 2020); energy, decarbonisation and negative emissions technologies (Kuzemko et al., 2019; Newell, 2019); degrowth and low-carbon economies (Perkins, 2019; Newell and Lane, 2020); solar radiation management (Ott, 2018); planetary health and sustainability transitions and transformation (Kohler et al., 2019) (Gill and Benatar, 2020). Review and assessment of this literature reveals our key insights about the relationship between the political economy and CRD.

First, the political economy drives coupled development–climate change trajectories and determines vulnerability, thereby potentially subjecting those least responsible for climate change to the greatest risk (Sovacool et al., 2015; Barnett, 2020). The legitimacy, viability and sustainability of the prevailing political economy is being called

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

into question because of its role in driving vulnerability in a changing climate (Barnett, 2020), thus undermining the prospects for CRD.As underpinning political economy ideologies, interests and institutions change, the cause of the vulnerable is being appropriated, the drivers of vulnerability and the adaptation agenda are depoliticised, and market-based solutions advocated in ways that sustain the prevailing political economy at the expense of those most at risk. Political economy interests and institutions that drive vulnerability are thus themselves at risk because worsening climate change raises questions about their legitimacy and political and economic viability (Barnett, 2020).

Second, assessment of this literature suggests four attributes of the political economy of adaptation influence development trajectories in diverse settings, from Australia to Honduras and the Maldives (Sovacool et al., 2015), as delivered through the Global Environment Facility's Least Developed Countries Fund (Sovacool et al., 2017). These include enclosure (public resources or authority captured by private interests); exclusion (stakeholders are marginalised from decision making); encroachment (natural systems and ecosystem services compromised); and entrenchment (inequality exacerbated). These attributes hamper adaptation efforts, and reveal the political nature of adaptation (Dolšak and Prakash, 2018) and, by extension, CRD. Paradoxically, development initiatives labelled as 'risk' reduction or resilience building or 'equitable and environmentally sustainable', such as coastal restoration efforts in Louisiana, USA, can compound inequity and climate risk, and perpetuate unsustainable development (Gotham, 2016; Eriksen et al., 2021b).

Third, a long-held view is that the effects of mitigation are global, while those of adaptation are local. A political economy perspective, however, underscores cross-scale linkages, and shows that local adaptation efforts, vulnerability and climate resilience are manifest in development trajectories that are shaped by both local and trans-local drivers, and defined by unequal power relations that cross scales and levels (Sovacool et al., 2015; Barnett, 2020; Newell, 2020), including in key sectors such as energy (Baker et al., 2014) and agriculture (Houser et al., 2019), as well as emergent blocs such as Brazil, Russia, India, China and South Africa (BRICS) (Power et al., 2016; Schmitz, 2017); and sub-national constellations such as cities (Fragkias and Boone, 2016; Béné et al., 2018).

Fourth, transitions towards CRD may be technically and economically feasible but are 'saturated' with power and politics (Tanner and Allouche, 2011) (Section 18.3), necessitating focused attention to political barriers and enablers of CRD (Newell, 2019). With a narrow window of time to contain dangerous levels of global warming, political economy research calls for CRD trajectories that counter the tendency of the prevailing political economy to compound climate change impacts and risk (Newell and Lane, 2020), especially given the opportunity to realise co-benefits through pandemic recovery efforts that take into account vulnerability and the intersection of economic power and public health, environmental quality, climate change, and human and indigenous rights (Bernauer and Slowey, 2020; Schipper et al., 2020b).

Given these insights, CRD can be understood as the sum of complex multi-dimensional processes consisting of large numbers of actions and societal choices made by multiple actors from government, the private sector and civil society, with important influences by science and the media (*very high confidence*). These actions and social choices are determined by the available solution space and options, along with a range of enabling conditions (Section 18.4.2) that are largely bounded by individual and collective worldviews, and related ethics and values. This view is consistent with sustainable development being a process constituted by multiple inter-related societal choices and actions that are often contested as the needs and interests of current and future generations are addressed. Development choices have path dependencies and context-sensitive synergies and trade-offs with natural and embedded human systems, and they are bounded by multiple and contested knowledges and worldviews (Goldman et al., 2018; Heinrichs, 2020; Nightingale et al., 2020; Schipper et al., 2020b). Consequently, societal choices about the political economy underpin prospects for moving towards or away from CRD.

18.4.2 Enabling Conditions for Near-Term System Transitions

Given actors, institutions and their engagement is fundamental to supporting system transitions needed for CRD (Section 18.3), this section assesses recent literature with respect to how the values, choices and behaviours of those actors enable or constrain specific enabling conditions. Such enabling conditions represent opportunities for policymakers to pursue actions that contribute to CRD beyond direct risk management options such as climate adaptation and GHG mitigation (Sections 18.2.5.1, 18.2.5.2).

18.4.2.1 Governance and Policy

An overarching enabling condition for achieving system transitions and transformations is the presence of enabling governance systems (*very high confidence*). Recent literature on the translation of governance into system transitions in practice suggests four key actions are important. The first is the critical reflection on so-called 'development solutions', alternatively framed by some as 'empty promises', that worsen climate risk, inequity, injustice and ultimately lead to unsustainable development (Mikulewicz, 2018; Mikulewicz and Taylor, 2020). Examples include development aid (Scoville-Simonds et al., 2020), large-scale development projects such as biofuel production in Ethiopia (Tufa et al., 2018) and urban growth management in Vietnam (DiGregorio, 2015). The second is the recognition that while the power of different actors and institutions is often tied to access to resources and the ability to constrain the actions of others, other dimensions of power such as its ability to produce knowledge as well as its contingency on circumstances and relationships are also important in enabling energy transitions (Avelino et al., 2016; Avelino and Wittmayer, 2016; Lockwood et al., 2016; Ahlborg, 2017; Avelino and Grin, 2017; Partzsch, 2017; Smith and Stirling, 2018). Third, governance systems can help to develop productive interactions between formal government institutions, the private sector and civil society including the provision 'safe arenas' for social actors to deliberate and pursue transitional and transformational change (Haukkala, 2018; Törnberg, 2018; Strazds; Ferragina et al., 2020; Koch, 2020) (Section 18.3.1, Box 18.1). Fourth, governance can address challenges such as climate change from a systems perspective and

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

pursue interventions that address the interactions among development, climate change, equity and justice, and planetary health (Harvey et al., 2019; Hölscher et al., 2019). This is evidenced by recent experience with the COVID-19 pandemic response as well as ongoing escalation of disaster risk associated with extreme weather events (Walch, 2019; Cohen, 2020; Schipper et al., 2020b; Wells et al., 2020).

One output from systems of governance is formal policy frameworks and policies that influence processes and outcomes of system transitions that support CRD (Section 18.1.3). The Paris Agreement, for example, provides a framework for CRD by defining a mitigation-centric goal of 'limiting warming to well below 2°C and enabling a transition to 1.5°C' (UNFCCC, 2015). It also provides for a broadly defined global adaptation goal (UNFCCC, 2015: Art. 7.1). The NDCs are the core mechanism for achieving and enhancing climate ambitions under the Paris Agreement. However, the pursuit of a given NDC within a specific country will likely necessitate a range of other policy interventions that have more immediate impact on technologies and behaviour, implicating transitions in energy, industry, land and infrastructure (*very high confidence*) (Section 18.3.1). SDG-relevant activities are increasingly incorporated into climate commitments in the NDCs (at last count 94 NDCs also addressed SDGs), contributing to several (154 out of the 169) SDG targets (Brandi and Dzebo; Pauw et al., 2018). This reflects the potential of the NDCs as near-term policy instruments and signposts for progress towards CRD (*medium agreement*, *limited evidence*) (McCollum et al., 2018b).

As reflected by the SDGs (and SDG 13 specifically), the mainstreaming of climate change concerns into development policies is one mechanism for pursuing sustainable development and CRD (*very high confidence*). However, such mainstreaming has also been critiqued for perpetuating 'development as usual', reinforcing established development logics, structures and worldviews that are themselves contributing to climate change and vulnerability (O'Brien et al., 2015) and for obscuring and depoliticising adaptation choices into technocratic choices (Murtinho, 2016; Webber and Donner, 2017; Benjaminsen and Kaarhus, 2018; Khatri, 2018; Scoville-Simonds et al., 2020). The coordinated implementation of sustainable development policy and climate action is nonetheless crucial for ensuring that the attainment of one does not come at the expense of others (Stafford-Smith et al., 2017). For example, aggressive pursuit of climate policies that facilitate transitions in energy systems can undermine efforts to secure sustainability transitions in other systems (Sections 18.3.1.1, 18.2.5.3, Table 18.7).

Several non-climate international policy agreements provide context for CRD such as the 1948 UN Universal Declaration of Human Rights, the UN Declaration on the Rights of Indigenous Peoples (Hjerpe et al., 2015) and the Convention on Biological Diversity (CBD; UNFCCC, 1992), the UN Convention to Combat Desertification (UN, 1994), as well as the more recent Sendai Framework for Disaster Risk Reduction (UNDRR, 2015) and the 'new humanitarianisms' which seeks to reduce the gap between emergency assistance and longer term development (Marin and Naess, 2017). Collectively they provide a global policy framework that protects people's rights that are potentially threatened by climate change (Olsson et al., 2014). These policies are relevant to transitions across multiple systems, particularly in societal systems towards more equitable and just development.

18.4.2.2 Economics and Sustainable Finance

18.4.2.2.1 Economics

System transitions towards CRD is contingent on reducing the costs of current climate variability on society while making investments that prepare for the future effects of climate change. Climate change and responses to climate change will affect many different economic sectors both directly and indirectly (Stern, 2007; IPCC, 2014a; Hilmi et al., 2017). As a consequence, the characteristics of economic systems will play an important role in determining their resilience (*very high confidence*). These effects will occur within the context of other developments, such as a growing world population, which increases environmental pressures and pollution. This impact is higher for developing countries than for high-income countries (Liobikienė and Butkus, 2018). While looking for sustainable climate-resilient policies, many complex and interconnected systems, including economic development, must be considered in the face of global-scale changes (Hilmi and Safa, 2010).

Miller (2017) discusses some of the planning for, and application of, adaptation measures that improve sustainability, noting the importance of considering a range of factors including complexities of interconnected systems, the inherent uncertainties associated with projections of climate change impacts and the effects of global-scale changes such as technological and economic development for decision makers. For example, addressing climate impacts in isolation is unlikely to achieve equitable, efficient or effective adaptation outcomes (*very high confidence*). Instead, integrating climate resilience into growth and development planning allows decision makers to identify what sustainable development policies can support climate-resilient growth and poverty reduction and understand better how patterns and trends of economic development affect vulnerability and exposure to climate impacts across sectors and populations, including distributional effects (Doczi, 2015). Markkanen and Anger-Kraavi (2019) highlighted that climate change mitigation policy can influence inequality both positively and negatively. Although higher levels of poverty, corruption, and economic and social inequalities can increase the risk of negative outcomes, these potential negative effects would be mitigated if inequality impacts were taken into consideration in all stages of policy making (*very high confidence*).

The primary objective of economic and financial incentives around carbon emissions is to redirect investment from high to low carbon technologies (Komendantova et al., 2016). Recent years have seen policy interventions to incentivise transitions in energy, land and industrial systems to address climate change and sustainability focus on price-based, as opposed to quantity based, interventions. Price-based interventions aim at leveraging market mechanisms to achieve greater efficiency in the allocation of resources and costs of mitigating climate change. For example, carbon pricing initiatives around the world today cover approximately 8 gigatons of carbon dioxide emissions, equivalent to about 20% of global fossil energy fuel emissions and 15% of total carbon dioxide GHG emissions (Boyce, 2018). Meanwhile, environmental taxes and green public procurement push producers to eliminate the negative environmental effects of production (Danilina and Trionfetti, 2019). There are several advantages for environmental taxation including environmental

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

effectiveness, economic efficiency, the ability to raise public revenue, and transparency (*very high confidence*). These gains can provide more resource-efficient production technologies and positively affect economic competitiveness (Costantini et al., 2018).

Policies encouraging eco-innovation, defined as '*new ideas, behaviour, products, and processes that contribute to a decreased environmental burden*' (Yurdakul and Kazan, 2020), can positively affect economic competitiveness. By implementing policies to encourage eco-innovation, countries enhance their energy efficiency. These gains can provide more resource-efficient production technologies and positively affect economic competitiveness (*very high confidence*) (Costantini et al., 2018; Liobikienė and Butkus, 2018). Other than eco-innovation, it is important to also consider exnovation, meaning the phasing out of old technologies, as otherwise the expansion of supply could lead to a rebound owing to cheaper prices for carbon-based products (Arne Heyen et al., 2017; David, 2017). Hence, decarbonisation strategies that set limits to carbon-based trajectories can be beneficial. Quantity-based interventions—or so-called 'command-and-control' policies—involve constraints on the quantity of energy consumption or GHG emissions through laws, regulations, standards and enforcement, with a focus on effectiveness rather than efficiency.

For a transition from dirty (more advanced) technologies to clean (less advanced) ones, market-based instruments such as carbon taxes should be considered alongside subsidies and other incentives that stimulate innovation (Acemoglu et al., 2016). Research and development in energy technologies, for example, can help reduce costs of deployment and therefore the costs of operating in a carbon-constrained world. Hémous (2016) indicates that a unilateral environmental policy which includes both clean research subsidies and trade tax can ensure sustainable growth, but unilateral carbon taxes alone might increase innovation in polluting sectors and would not generally lead to sustainable growth.

18.4.2.2.2 Climate Finance

Achieving progress on system transitions will be contingent on the ability of actors and institutions to access the financing they need to invest in innovation, adaptation and mitigation, and broader system change (*very high confidence*). By greening their investment portfolios, investors can support reduction in vulnerability to the consequences of climate change and the reduction of GHG emissions. Finance can contribute to the reduction of GHG emissions, for example, by efficiently pricing the social cost of carbon, by reflecting the transition risks in the valuation of financial assets, and by channelling investments in low-carbon technologies (OECD, 2017). At the same time, there is a growing need to spur greater public and private capital into climate adaptation and resilience including climate-resilient infrastructure and nature-based solutions to climate change. For instance, the Green Climate Fund, established within the framework of the UNFCCC, is assisting developing countries in adaptation and mitigation initiatives to counter climate change.

Recent evidence sheds light on the magnitude and pervasiveness of climate risk exposure for global banks and financial institutions. According to Dietz et al. (2016), up to about 17% of global financial assets are directly exposed to climate risks, particularly the impacts of extreme weather events on assets and their outputs. However, when indirect exposures via financial counterparts are considered, the share of assets subject to climate risks is much larger (40–54%) (Battiston et al., 2017). Hence, the magnitude of climate change-related risks is substantial, and similar to those that started the 2008 financial crisis (*high agreement*, *limited evidence*).

Financial actors increasingly recognise that the generation of long-term, sustainable financial returns is dependent on stable, well-functioning and well-governed social, environmental and economic systems *(very high confidence*) (Shiller, 2012; Schoenmaker and Schramade, 2020). Institutional approaches to a variety of environmental domains (Krueger et al., 2019) which seek to integrate the pursuit of green strategies with financial returns include targeted investments in green assets (e.g., green bonds, clean energy public equity) and specialised funds/vehicles for renewable energy infrastructure (Tolliver et al., 2019; Gibon et al., 2020); cleantech venture capital and alternative finance (Gianfrate and Peri, 2019); investment screening to steer capital to green industries (Nielsen and Skov, 2019; Ambrosio et al., 2020); and active ownership to influence organisational behaviour (Silvola and Landau, 2021).

Despite the expansion of green mandates across the investment chain, definitions of some of the asset classes associated with green investing are ambiguous and poorly defined. The EU taxonomy for sustainable activities is a promising step in the right direction. For example, a 'green' label for bonds is often stretched to encompass financing facilities of issuers that misrepresent the actual environmental footprint of their operations (the so-called risk of 'greenwashing'). Even in cases where the bonds' proceeds are actually used to finance green projects, investors often remain exposed to both the green and 'brown' assets of the issuers (Gianfrate and Peri, 2019; Flammer, 2020). The heterogeneity of metrics and rating methodologies (along with inherent conflict of interests between issuers, investors and score/rating providers) results in inconsistent and unreliable quantification of the actual environmental footprint of corporate and sovereign issuers (Battiston et al., 2017; Busch et al.).

In order to promote financial climate-related disclosures for companies and financial intermediaries, the financial system could play a key role in pricing carbon and in allocating capital towards low-carbon emission companies (Aldy and Gianfrate, 2019; Bento and Gianfrate, 2020; Aldy et al., 2021). Stable and predictable carbon-pricing regimes would significantly contribute to fostering financial innovation that can help further accelerate the decarbonisation of the global economy, even in jurisdictions which are more lenient in implementing climate mitigation actions (*very high confidence*) (Baranzini et al., 2017). A growing number of financial regulators are intensifying efforts to enhance climate-related disclosure of financial actors. In particular, the Financial Stability Board created the Task Force on Climate-related Financial Disclosures (TCFD) to improve and increase reporting of climate-related financial information. Several countries are considering implementing mandatory climate risk disclosure in line with TCFD's recommendations. Central Banks are also considering mandatory disclosure and climate stress testing for banks. For instance, in November 2020 the European Central Bank (ECB) published a guide on climate-related and environmental risks explaining how the ECB expects banks to prudently manage and transparently disclose such

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

risks under current prudential rules. The ECB also announced that banks in the Euro-zone will be stress tested on their ability to withstand climate change-related risks. In addition to disclosure requirements and stress testing, some Central Banks are considering the possibility of steering or tilting the allocation of their assets to favour the less polluting issuers (Schoenmaker, 2019). This, in turn, would translate into lower cost of capital for cleaner sectors, significantly accelerating the greening of the real economy.

18.4.2.3 Institutional Capacity

Institutional capacity for system transitions refers to the capacity of structures and processes, rules, norms and cultures to shape development expectations and actions aimed at durable improvements in human well-being. The AR5 highlighted the need for strong institutions to create enabling environments for adaptation and GHG mitigation action (Denton et al., 2014). Institutions stand within the social and political practices and broader systems of governance that ultimately drive adaptation and development processes and outcomes. They are thus produced by them and can become tools by which some actors constrain the actions of others (Gebreyes, 2018). As a consequence, they and can become a significant barrier to change, whether incremental or more transformational (*very high confidence*). The post-AR5 focus on transformational adaptation and resilience present in the literature suggests that institutions that enable system transitions towards CRD are secure enough to facilitate a wide range of voices, and legitimate enough to change goals or processes over time, without reducing confidence in their efficacy.

The limited literature on institutions and pathways relevant to system transitions and CRD suggests that institutions are most effective when taking a development-first approach to adaptation. This is consistent with the principles of CRD which emphasise not simply reducing climate risk, but rather making development processes resilient to the changing climate. There is agreement in this literature that such an approach allows for the effective integration of climate challenges into existing policy and planning processes (*very high confidence*) (Pervin et al., 2013; Kim et al., 2017b; Mogelgaard et al., 2018). However, this approach generally rests on an incremental framing of institutional change (Mahoney and Thelen, 2009) based on two critical assumptions. The first is that existing processes and institutions are capable of bringing about system transitions that generate desired development outcomes and thus can be considered appropriate vehicles for the achievement of CRD. A large critical literature questions the efficacy of formal state and multilateral institutions. The evidence for the ability of local, informal institutions to achieve development goals remains uneven, with robust evidence of positive impacts on public service delivery, but more ambiguous evidence on behaviour changes associated with strengthened institutions (Berkhout et al., 2018). The second is that the mainstreaming of adaptation will bring about changes to currently unsustainable development practices and pathways, instead of merely strengthening development as usual by subsuming adaptation to existing development pathways and allowing them to endure in the face of growing stresses (Eriksen et al., 2015; Godfrey-Wood and Otto Naess, 2016; Scoville-Simonds et al., 2020). There is evidence that countries with poor governance have limited adaptation planning or action at the national level, even when other determinants of adaptive capacity are present (Berrang-Ford et al., 2014). This suggests that, in these contexts, adaptation efforts are likely to be subsumed to existing government goals and actions, rather than having transformational impact.

18.4.2.4 Science, Technology and Innovation

Ongoing innovations in technology, finance and policy have enabled more ambitious climate action over the past decade, including significant growth in renewable energy, electrical vehicles and energy efficiency. However, access to, and the benefits of, that innovation have not been evenly distributed among global regions and communities, and continued innovation is needed to facilitate climate action and sustainable development (*very high confidence*). Policymakers need useful science and information (Cornell et al., 2013; Kirchhoff et al., 2013; Calkins, 2015; IPCC, 2019 f; Guido et al., 2020) to make informed decisions about possible risks, and the benefits, costs and trade-offs of available adaptation, mitigation and sustainable development solutions (i.e., Article 4.1 of the Paris Agreement; UNFCCC, 2015). Moreover, recent literature has emphasised the need for deep technological, as well social, changes to avert the risks of conventional development trajectories (Gerst et al., 2013; IPCC, 2014a).

An effective and innovative technological regime is one that is integrated with local social entities across different modes of life, local governance processes (Pereira, 2018; Nightingale et al., 2020) and local knowledge(s), which increasingly support adaptation to socio-environmental drivers of vulnerability (Schipper et al., 2014; Nalau et al., 2018; IPCC, 2019 f). These actors and their knowledge are often ignored in favour of knowledge held by experts and policymakers, exacerbating uneven power relations (Naess, 2013; Nightingale et al., 2020). For example, achieving sustainability and shifting towards a low carbon energy system (e.g., hydropower dams, wind farms) remains a contested space with divergent interests, values and future prospects (Bradley and Hedrén, 2014; Avila, 2018; Mikulewicz, 2019), and potential impacts on human rights as embodied by the Paris Agreement (UNFCCC, 2015). A number of studies have emphasised the limits of relying upon technology innovation and deployment (e.g., expansion of renewable energy systems and/or carbon capture) as a solution to challenges of climate change and sustainable development (Section 18.3.1.2). This is because such solutions may fail to consider the local historical contexts and barriers to participation of vulnerable communities, restricting their access to land, food, energy and resources for their livelihoods.

18.4.2.5 Monitoring and Evaluation Frameworks

Enabling system transitions towards CRD is dependent in part on the ability to monitor and evaluate system transitions and broader development pathways to identify effective interventions and barriers to their implementation (*very high confidence*). However, the monitoring and evaluation of individual system transitions, much less CRD, remains highly challenging for multiple reasons (Persson, 2019). The highly contextual nature of resilience, adaptation and sustainable development means that, unlike climate mitigation, it is difficult to define universal metrics or targets for adaptation and resilience (Pringle and Leiter, 2018); (Brooks et al., 2014). This is demonstrated by the Paris Agreement's global goal for adaptation, The mismatch

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Box 18.6 | 'Green' Strategies of Institutional Investors

Negative and Positive Screening. Investors assess the carbon footprint of issuers and identify the best and worst performers (Boermans and Galema, 2019). The issuers with excessive carbon footprint are divested and fall into the 'exclusion lists' (negative screening). Alternatively, the investors commit to pick only the best in class (positive screening). As a bare minimum, screening approaches force more transparent environmental reporting from issuers. In the most optimistic scenario, to avoid exclusion lists issuers may progressively divest their non-green operations. In the long term, the combination of positive and negative screening will reward sustainable issuers relative to non-green sectors, thus reducing the cost of capital for less polluting entities.

Active Ownership. Equity investors can exercise the voting rights at shareholders' meetings in relation to governance and business strategy, including the environmental performance. In addition, institutional investors engage with the management and the boards of directors of investee companies. Active ownership is therefore defined as the full exercise of the rights that accrue to the 'owners' of the securities issued by companies (Dimson et al., 2015; Dimson et al., 2020). Active owners are entitled to question and challenge the robustness of financial analyses and the risk assessment behind strategic decisions including the environmental footprint ones. For instance, since fossil fuel businesses face the prospect of dramatic business decline (Ansar et al., 2013) and must revisit their business model to survive, active ownership by institutional investors may foster the transition to cleaner production and supply chain. Companies more exposed to carbon risks particularly need the active support of long-term shareholders. In turn, investors adopting an active ownership approach can manage their holdings' exposure to climate change risks, thus protecting the value of their investments on a long-term horizon (Krueger et al., 2019).

Specialized Financial Instruments and Investors. New asset classes have been created to address the climate change challenge. Also, specialised investment funds and vehicles came to life with the primary objective of addressing climate issues. While these financial instruments and funds prioritise the achievement of climate objectives, they do not sacrifice financial returns and are able to attract private capital. To mention a few examples:

- *Green bonds* are typically issued by companies, banks, municipalities and governments with the commitment to use the proceeds exclusively to finance or refinance green projects, assets or business activities. These bonds are equivalent to any other bond issued by the same entity except for the label of 'greenness' that ideally is verified *ex ante* at the launch and *ex post* when the proceeds are actually used by the issuer. Early evidence show that green bonds do not penalise financially issuers (Gianfrate and Peri, 2019; Flammer, 2020).
- *Carbon funds* are designed to help countries achieve long-term sustainability typically financing forest conservation. They are intended to reduce climate change impacts from forest loss and degradation.
- *Project finance.* New renewable energy initiatives are likely to recur more and more to project finance. Project finance relies on the creation of a special purpose vehicle (SPV), which is legally and commercially self-contained and serves only to run the renewable energy project. The SPV is financed without (or very limited) guarantees from the sponsors (typically energy companies: investors are therefore paid back on the basis only of SPV's future cash flows only and cannot recourse on the sponsors' assets) (Steffen, 2018).
- *Cleantech venture capital*. These funds invest exclusively in early-stage companies working on innovative, but not yet fully tested, clean technologies. The risk profile of such investments is usually very high. The extent to which this segment of the financial industry can successfully support 'deep' energy innovations is still debated (Gaddy et al., 2017). When cleantech start-ups develop hardware requiring a high upfront investment, support from the public sector seems necessary to attract further investments from large corporations and patient institutional investors.
- *Crowdfunding and alternative finance* are emerging as a channel to both finance small-scale clean energy projects as well as fund early-stage innovative clean technologies (Cumming et al., 2017; Bento et al., 2019).

between timescales associated with resilience and adaptation interventions and those over which the results of such interventions are expected to become apparent tends to result in a focus on the measurement of spending, outputs and short-term outcomes, rather than longer-term impacts (Brooks et al., 2014; Pringle and Leiter, 2018). The need to assess resilience and adaptation against a background of evolving climate hazards, and to link resilience and adaptation with development outcomes, present further methodological challenges (*very high confidence*) (Brooks et al., 2014).

Currently, the ability to monitor different components of CRD are in various stages of maturity (*very high confidence*). Monitoring of the SDGs, for example, is a routine established practice at global and regional levels, and UNDP publishes annual updates on progress towards the SDGs (United Nations, 2021). For resilience, Brooks et al. (2014) identify three broad approaches to its measurement, each of which could offer potential mechanisms for monitoring progress towards CRD. One is a 'hazards' approach, in which resilience is described in terms of the magnitude of a particular hazard that can be accommodated by a system, useful in contexts where thresholds

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

in climate and related parameters can be identified and linked with adverse impacts on human populations, infrastructure and other systems (Naylor et al., 2020). An 'impacts' approach is one in which resilience is measured in terms of actual or avoided impacts and is suited for tracking adaptation success in delivering CRD over longer timescales, for example at the national level (Brooks et al., 2014). Finally, a 'systems' approach is one where resilience is described in terms of the characteristics of a system using quantitative or qualitative indicators which are often associated with different 'dimensions' of resilience (Serfilippi and Ramnath, 2018; Saja et al., 2019). This allows measurement of key indicators that are proxies for resilience at regular intervals, even in the absence of significant climate hazards and associated disruptions (*very high confidence*) (Brooks et al., 2014) (see also Cross-Chapter Box ADAPT in Chapter 1). Similar criteria could be applied to evaluating adaptation options and their implementation as well as various interventions in pursuit of SDGs.

18.4.3 Arenas of Engagement

Much of the enabling conditions for system transitions discussed in Section 18.4.2 are inherently linked to actors and their agency in pursuing system change. Yet a significant literature has developed since the AR5, exploring not only the role of different actors in pursuing adaptation, mitigation and sustainable development options, but also how those actors interact with one another to drive outcomes. CRDPs are determined by the interactions between societal actors and networks, including government, civil society and the private sector, as well as science and the media. The resultant social choices and cumulative private and public actions (and inactions) are institutionalised through both formal and informal institutions that evolve over time and seek to provide societal stability in the face of change. The degree to which the emergent pathways foster just and CRD depends on how contending societal interests, values and worldviews are reconciled through these interactions. These interactions occur in many different arenas of engagement, that is, the settings, places and spaces in which societal actors interact to influence the nature and course of development, including political, economic, socio-cultural, ecological, knowledge–technology and community arenas (Figures 18.1, 18.2).

For example, political arenas range from formalised election and voting procedures to more informal and less transparent practices, such as special interest lobbying. Town squares and streets can become sites of political struggle and dissent, including protests against climate inaction. As a more specific case in point, the formal space for national, sub-national and international adaptation governance emerged at COP 16 (UNFCCC, 2010) when adaptation was recognised as having a similar level of priority as mitigation. The Paris Agreement (UNFCCC, 2015) built on this and the 2030 Sustainable Development Agenda (United Nations, 2015) to link adaptation to development and climate justice, widening the scope of adaptation governance beyond formal government institutions. It also highlighted the importance of multi-level adaptation governance, including non-state voices from civil society and the private sector. This implied the need for wider arenas and modes of engagement around adaptation (Chung Tiam Fook, 2017; Lesnikowski et al., 2017; IPCC, 2018a) that facilitate coordination and convergence among these diverse actors including individual citizens to collectively solve problems and unlock the synergies between adaptation and mitigation and sustainable development (IPCC, 2018a; Romero-Lankao et al., 2018).

There are many other visible and less visible arenas of engagement in the other interconnected spheres of societal interaction spanning scales from the local to international level. The metaphor of arenas derives from diverse social and political theory, with applications in studies of, among other things, governance transformation and transitions (Healey, 2006; Jørgensen, 2012; Jørgensen et al., 2017). It underscores that these arenas can be enduring or temporary in nature, are historically situated and often spatially bounded, and signifies the many different mechanisms by which societal actors interact in dynamic and emergent ways. Power and politics impact access and influence in these arenas of engagement—with varying levels of inclusion and exclusion shaping the nature and trajectory of development. In practice, some arenas of engagement are 'struggle arenas' as different societal actors strive to influence the trajectory of development, with inevitable winners and losers.

Institutional arrangements to foster CRD are at an early stage of development in most regions (*medium agreement*, *limited evidence*). They need to be further clarified and strengthened to enable a sharing of resources and responsibilities that facilitate climate actions embracing climate resilience, equity, justice, poverty alleviation and sustainable development (Wood et al., 2017; IPCC, 2018a; Reckien et al., 2018). These endeavours are strongly influenced by how contested and complementary worldviews about climate change and development are mobilised by societal actors to justify, direct, accelerate and deepen transformational climate action or entrench maladaptive business as usual practices (Section 18.4.3.1).

18.4.3.1 Worldviews

Worldviews are overarching systems of meaning and meaning-making that inform how people interpret, enact and co-create reality (De Witt et al., 2016). Worldviews shape the vision, beliefs, attitudes, values, emotions, actions and even political and institutional arrangements. As such, they can promote holistic, egalitarian approaches to enable, accelerate and deepen climate action and environmental care (Ramkissoon and Smith, 2014; De Witt et al., 2016; Lacroix and Gifford, 2017; Sanganyado et al., 2018; Brink and Wamsler, 2019). Alternatively, they can also serve as significant barriers to system transitions and transformation, based on anthropocentric, mechanistic and materialistic worldviews and the utilitarian, individualist or skeptical values and attitudes they often promote (*very high confidence*) (Beddoe et al., 2009; van Egmond and de Vries, 2011; Stevenson et al., 2014; Zummo et al., 2020).

Traditional, modern and post-modern worldviews have different, and in many ways, complementary potentials for enabling diverse approaches to climate action and sustainable development. They can also shift societal values and societal concern for climate change (Shi et al., 2015), resulting in changes in behaviour and acceptance of climate change policies (van Egmond and de Vries, 2011; Van Opstal and Hugé, 2013; De Witt et al., 2016; Shaw, 2016) which are predictors of concern. Among the challenges of strongly different climate-related worldviews,

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

is that they rarely co-exist. Some worldviews become incompatible or hostile to other worldviews, openly seeking to dominate, eliminate or segregate competing perspectives (*medium agreement*, *medium evidence*) (de Witt, 2015; Jackson, 2016; Nightingale, 2016; Xue et al., 2016; Goldman et al., 2018).

To address these difficult contests, worldviews regarding climate and global environmental change are often expressed in scientific language and themes (Parsons et al., 2016; Goldman et al., 2018). This can exclude other worldviews grounded in other forms of knowledge or ways of knowing which ultimately narrows understanding of climate change and the solution space. Hence, the post-AR5 literature on worldviews focuses on the numerous meanings, associations, narratives and frames of climate change and how these shape perceptions, attitudes and values (Morton, 2013; Boulton, 2016; Hulme, 2018; Nightingale Böhler, 2019). The recognition of the diversity of interpretations and meanings has led to multidisciplinary and transdisciplinary research that incorporates the humanities and the arts (Murphy, 2011; Elliott and Cullis, 2017; Steelman et al., 2019; Tauginienė et al., 2020), feminist studies (MacGregor, 2003; Demeritt et al., 2011; Bell, 2013; Brink and Wamsler, 2019; Plesa, 2019) and religious studies (Sachdeva, 2016; McPhetres and Zuckerman, 2018) to examine diverse understandings of reality and knowledge possibilities around climate change. In addition, literature on cultural cognition, epistemological plurality and relational ontologies draws on non-Western worldviews and forms of knowledge (Goldman et al., 2018)); .

On the other hand, the tendency for certain worldviews to dominate the policy discourse has the potential to exacerbate social, economic and political inequities as well as ontological, epistemic and procedural injustices (*very high confidence*). Research aimed at exploring the existing political ontology and knowledge politics of exclusion that marginalise certain communities and actors originated in academic or scientific perspectives. This includes institutions such as the IPCC and is subsequently replicated in social representations, including the media, public policy and the development agenda, narrowing possibilities for social transformation (Jackson, 2014; Luton, 2015; Escobar, 2016; Burman, 2017; Newman et al., 2018; Sanganyado et al., 2018; Wilson and Inkster, 2018).

18.4.3.2 Political and Government Arenas

CRD is embedded in social systems, in the political economy and its underlying ideologies, interests and institutions (Section 18.4.1). The pursuit of CRD, and shifting development pathways away from prevailing trends, unfolds in an array of political arenas, from the offices of bureaucrats to parliament buildings, sidewalks and streets, to discursive arenas in which governance actors interact—from the village level to global forums (Jørgensen et al., 2017; Montoute et al., 2019; Sørensen and Torfing, 2019; Pasquini, 2020). Paradoxically, the post-AR5 literature suggests that political arenas are often used to shut down efforts to explore the solution space for climate change and sustainable development (*medium agreement, robust evidence*) (e.g., Kenis and Mathijs, 2012; Kenis and Mathijs, 2014; Beveridge and Koch, 2016; Kenis and Lievens, 2016; Driver et al., 2018; Meriluoto, 2018; Swyngedouw, 2018; Mocca and Osborne, 2019). Power relationships among different actors create opportunities for people to be included or excluded in collective action (Siméant-Germanos, 2019) (Sections 18.3.1.6, 18.4.3.5). Therefore, as evidenced by examples from the UK (MacGregor, 2019) and China (Huang and Sun, 2020), small-scale collective environmental action has transformative potential in part owing to its ability to increase levels of cooperation among different actors (*medium agreement*, *limited evidence*) (Green et al., 2020; Blühdorn and Deflorian, 2021).

In addition to the 'arm's length' acts of voting, social mobilisation, protest and dissent can be critical catalysts for transformative change (Porta, 2020). These are competitions for recognition, power and authority (Nightingale, 2017) that take place in settings. This is evidenced by experiences from the energy sector in Bangladesh which became a contested national policy domain and where social movements eventually transformed the nation's energy politics (Faruque, 2017). Similarly, in Germany, the nation's energy transition led to marked changes in agency and legal frameworks, and energy markets drove the proliferation of so-called municipalisations of energy systems—a reversal of years of system privatisation (Becker et al., 2016). Meanwhile, experience in Bolivia demonstrate that the transformative potential of political conflict depends on transcending narrow issues to form broad coalitions with a collective identity that challenge prevailing development objectives and trajectories (Andreucci, 2019). Such examples illustrate the power of the communities as a vanguard against environmentally destructive practices (Villamayor-Tomas and García-López, 2018). Social movements have been successful at countering fossil fuel extraction (Piggot, 2018) and open up political opportunities in the face of increasing efforts to capture natural resources (Tramel, 2018) and are bolstered by resistance from within some corporations and/or their shareholders (Fougère and Bond, 2016; Swaffield, 2017; Walton, 2018a; Walton, 2018b).

Coincident with these social movements targeting climate change and sustainability has been a rise of political conservatism and populism as well as growth in misinformation (*high agreement*, *medium evidence*) (Mahony and Hulme, 2016; Swyngedouw, 2019). This reflects efforts to maintain the status quo by actors in positions of power in the face of rising social inertia for climate action (Brulle and Norgaard, 2019). Political arenas of the future could include a new body politic that integrates non-humans and a new geo-spatial politics (Latour et al., 2018).

As introduced in the discussion of governance as an enabling condition (Section 18.4.2.1), a wide range of actors are involved in successful adaptation, mitigation, and sustainability policy and practice including national, regional and local governments, communities and international agencies (Lwasa, 2015). As of 2018, 197 countries had between them over 1500 laws and policies addressing climate change as compared with 60 countries with such legislation in 1997 when the Kyoto Protocol was agreed upon (Nachmany et al., 2017; Nachmany and Setzer, 2018). In judicial branches, climate change litigation is increasingly becoming an important influence on policy and corporate behaviour among investors, activists and local and state governments (Setzer and Byrnes, 2019). There is enhanced action on climate change at both national and sub-national levels, even in cases where national policies are inimical, as in the USA (Carmin et al., 2012; Hansen et al., 2013).

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box INDIG | The Role of Indigenous Knowledge and Local Knowledge in Understanding and Adapting to Climate Change

Authors: Tero Mustonen (Finland), Sherilee Harper (Canada), Gretta Pecl (Australia), Vanesa Castán Broto (Spain), Nina Lansbury (Australia), Andrew Okem (Nigeria/South Africa), Ayansina Ayanlade (Nigeria), Jackie Dawson (Canada), Pauline Harris (Aotearoa-New Zealand), Pauliina Feodoroff (Finland), Deborah McGregor (Canada)

Indigenous knowledge refers to the understandings, skills and philosophies developed by societies with long histories of interaction with their natural surroundings (UNESCO, 2018; IPCC, 2019a). Local knowledge refers to the understandings and skills developed by individuals and populations, specific to the places where they live (UNESCO, 2018; IPCC, 2019a). Indigenous knowledge and local knowledge are inherently valuable but have only recently begun to be appreciated and in western scientific assessment processes in their own right (Ford et al., 2016). In the past these often endangered ways of knowing have been suppressed or attacked (Mustonen, 2014). Yet these knowledge systems represent a range of cultural practices, wisdom, traditions and ways of knowing the world that provide accurate and useful climate change information, observations and solutions (*very high confidence*) (Table Cross-Chapter Box INDIG.1). Rooted in their own contextual and relative embedded locations, some of these knowledges represent unbroken engagement with the earth, nature and weather for many tens of thousands of years, with an understanding of the ecosystem and climatic changes over longer-term timescales that is held both as knowledge by Indigenous Peoples and local peoples, as well as in the archaeological record (Barnhardt and Angayuqaq, 2005; UNESCO, 2018).

Indigenous Peoples around the world often hold unique worldviews that link today's generations with past generations. In particular, many Indigenous Peoples consider concepts of responsibility through intergenerational equity, thereby honouring both past and future generations (Matsui, 2015; McGregor et al., 2020). This can often be in sharp contrast to environmental valuing and decision making that occurs in Western societies (Barnhardt and Angayuqaq, 2005). Therefore, consideration of Indigenous knowledge and local knowledge needs to be a priority in the assessment of adaptation futures (Nakashima et al., 2012); Ford et al., 2016) (Chapter 1), although adequate indigenous cultural and intellectual property rights require legal and non-legal measures for recognition and protection (Janke, 2018).

Indigenous knowledge and local knowledge are crucial to address environmental impacts, such as climate change, where the uncertainty of outcome is high and a range of responses are required (Mackey and Claudie, 2015). However, working with this knowledge in an appropriate and ethically acceptable way can be challenging. For instance, questions of data 'validity' and the requirement to communicate such knowledge in the dominant language can lead to inaccurate portrayals of Indigenous knowledge as inferior to science. This may overlook the uniqueness of Indigenous knowledge and then lead to the overall devaluation of indigenous political economies, cultural ecologies, languages, educational systems and spiritual practices (Smith, 2013; Sillitoe, 2016; Naude, 2019; Barker and Pickerill, 2020). Furthermore, Indigenous knowledge is too often only sought superficially—focusing only on the 'what', rather than the 'how' of climate change adaptation and/or seen through the lenses of 'romantic glorification' leaving little room for the knowledge to be expressed as authored by the communities and knowledge holders themselves (Yunkaporta, 2019).

Multiple knowledge systems and frameworks

Indigenous knowledge systems include not only the specific narratives and practices to make sense of the world, but also profound sources of ethics and wisdom. They are networks of actors and institutions that organise the production, transfer and use of knowledge (Löfmarck and Lidskog, 2017). There is a pluralism of forms of knowledge that emerge from oral traditions, local engagement with multiple spaces, and Indigenous cultures (Peterson et al., 2018). Recognising such multiplicity of forms of knowledge has long been an important concern within sustainability science (Folke et al., 2016). Less dominant forms of knowledge should not be put aside because they are not comparable or complementary with scientific knowledge (Brattland and Mustonen, 2018; Mustonen, 2018; Ford et al., 2020; Ogar et al., 2020). Instead, Indigenous knowledge and local knowledge can shape how climate change risk is understood and experienced, the possibility of developing climate change solutions grounded in place-based experiences, and the development of governance systems that match the expectations of different Indigenous knowledge and local knowledge holders (*very high confidence*).

Different frameworks that enable the inclusion of Indigenous knowledge have emerged from efforts to utilise more than one knowledge system (*robust evidence*, *high agreement*). For example, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) has developed a 'nature's contribution to peoples' framework that provides a common conceptual vocabulary and structural analysis (Díaz et al., 2015; Tengö et al., 2017; Díaz et al., 2018; Peterson et al., 2018). The IPBES approach complements other efforts to study areas of intersection between scientific and indigenous worldviews (Barnhardt and Angayuqaq, 2005; Huaman and Sriraman, 2015) or 'boundaries' that illustrate 'blind spots' in scientific knowledge (Cash et al., 2003; Clark et al., 2016; Brattland and Mustonen, 2018). These frameworks highlight areas of collaboration but provide less guidance in areas where sources of evidence conflict across different knowledge systems (Löfmarck and Lidskog, 2017). These experiences suggest that the inclusion of Indigenous knowledge and local knowledge in international assessments may transform the process of assessment of scientific, technical and

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box INDIG (continued)

socioeconomic evidence (*medium evidence*, *high agreement*). These knowledge systems also point to novel discoveries that may be still unknown to the scientific world but have been known by communities for millennia (Mustonen and Feodoroff, 2020).

The importance of free and prior-informed consent

Obtaining free and prior-informed consent is a necessary but not sufficient condition to engage in knowledge production with Indigenous Peoples (Sillitoe, 2016). Self-determination in climate change assessment, response and governance is critical (Chakraborty and Sherpa, 2021), and Indigenous Peoples are actively contributing to respond to climate change (Etchart, 2017). Climate change assessment and adaptation should be self-determined and led by Indigenous Peoples, acknowledge the importance of developing genuine partnerships, respect Indigenous knowledge and ways of knowing, and acknowledge Indigenous Peoples as stewards of their environment (Country et al., 2016; Country et al., 2018; ITK, 2019; Barker and Pickerill, 2020; Chakraborty and Sherpa, 2021). Supporting Indigenous Peoples' leadership and rights in climate adaptation options at the local, regional, national and international levels is an effective way to ensure that such options are adapted to their living conditions and do not pose additional detrimental impacts to their lives (*very high confidence*). Chapter 18 shows that the transformations required to deliver climate-resilient futures will create societal disruptions, with impacts that are most often unevenly experienced by groups with high exposure and sensitivity to climate change, including Indigenous Peoples and local communities (Schipper et al., 2020a). Climate-resilient futures depend on finding strategies to address the causes and drivers of deep inequities (Chapter 18). For example, climate-resilient futures will depend on recognising the socioeconomic, political and health inequities that often affect Indigenous Peoples (Mapfumo et al., 2016; Ludwig and Poliseli, 2018) (*very high confidence*).

International conventions to support and utilise Indigenous knowledge and local knowledge

Several tools within international conventions may support instruments to develop equitable processes that facilitate the inclusion of Indigenous knowledge and leadership in climate change adaptation initiatives. The International Labour Convention 69 recognised Indigenous People's right to self-determination in 1989 (ILO, 1989). The United Nations' Declaration on the Rights of Indigenous Peoples (United Nations, 2007) includes articles on the right to development (Article 23), the right to maintain and strengthen their distinctive spiritual relationship and to uphold responsibilities to future generations (Article 25), and the right to the conservation and protection of the environment and the productive capacity of their territories (Article 29). Article 26 upholds the right to the lands, territories and resources, the right to own, use, develop and control the lands, and legal recognition and protection of these lands, territories and resources. Indigenous Peoples are also recognised within the Sustainable Development Goals as a priority group (Carino and Tamayo, 2019). International events such as the 'Resilience in a time of uncertainty: Indigenous Peoples and Climate Change' conference brought together Indigenous Peoples' representatives and government leaders from around the world to discuss the role of Indigenous Peoples in climate adaptation (UNESCO, 2015).

The value of Indigenous knowledge and local knowledge in climate adaptation planning

There have been increasing efforts to enable Indigenous knowledge holders to participate directly in IPCC assessment reports (Ford et al., 2012; Nakashima et al., 2012; Ford et al., 2016). Adaptation efforts have benefited from the inclusion of Indigenous knowledge and local knowledge (IPCC, 2019e) (*very high confidence*). Moreover, it has been recognised that including Indigenous knowledge and local knowledge in IPCC reports can contribute to overcoming the combined challenges of climate change, food security, biodiversity conservation, and combating desertification and land degradation (IPCC, 2019c) (*high confidence*). Limiting warming to 1.5°C necessitates building the capability of formal assessment processes to respect, include and utilise Indigenous knowledge and local knowledge (IPCC, 2018a) (*medium evidence*, *high agreement*).

However, these efforts have been accompanied by a recognition that 'integration' of Indigenous knowledge and local knowledge cannot mean that those knowledge systems are subsumed or required to be validated through typical scientific means (Gratani et al., 2011; Matsui, 2015). Such a critique of 'validity' can be inappropriate, unnecessary, can disrespect Indigenous Peoples' own identities and histories, limits the advancement and sharing of these perspectives in the formal literature, and overlooks the structural drivers of oppression and endangerment that are associated with Western civilisation (Ford et al., 2016). Moreover, by underutilising Indigenous knowledge and local knowledge systems, opportunities that could otherwise facilitate effective and feasible adaptation action can be overlooked. We should also reserve space for the understanding that each cultural knowledge system, building on linguistic-cultural endemicity, is unique and inherently valuable.

Indigenous Peoples have often constructed their ways of knowing using oral histories as one of the vehicles of mind and memory, observance, governance and maintenance of customary law (Table Cross-Chapter Box INDIG.2). These ways of knowing can also incorporate the relationships between multiple factors simultaneously which adds particular value towards understanding complex systems that is in contrast to the dominant reductionist, Western approach, noting that non-reductionist approaches also exist (Ludwig et al., 2014; Hoagland, 2017).

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box INDIG (continued)

For climate research, the role of oral histories as a part of Indigenous knowledge and local knowledge is extremely relevant. For example, ocean adaptation initiatives can be guided by oral historians and keepers of knowledge who can convey new knowledge and baselines of ecosystem change over long-time frames (Nunn and Reid, 2016). Oral histories can also convey cultural indicators and linguistic devices of species identification as a part of a local dialect matrix, and changes in ecosystems and species using interlinkages not available to science (Mustonen, 2013; Frainer et al., 2020). Oral histories attached to maritime place names, especially underwater areas (Brattland and Nilsen, 2011), can position observations relevant for understanding climate change over long ecological timeframes (Nunn and Reid, 2016). Species abundances, well-being and locations are some of the examples present in the ever-evolving oral histories as living ways of knowing. Indigenous knowledge and oral histories may also have the potential to convey governance, moral and ethical frameworks of sustainable livelihoods and cultures (Mustonen and Shadrin, 2020) rooted in the particular Indigenous or local contexts that are not otherwise available in written or published forms.

Climate change research involving Indigenous Peoples and local communities has shown that the generation, innovation, transmission and preservation of Indigenous knowledge is threatened by climate change (Kermoal and Altamirano-Jiménez, 2016; Simonee et al., 2021). This is because Indigenous knowledge is taught, local knowledge is gained through experience, and relationships with the land are sustained through social engagement within and among families, communities and other societies (Tobias J.K, 2014; Kermoal and Altamirano-Jiménez, 2016). The knowledge that has traditionally been passed on in support of identity, language and purpose has been disrupted at an intergenerational level (Lemke and Delormier, 2017). Many of these dynamics have affected local knowledge transfers equally (Mustonen, 2013). This scenario represents a tension for Indigenous Peoples, where Indigenous knowledge in the form of land-based life ways, languages, food security, intergenerational transmission and application are threatened by climate change, yet in parallel, these same practices can enable adaptation and resilience (McGregor et al., 2020).

Table Cross-Chapter Box INDIG.1 | Examples of Indigenous knowledge and local knowledge about climate change used in this Assessment Report

Issue	Examples of Indigenous Peoples' and local communities' action	Context, peoples and location	Source
Climate forecasting/ early warning	Phenological cues to forecast and respond to climate change	Smallholder farmers, Delta State, Nigeria	Chapter 9
	Forecasting of weather and climate variation through observation of the natural environment (e.g., changes in insects and wildlife).	Afar pastoralists, north-eastern Ethiopia	
	Observation of wind patterns to plan response to coastal erosion/flooding	Inupiat, Alaska, USA	Chapter 14
	Sky and moon observation to determine the onset of rainy season	Maya, Guatemala	Chapter 12
Fire hazards	Prescribed burning	Indigenous nations in Venezuela, Brazil, Guyana, Canada and USA	Chapter 12 Chapter 14
Crop yield/food security	Water management, native seeds conservation and exchange, crop rotation, polyculture and agroforestry	Mapuche, Chile	Chapter 12
	Crop association (milpa) agroforestry, land preparation and tillage practices, native seed selection and exchange, adjusting planting calendars	Maya, Guatemala	Chapter 12
	Harvesting rainwater and the use of maize landraces by Indigenous farmers to adapt to climate impacts and promote food security in Mexico	Yucatán Peninsula, Mexico	Chapter 14
Livelihood and well-being	Cultural values ingrained in knowledge system: reciprocity, collectiveness, equilibrium and solidarity	Quechua, Cusco, Peru	Chapter 12
Ecosystem degradation	Ecosystem restoration including rewilding	Sámi, Nenets, and Komi, Scandinavia and Siberia	Chapter 13
	Collaboration with researchers, foresters and landowners to manage native black ash deciduous trees against emerald ash borer	Indigenous Nations in Canada and USA	Chapter 14
	Selection and planting of native plants that reduce erosion Whole-of-island approaches that embed Indigenous knowledge and local knowledge in environmental governance	Small Islands States (as defined by Chapter 15)	Chapter 15
Fisheries	Traditional climate-resilient fishing approaches	Indigenous nations across North America and the Arctic	Chapter 14 CCP6
Management of urban resources	Restoration of traditional network of water tanks	Traditional communities and activists in South Indian cities such as Bengaluru	Chapter 6

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box INDIG (continued)

Table Cross-Chapter Box INDIG.2 | Case study summary

Region	Summary
Africa	Many rural smallholder farmers in Africa use their ingrained Indigenous knowledge systems to navigate climatic changes as many do not have access to Western systems of weather forecasting. Instead, these farmers have been reported to use observations of clouds and thunderstorms, and migration of local birds to determine the start of the wet season, as well as create temporary walls by rivers to store water during droughts. Indigenous knowledge systems should be incorporated into strategic plans for climate change adaptation policies to help smallholder farmers cope with climate change (Mapfumo et al., 2016).
Arctic	For local Inuit hunters and others who travel across Arctic land, ice and sea, there is evidence that the most accurate approach to reduce risk and enable informed decision making for safe travel is to combine Indigenous knowledge and local observations of weather with official online weather and marine services information that is available nationally (Simonee et al., 2021). Combining Inuit and local knowledge of weather, water, ice and climate information with official forecasts has provided local hunters with more accurate, locally relevant information, and has on several occasions helped to avoid major weather-related accidents.
Latin America	In Venezuela, Brazil and Guyana, Indigenous knowledge systems have led to a lower incidence of wildfires, reducing the risk of rising temperatures and droughts (Mistry et al., 2016). The Mapuche Indigenous Peoples in Chile use various traditional and sustainable agricultural practices, including native seed conservation and exchange (*trafkintu*), crop rotation, polyculture and tree-crop association. They also give thanks to Mother Earth through rituals to nurture socio-ecological sustainability (Parraguez-Vergara et al., 2018). In the rural Cusco Region of Peru, 'cultures values known in Quechua as *ayni* (reciprocity), *ayllu* (collectiveness), *yanantin* (equilibrium) and *chanincha* (solidarity)' have led to successful adaptation to climate change (Walshe and Argumedo, 2016).
Māori (Aotearoa New Zealand)	The traditional calendar system (*maramataka*) used by the Māori in Aotearoa, New Zealand, incorporates ecological, environmental and celestial Indigenous knowledge. Māori practitioners are collaborating with scientists through the Effect of Climate Change on Traditional Māori Calendars project (Harris et al., 2017) to examine if climatic changes are impacting the use of the *maramataka*, which can be used as a framework to identify and explain environmental changes. Observations are being documented across Aotearoa, New Zealand to improve understandings of environmental changes and explore the use of Indigenous Māori knowledge in climate change assessment and adaptation.
Skolt Sámi (Finland)	In 2011, the Skolt Sámi in Finland began the first co-governance initiative where collaborative management and Indigenous knowledge were utilised to effectively manage a river and Atlantic Salmon (*Salmo salar*). This species is culturally and spiritually significant to the Skolt Sámi and has been adversely impacted by rising water temperatures and habitat loss (Brattland and Mustonen, 2018; Feodoroff, 2020; Ogar et al., 2020) (see also CCP Polar). Using Indigenous knowledge, they mapped changes in catchment areas and used cultural indicators to determine the severity of changes. Through collaborative management efforts that utilised both Indigenous knowledge and science, spawning and juvenile habitat areas for trout and grayling were restored, demonstrating the autonomous community capacity (Huntington et al., 2017) of the Indigenous Skolt Sámi and the capacity of Indigenous knowledge to address climate change impacts and detection of very first microplastics pollution together with science (Pecl et al., 2017; Brattland and Mustonen, 2018; Mustonen and Feodoroff, 2020).

The strong role of governments in climate action has implications for the nature of democracy, the relationship between the local and the national state, and between citizens and the state (Dodman and Mitlin, 2015). More integration of government policy and interventions across scales, accompanied by capacity building to accelerate adaptation is needed (*very high confidence*). Key needs include enhanced funding, clear roles and responsibilities, increased institutional capability, strategic approaches, community engagement and judicial integrity (Lawrence et al., 2015). More resources, and more active involvement of the private sector and civil society can help maintain adaptation on the policy agenda. Multi-level adaptation approaches are also relevant in low-income countries where local governments have limited financial resources and human capabilities, often leading to dependency on national governments and donor organisations (Donner et al., 2016; Adenle et al., 2017).

Unlike mitigation, adaptation has traditionally been viewed as a local process, involving local authorities, communities and stakeholders (Preston et al., 2015). The literature on the governance of adaptation continues to emphasise that local governments have demonstrated leadership in implementation by collaborating with the private sector and academia. Local governments can also play a key role (Melica et al., 2018; Romero-Lankao et al., 2018) in converging mitigation and adaptation strategies, coordinating and developing effective local responses, enabling community engagement and more effective policies around exposure and vulnerability reduction (Fudge et al., 2016). Local authorities are well-positioned to involve the wider community in designing and implementing climate policies and adaptation implementation (Slee, 2015; Fudge et al., 2016). Local governments also help deliver basic services and protect their integrity from climate impacts (Austin et al., 2015; Cloutier et al., 2015; Nalau et al., 2015; Araos et al., 2017). However, the resource limitations of local governments as well as their small geographic sphere of influence suggests the need for more funding for this from higher levels of government, particularly national governments, to address adaptation gaps (*very high confidence*) (Dekker, 2020). Local adaptation implementation gaps can be linked to limited political commitment at higher levels of government and weak cooperation between key stakeholders (Runhaar, 2018). Incongruities and conflicts can exist between adaptation agendas pursued by national governments and the spontaneous adaptation practices of communities. There may be grounds for re-evaluating current consultative processes integral to policy development, if narrow technical approaches emerge as the norm for adaptation (Smucker et al., 2015).

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Therefore, the traditional view of adaptation as a local process has now widened to recognise it as a multi-actor process that transcends scales from the local and sub-national to national and even international (*very high confidence*) (Mimura et al., 2014). Many of the impacts of climate change are both local and transboundary, so that local, bilateral and multilateral cooperation is needed (Nalau et al., 2015; Donner et al., 2016; Magnan and Ribera, 2016; Tilleard and Ford, 2016; Lesnikowski et al., 2017). National policies and transnational governance should be seen as complementary, especially where they favour transnational engagement with sub- and non-state actors (Andonova et al., 2017). National governments typically act as a pivot for adaptation coordination, planning, determining policy priorities, and distributing financial, institutional and sometimes knowledge resources. National governments are also accountable to the international community through international agreements. National governments have helped enhance adaptive capacity through building awareness of climate impacts, encouraging economic growth, providing incentives, establishing legislative frameworks conducive to adaptation and communicating climate change information (Berrang-Ford et al., 2014; Massey et al., 2014; Austin et al., 2015; Huitema et al., 2016).

18.4.3.3 Economic and Financial Arenas

The performance of local, national and global economies is a priority consideration shaping perceptions of climate risk and the costs and benefits of different policy responses to climate change. The most commonly used indicator of performance is GDP (Hoekstra et al., 2017). Traditionally, national development efforts have sought to maximise the growth of GDP under the assumption that GDP growth equates not only to economic prosperity (including poverty reduction) but also to increased efficiency and reduced environmental externalities (Ota, 2017). Such assumptions often employ models such as the environmental Kuznets curve (EKC) that postulates that economic development initially increases environmental impacts, but these trends eventually reverse with continued economic growth. Wealthy nations of the Global North, including for example the USA, Great Britain, Iceland and Japan, have had success over the past decade in reducing their GHG emissions while growing their economies (*very high confidence*). However, attempts to empirically test EKC in different national contexts has yielded mixed results. Case studies in Myanmar, China and Singapore, for example, suggest that the impacts of GDP on environmental quality are contingent on the development context and the environmental impact under consideration (Aung et al., 2017; Lee and Thiel, 2017; Xu, 2018; Chen and Taylor, 2020). In addition, an extensive literature now argues that current patterns of development, and the economic systems underpinning that development, are unsustainable (Washington and Twomey, 2016), and thus economic growth may not necessarily continue indefinitely in the absence of more concerted effort to pursue sustainable development, including reducing the impacts of climate change.

Given such criticisms of the link between development and economic growth, a growing number of researchers argue for the need for alternatives to GDP to guide development and evaluate the costs and benefits of different policy interventions (Hilmi et al., 2015). For example, while GDP growth can drive growth in income, it can also drive growth in inequality which can undermine poverty reduction efforts (*very high confidence*) (Fosu, 2017). Hence, recent years have seen significant interest in the concept of well-being as a more robust measure for linking policy and the economy with sustainable development for a healthy Anthropocene era (Fioramonti et al., 2019).

Another mechanism for evaluating environmental performance is to include environmental data in the System of National Accounts (SNA) through the System of Environmental-Economic Accounting (SEEA) introduced by the UN. As the international statistical standard for environmental–economic accounting (Pirmana et al., 2019), SEEA includes natural capital resources in national accounting. A number of recent studies conclude that failure to account for natural capital in macroeconomic impact assessments results in overly optimistic outcomes (Pirmana et al., 2019; Jendrzejewski, 2020; Naspolini et al., 2020); (Banerjee et al., 2019; Kabir and Salim, 2019; Keith et al., 2019). For example, Jendrzejewski (2020) inserted natural capital into a computable general equilibrium model of the 2017 European windstorm on state-owned forests in Poland. This resulted in more negative assessment of impacts, suggesting excluding natural capital could lead to erroneous investments, strategies or policies. Similarly, other studies rely on Quality of life (QOL) measurements as alternatives for GDP. Estoque et al. (2018) suggested a 'QOL-Climate' assessment framework, designed to capture the social-ecological impacts of climate change and variability.

Another alternative to GDP is Green GDP which seeks to incorporate the environmental consequences of economic growth (Boyd, 2007; Stjepanović et al., 2017; Stjepanović et al., 2019). Green GDP is difficult to measure, because it is difficult to evaluate the environmental depletion and ecological damages of growth (Stjepanović et al., 2019). Although there is no consensus in measuring Green GDP, attempts have been made for select countries including the USA (Garcia and You, 2017), Europe (Stjepanović et al., 2019), China (Chi and Rauch, 2010; Yu et al., 2019; Wang et al., 2020), Ukraine and Thailand (Harnphatananusorn et al., 2019), and Malaysia (Vaghefi et al., 2015). Le (2016) illustrated the potential negative impacts of climate change vulnerability on green growth. Some studies have suggested that focusing on green growth as the only strategy to address climate change would be risky. Hickel and Kallis (2020) argue that green growth is likely to be a misguided goal due to the difficulties of separating economic growth from resource use and, therefore, carbon emissions (see also (Antal and van den Bergh, 2014). Therefore, alternative strategies are required (Hickel and Kallis, 2020). In addition, green growth should also be able to justly respond to social movements involving contestation, internal debates and tensions (Mathai et al., 2018).

The emphasis on Green GDP is mirrored by another concept, Blue Growth, that focuses on pursuing sustainable development through the ecosystem services derived from ocean conservation (Mustafa et al., 2019). Synthesis studies suggest that more intensive use of ocean resources, such as scaling up seaweed aquaculture, can be used to enhance CO_2-eq sequestration, thereby contributing to GHG mitigation, while also achieving other economic goals (Lillebø et al., 2017; Froehlich et al., 2019). Similarly, Sarker et al. (2018) present a framework for linking Blue Growth and CRD in Bangladesh, with Blue Growth representing an opportunity for adapting to climate change. Bethel et al. (2021) also links Blue Growth to resilience, noting that a Blue economy

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

can help facilitate recovery from the COVID-19 pandemic. Nevertheless, consistent with earlier assessment of enabling conditions for system transitions (Section 18.4.2.1), implementation of Blue Growth initiatives is contingent upon the successful achievement of social innovation as well as creating an inclusive and cooperative governance structure (*very high confidence*) (Larik et al., 2017; Soma et al., 2018).

A potential critique of the various alternative metrics and models for economic development is that they are all framed in the context of growth. Over the past decade, ecological economists and political scientists have proposed degrowth (e.g., Kallis, 2011; Demaria et al., 2013) and managing without growth (e.g., Jackson, 2009) as a solution for achieving environmental sustainability and socioeconomic progress. Such concepts are a deliberate response to concerns about ecological limits to growth and the compatibility between growth-oriented development and sustainability (Kallis et al., 2009). Sustainable degrowth is not the same as negative GDP growth, which is typically referred to as a recession (Kallis, 2011). Degrowth goes beyond criticising economic growth; it explores the intersection among environmental sustainability, social justice and well-being (Demaria et al., 2013). Under current economic and fiscal policies (see Box 18.7), degrowth has been argued as an unstable development paradigm because declining consumer demand leads to rising unemployment, declining competitiveness and a spiral of recession (Jackson, 2009: 46). More comprehensive modelling of socioeconomic performance understands the segments of sufficient social transformation to guarantee maintenance and rises in well-being coupled with reduced 'footprints' (Raworth, 2017; Hickel, 2019; D'Alessandro et al., 2020).

18.4.3.4 Knowledge–Technology and Ecological Arenas

Knowledge–technology arenas comprise the interaction in knowledge spaces connected to technology transitions. The institutional and political architecture through which knowledge and technology interact is described in sustainability transitions literature (Fazey et al., 2018b; Sengers et al., 2019l Kanger, 2020 #3709). A common theme explored in that literature is the ability of actors to access and apply various forms of knowledge as a means of effecting change. Different forms of innovation are recognised as a core enabling condition for achieving system transitions for CRD (Section 18.3.3; Cross-Chapter Box INDIG). However, while scientific and technology knowledge may be useful, in some cases, they remain subordinate to political agendas, or are controlled by actors in positions of power and thus not equitably distributed (*very high confidence*) (Mormina, 2019). Participatory decision making, for example, assumes that multiple actors, with differing motivations, agency and influence, engage with climate decision making and co-produce actions. Yet some actors may not participate in the process if the proposed actions do not align with their motivations or if they do not have adequate agency (Roelich and Giesekam, 2019). Hence, effectively using knowledge to inform policy is challenging for both scientists, policymakers and civil society alike.

Science, technology and innovation (STI) policies are expected to shape expectations of the potential for a better world based on access to information, clean technologies, higher labour productivity, economic growth and a healthier environment (Brasseur and Gallardo, 2016; Schot and Steinmueller, 2018; Singh et al., 2018; Mormina, 2019; Bamzai-Dodson et al., 2021). STI policies are considered as 'social goods for development'. Hence, STI policies are often proposed or implemented as means of addressing environmental challenges such as climate change along with SDGs such as the reduction of inequality, poverty and environmental pollution (Mormina, 2019). Realising the benefits of STI, however, may be contingent on building broader STI capacity and bolstering nations' systems of innovation (*very high confidence*) (Mormina, 2019). This could include building global research partnerships to address priority STI needs as well as long-standing gaps between the Global North and South. Such an approach shifts the framing of STI as one focused on individual

Box 18.7 | Macroeconomic Policies in Support of Climate Resilient Development

Climate change risk may differ from other economic and financial risks in a number of ways: climate change is global; it involves long-term impacts and a great deal of uncertainty; and it has the possibility of irreversible change (Hansen, 2021). The macroeconomic implications will differ across countries, with less developed countries likely to suffer more relative to more advanced ones (Batten, 2018). Hence, policymakers need to understand the impact of climate change on macroeconomic issues such as potential output growth, capital formation, productivity and long-run levels of interest rates, in order to better design policy interventions, be it monetary or fiscal (Economides and Xepapadeas, 2018; Bank of England, 2019; Rudebusch, 2019). As discussed, below are a range of fiscal tools that can be leveraged to mitigate the effects of climate change (Krogstrup and Oman, 2019).

Monetary Policy

Changes in climate and subsequent policy responses could increase volatility of food and energy prices, resulting in higher headline inflation rates. Thus, Central Banks (CBs) have to pay careful attention to underlying inflationary factors to maintain their inflationary targets. In response, CBs can take a number of actions. For example, they could require that collateral comprises assets that support the move to low-carbon economy, or their refinancing operations and crisis facilities could incentivise borrowers' move to low-carbon activities, particularly in countries where CBs' mandate has been expanded to account for climate impact (Papoutsi et al., 2021). Other actions that CBs could take include adoption of sustainable and responsible investment principles (Rudebusch, 2019) and requiring financial firms to disclose their climate-related risks (ECB, 2020; Lee, 2020). Despite these opportunities, there is ongoing debate regarding whether CBs should actively use monetary policy to address climate change and its risks (Honohan, 2019).

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Box 18.7 (continued)

Fiscal Policy

The application of green fiscal policies to address climate change could lead to environmental benefits, including environmental revenues that may be used for broader fiscal reforms (OECD, 2021). As the USA aims at becoming carbon neutral by 2050, fiscal policies at the national, sectoral and international level can help to achieve this goal, along with investment, regulatory and technology policies (Parry, 2021). The effectiveness of green fiscal policies are through their fiscal potential, opportunities for efficiency gains, distributional and macroeconomic impacts, and their political economy implications (Metcalf, 2016). The International Monetary Fund argues public support for green policies may rise in response to the COVID-19 crisis (IMF, 2017). For example, Leibenluft (2020) argues that investments to combat climate change should be an important component of the efforts to rebuild the economy in the wake of COVID-19. Such action is justified not only on ecological and social welfare grounds, but from a long-term fiscal perspective. For example, climate change impacts and/or efforts to adapt to those impacts drive increased spending in areas such as public health and disaster mitigation or response. Preventive and corrective actions would strengthen resilience to shocks and alleviate the financial constraints they create, particularly for small countries (Catalano et al., 2020). For example, Mallucci (2020) found that natural disasters exacerbate fiscal vulnerabilities and trigger sovereign defaults in seven Caribbean countries. Ryota (2019) illustrates how to include natural disaster and climate change in a fiscal policy framework to developing countries.

Carbon Pricing

Pricing of GHGs, including carbon, is a crucial tool in any cost-effective climate change mitigation strategy, as it provides a mechanism for linking climate action to economic development (IMF/OECD, 2021). By 2019, 57 nations around the world had implemented or scheduled implementation of carbon pricing. These initiatives cover 11 gigatons of carbon dioxide or about 20% of GHG emissions. Carbon prices in existing initiatives range between USD 1 and USD 127 per ton of carbon dioxide, while 51% of the emissions that are covered are priced more than USD 10 per ton of carbon dioxide. Moreover, in 2018, Governments raised about USD 44 billion in carbon pricing revenues (World Bank, 2019). However, the carbon prices are lower than the levels required for attaining the ambitious goal of climate change mitigation, and therefore, prices would need to increase if pricing alone is going to be used to drive compliance with the Paris Agreement. Higher carbon prices would also be warranted if prices are based on the social cost of carbon, which represents the present value of the marginal damage to economic output caused by carbon emissions (Cai and Lontzek, 2018). This cost needs to be considered with the social benefits of reducing carbon emissions through cost-benefit analyses to make the intended regulation acceptable.

Taxes

Carbon taxes represent another financial mechanism for addressing climate change (Metcalf, 2019), 2019b). For example, the implementation of a carbon tax and a value-added tax on transport fuel in Sweden resulted in a reduction of CO_2 emissions from transport of about 11%, of which the carbon tax had the largest share (Andersson, 2019). In the USA, for example, a carbon tax could increase fiscal flexibility by collecting new revenues that can be redeployed to finance reforms and help stimulate economic growth. However, US tax-inclusive energy prices would have to be 273% higher than laissez-faire levels in 2055 in order to meet international agreements (Casey, 2019). Similarly, limiting global warming to 2°C or less would likely require a carbon tax rate in the Asia/Pacific region to be significantly higher than USD 25 per ton (IMF, 2021). Therefore, using tax revenues to issue payments back to taxpayers that are disproportionately impacted, or to redistribute capital among regions, may be one of the most important features of carbon tax policies. Although the average effect of carbon tax on welfare would be positive, some regions (56%) will gain and some regions (44%) lose (Scobie, 2013). Therefore, large transfer payments are needed to compensate those losing from carbon tax (Krusell and Smith, 2018). The International Monetary Fund (IMF (2019) argues that, of the various mitigation strategies to reduce fossil fuel CO_2 emissions, carbon taxes are the most powerful and efficient, because they allow firms and households to find the lowest-cost ways of reducing energy use and shifting towards cleaner alternatives.

Subsidies

The World Bank has been encouraging both developed and developing states, especially those with petroleum reserves, to use the removal of subsidies as a mechanism for promoting energy transitions away from fossil fuels. The transition has led to social unrest in some cases, especially where there is a culture of entitlement to low-cost energy because it is an indigenous resource. Such reforms have been more effective when governments have been able to clearly show how savings are applied to social and health programs that benefit human well-being. Nevertheless, policymakers should not underestimate the complexity of issues involved in the removal of subsidies that will increase the cost of carbon and hasten the transition to cleaner fuels (Scobie, 2017; Scobie et al., 2018; Chen et al., 2020a). A crucial issue to take into account is the harmful effects some subsidies have on biodiversity. Although governments agreed in 2010 to make progress on reducing subsidies in 2010, by 2020 few governments had identified specific incentives to remove or taken action towards their removal. Further investigation of the positive and negative effects of subsidy redirection or elimination on people and the environment (Dempsey et al., 2020).

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

investigators to one comprised of building knowledge networks. It also creates opportunities for integration of disparate forms of knowledge and innovation, including local and Indigenous knowledge, into global knowledge systems (Cross-Chapter Box INDIG).

Furthermore, an extensive literature increasingly incorporates natural and ecological systems as knowledge domains relevant to understanding opportunities for sustainability and CRD. For example, the literature on socio-ecological systems (SES) (Sterk et al., 2017; Holzer et al., 2018; Avriel-Avni and Dick, 2019; Martínez-Fernández et al., 2021) as well as social, ecological and technological systems (SETS) (McPhearson and Wijsman, 2017; Webb et al., 2018; Ahlborg et al., 2019), explicitly integrate ecological knowledge into sustainability, including concepts such as planetary boundaries (Section 18.1.1), adaptation and nature-based solutions, natural resources management, rights and access to nature, and understanding of how humans govern society–nature interactions in the face of climate change (Benjaminsen and Kaarhus, 2018; Mikulewicz, 2019; Nightingale et al., 2020). Some of these interactions are explained in Cross-Chapter Box INDIG, including conflict over which knowledges are recognised as valuable in understanding and responding to climate change and therefore shape the nature of climate actions. Actor engagement in stewardship, solidarity and inclusion of multiple knowledges and nature–society connectedness can highlight the intertwined nature of ecological change and knowledge relations, thereby supporting shifts to sustainability (Pelling, 2010; Hulme, 2018; Ives et al., 2019; Nightingale et al., 2020) (see also Box 18.6).

The expanding definition of what constitutes credible, relevant and legitimate knowledge is leading to the democratisation of knowledge and efforts to address historical inequities in access to knowledge (Ott and Kiteme, 2016; Rowell and Feldman, 2019). This is reflected in the communication of science, which is increasingly focused on reducing the distance between internal scientific and public communication and more engagement in public science governance and knowledge production (Waldherr, 2012; Peters, 2013). One innovative approach in co-production of knowledge is mobilising communities through citizen science (Heigl et al., 2019). This also presents additional opportunities to incorporate local knowledge with scientific research, and better match scientific capability to societal needs.

18.4.3.5 Community Arenas

Societal choices and development trajectories emerge from decisions made in different arenas which intersect and interact across levels and scales, in diverse institutional settings—some formal with their associated instruments and interventions, while others are informal. Since AR5, both formal and informal setting are increasingly arenas of debate and contestation regarding development choices and pathways (*very high confidence*) (Section 18.4.4, Chapters 1, 6, 8, 10 and 17). Community arenas exist from the local to the global scale and constitute the many interactions between governance actors, often transcending any one scale to reflect the emergent outcomes of interactions in political, economic, socio-cultural, knowledge-technology and ecological arenas of engagement. Actions within and between these five arenas hence come together in the community arena of engagement. While community engagement is often described at the level of villages and cities (Ziervogel et al., 2021) (Chapter 8), communities in terms of people interacting with each other sharing worldviews, values and behaviours, also exist at the regional and global levels. For example, civil society engagement in climate action reached a peak in 2019, notably through the global youth movement which led to large global mobilisation and street demonstrations on all continents and in many large cities (Bandura and Cherry, 2020; Han and Ahn, 2020; Martiskainen et al., 2020). Calling for enhanced climate action by governments and other societal actors, the youth movement was supported by many other societal groups and networks, including arenas of community interaction.

While the SR1.5 (de Coninck et al., 2018) for the first time comprehensively assessed behavioural dimensions of climate change adaptation, most literature still has a greater focus on what triggers mitigation behaviour (Lorenzoni and Whitmarsh, 2014; Clayton et al., 2015). Meanwhile, with CRD still a relatively young concept, there is little literature focused on what motivates action in pursuit of CRD rather than its sub-components of climate action and sustainable development. Nevertheless, a common motivation that is emerging in the literature is clinically significant levels of climate distress among individuals (Bodnar, 2008), which is experienced as a continuing distress over a changed landscape which no longer offers solace, also known as solastalgia (*high agreement*, *medium evidence*) (Albrecht et al., 2007). This is accompanied by a shift from blaming natural forces for disasters to attributing it to human negligence, which is known to lead to more acute perceptions of risk as well as more prolonged post-traumatic stress disorder (PTSD) than trauma arising from non-human causes. Improving social connections, acknowledging anxiety, reconnecting to nature and finding creative ways to re-engage are identified as ways of managing this growing anxiety (Lertzman, 2010; Clayton et al., 2017). Climate action in communities at various scales could fulfil many of these needs.

18.4.4 Frontiers of Climate Action

After decades of limited government action and social inertia to reduce the risk of climate change, there is also increasing social dissent towards the current political, economic and environmental policies to address climate (Brulle and Norgaard, 2019; Carpenter et al., 2019). Social movements are demanding radical action as the only option to achieve the mobilisation necessary for deep societal transformation (*very high confidence*) (Hallam, 2019; Berglund and Schmidt, 2020).

Prompted by SR1.5, new youth movements seek to use science-based policy to break with incremental reforms and demand radical climate action beyond emissions reductions (Hallam, 2019; Klein, 2020; Thackeray et al., 2020; Thew et al., 2020). Recent social movements and climate protests embrace new modalities of action related to political responsibility for climate injustice through disruptive collective political action (Young, 2003; Langlois, 2014). This is complemented by a regenerative culture and ethics of care (Westwell and Bunting, 2020). These new social movements are based on non-violent methods of resistance, including actions classified as dutiful, disruptive and dangerous dissent (O'Brien, 2018).

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

The new climate movement mixes messages of fear and hope to propel urgency and the need to respond to a climate emergency (Gills and Morgan, 2020). While some consider the mix between fear and hope as beneficial to success, depending on psychological factors (Salamon, 2019) or political geography (Kleres and Wettergren, 2017), others warn of the risks of a rhetoric of emergency and its political outcomes (Hulme and Apollo-University Of Cambridge Repository, 2019; Slaven and Heydon, 2020).

Research shows that new climate movements have increased public awareness, and also stimulated unprecedented public engagement with climate change (*very high confidence*) (Lee et al., 2020; Thackeray et al., 2020) and has helped rethink the role of science with society (Isgren et al., 2019). Such movements may represent new approaches to accelerate social transformation and have resulted in notable political successes, such as declarations of climate emergency at the national and local level, as well as in universities. Their methods have also proven effective to end fossil fuel sponsorship (Piggot, 2018). Social demands for radical action are likely to continue to grow, as there is growing discontent with political inertia and a rejection of reformist positions (Stuart et al., 2020).

Box 18.8: The Role of the Private Sector in Climate Resilient Development via Climate Finance, Investments and Innovation

Climate finance broadly refers to resources that catalyse low-carbon and climate resilient development. It covers the costs and risks of climate action, supports an enabling environment and capacity for adaptation and mitigation, and encourages research and development (R&D) and deployment of new technologies. Climate finance can be mobilised through a range of instruments from a variety of sources, international and domestic, public and private (Section 18.4.2.2).

The private sector has particular competencies which can make significant contributions to adaptation, through innovative technology, design of resilient infrastructure, development and implementation of improved information systems, and the management of major projects. The private sector can be seen as a 'supplier of innovative goods and services' to meet the adaptation priorities of developing countries with expertise in technology and service delivery (Biagini and Miller, 2013).

Future investment opportunities in climate resilient development (CRD) are in water resources, agriculture and environmental services. Provision of clean water is another opportunity, requiring investment in water purification and treatment technologies such as desalination and wastewater treatment. Weather and climate services are a possible area for private investment. (Hov et al., 2017; Hewitt et al., 2020).

18.5 Sectoral and Regional Synthesis of Climate Resilient Development

Prior sections of this chapter assessed the literature relevant to CRD inclusive of climate risk management, systems transitions and transformation, and actors and the arenas in which they engage one another to enable or constrain CRD. Here, this knowledge is explored in different climatological and development contexts through a synthesis of CRD-relevant assessments within the WGII sectoral and regional chapters.

18.5.1 Regional Synthesis of Climate Resilient Development

In synthesising regional knowledge relevant to the pursuit of CRD, this section first considers geographic heterogeneity in regional responses of common climate variables to increases in globally averaged temperatures. Such heterogeneity is a key driver of climate risk in different global regions, as well as human and natural systems within those regions. This is followed by synthesis of various national development indicators, aggregated to the regional level, as well as various challenges, opportunities and options supporting CRD reported within WGII regional chapters.

18.5.1.1 Climate Change Risk for Different Global Regions

Two important elements of understanding the opportunities and challenges associated with the pursuit of CRD in different regional contexts are a) the geographic variability in climate conditions that shape livelihoods, behaviours and responses of human and natural systems; and b) how those conditions could shift in the future in response to climate change, which determines the additional burden that climate change could create for adaptation and sustainable development.

The climate analyses of WGI provide information on regional differences in temperature, rainfall and sea surface temperatures for different global regions and how they are projected to change in response to different levels of aggregate global warming (Table 18.4). Such data reveal that even when aggregated to broad geographic regions, significant variations exist for all of these parameters, which is a function of the baseline climatology of each region. For example, temperatures in Africa and Australia are, on average, warmer than in Europe or North America. Significant variations are also observed for rainfall variables. Such regional variation in climate conditions is part of the regional context that shapes current patterns of development of the past present and future. They influence biodiversity and natural resource availability as well as exposure to climatic extremes (tropical storms, heatwaves and drought) that contribute to disasters.

The WGI data also indicate that increases in globally averaged temperatures will have different consequences for regional climate change (Table 18.4), including variation in the magnitude and, for precipitation, even the direction of change (*very high confidence*). For example, although average temperatures, daily minimum temperature and the number of days over a given threshold are projected to increase

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

in all regions except Antarctica, the magnitude of the change varies. Moreover, little change is projected for daily maximum temperatures across different regions. Nevertheless, the number of days over different temperature thresholds such as 35°C increases markedly in most regions, reflecting the disproportionate impact that global warming has on the tails of temperature distributions. Given outcomes in many systems including public health, agriculture, ecosystems and biodiversity, and infrastructure are often associated with biophysical thresholds (e.g., physiological or design thresholds), those regions where such thresholds are increasingly exceeded due to climate change may experience disproportionately higher impacts (*very high confidence*). Given such temperatures occur more frequently in regions such as Africa and Central and South America, this disproportionate exposure is exacerbated by disproportionate vulnerability, adaptation gaps and development needs (*very high confidence*; Section 18.2.4; Table 18.4).

The regional response of precipitation to globally averaged temperature increases is less clear than temperature, in part due to high intra-region variability. Average daily precipitation remains fairly stable in all global regions in response to higher magnitudes of global warming (Table 18.4). However, 5-day precipitation totals provide a clearer signal of increasing hydrologic activity in response to higher globally averaged temperatures (Table 18.4). Such data does not necessarily reflect changes in rainfall extremes that could occur with downstream consequences for hazards such as drought or flooding. Similarly, while sea surface temperatures (SSTs) are more uniform across global ocean basins, all basins are anticipated to warm in response to higher globally averaged temperatures (Table 18.5). Unlike temperature, however, SST increases are anticipated to be only a fraction of the globally averaged increase in temperature, due in large part to the heat capacity of the oceans. Nevertheless, such higher SSTs have implications not only for ocean ecosystems and the distribution of marine species, but also for weather patterns, such as formation and intensity of tropical cyclones (*very high confidence*).

The other aspect of the regional climate responses to global temperature increases that is important for CRD is the marked differences observed between changes in response to 1.5°C versus 4°C of warming. Higher levels of global warming are associated with higher regional changes, including changes in extremes of temperature. This in turn increases climate risk to exposed and vulnerable human and natural systems, thereby increasing demand for adaptation. If that demand is not met, then the adaptation gap will be larger, with greater risk of loss and damage (*very high confidence*) (Schaeffer et al., 2015; Chen et al., 2016; United Nations Environment Programme, 2021). This is true not only for regions, but also at the sectoral level (Section 18.5.2). Therefore, CRD pathways must balance the demands for emissions reductions to reduce exposure, adaptation to manage residual climate change risks, and sustainable development to address vulnerability and enhance capacity for sustainable development.

18.5.1.2 Regional Perspectives on Climate Resilient Development

The various regional chapters within the AR6 WGII report each provide insights into progress towards CRD as well as the opportunities and challenges associated with future pursuit of different CRD pathways. Common indicators of development reflect the significant diversity that exists across different global regions with respect to their development context (*very high confidence)*. For example, the Human Development Index, recently adjusted to reflect the effect of planetary pressures (PPAHDI), illustrates the overall higher levels of development of North America and European countries of the Global North as well as Australasia compared with Asia, Africa, Central and South America and small islands of the Global South. Generally, this reflects the higher levels of vulnerability and greater need for both sustainable developments to reduce poverty and support sustainable economies as well as climate action to address climate risk (Table 18.6).

However, even within a given region, there is significant variation in PPAHDI among nations. Such differences reflect fundamental differences in historical patterns of development, as well as current development needs and challenges, and they imply differences in what future development pathways would be consistent with CRD. In addition, nations and regions with lower PPAHDI values suggests greater capacity challenges for both GHG mitigation and climate adaptation. However, nations and regions with high PPAHDI values also tend to have higher per capita CO_2-e emissions production, indicating that economic development based on fossil fuel use undermines both efforts on climate action as well as the SDGs (*very high confidence*) (Figure 18.6). Such challenges are also reflected by differential Gini coefficients and metrics of state fragility among regions, which reflect inequities in income distribution and broader vulnerability of nations and regions to shocks and stressors (Figure 18.6). In addition, high variation is observed in CO_2 emissions production, even among comparatively wealthy nations, suggesting CO_2-e emissions of some nations are tightly coupled to development, while others have pursued more carbon neutral development trajectories. Even within regions such as Africa, Asia, Central and South America, and Europe, large within-region variations are observed in inequality and state fragility, suggesting high variability among nations. Given the emphasis in the sustainable development and CRD literature on equity and vulnerability, addressing such determinants of vulnerability is a core design principle for CRDPs.

In addition to development indicators, the literature assessed in the WGII regional chapters indicates that different regions experience a range of development challenges and opportunities that affect the pursuit of CRD (*very high confidence*). These represent dimensions of governance, institutions, economic development, capacity, and social and cultural factors that shape decision making, investment and development trajectories. For example, significant challenges exist within regions with respect to managing debt and the ability to fund or finance climate action and sustainable development interventions (*very high confidence*). On the other hand, a broad range of opportunities exist to pursue CRD including challenges with debt and financing of adaptation competing policy objectives, social protection programmes, economic diversification, investing in education and human capital development, and expanding disaster risk reduction efforts (*very high confidence*).

There are a wide variety of more focused options for climate action and sustainable development (*very high confidence*). Such options have potential for synergies and trade-offs including implications for GHG mitigation, land use change and conservation, food and water,

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Table 18.4 | Projected continental level result ranges for select temperature and precipitation climate change variables by global warming level. Ranges are 5th and 95th percentiles from SSP5-8.5 WGI CMIP6 ensemble results. There is little variation in the 5th and 95th percentile values by GWL across the SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5 projections. Source: WGI AR6 Interactive Atlas (Gutiérrez et al., 2021).

Climate variable	Global warming level	All Regions	North America	Europe	Asia	Central–South America	Africa	Australia	Antarctica
Mean temperature (°C)	4°C	12 to 15	8 to 11	5 to 9	12 to 14	24 to 27	26 to 29	24 to 27	–33 to –27
	3°C	11 to 14	6 to 11	4 to 7	10 to 14	23 to 26	25 to 28	23 to 26	–35 to –26
	2°C	10 to 13	5 to 9	3 to 6	8 to 12	22 to 25	24 to 27	22 to 25	–36 to –27
	1.5°C	9 to 12	4 to 8	2 to 5	8 to 12	22 to 24	24 to 26	22 to 24	–36 to –27
Minimum of daily minimum temperatures (°C)	4°C	–12 to –5	–25 to –15	–22 to –14	–18 to –9	11 to 15	10 to 14	5 to 10	–64 to –48
	3°C	–13 to –6	–27 to –15	–24 to –15	–20 to –11	10 to 15	8 to 14	4 to 10	–64 to –50
	2°C	–15 to –8	–30 to –18	–27 to –17	–22 to –13	9 to 14	7 to 13	3 to 9	–65 to –51
	1.5°C	–16 to –9	–32 to –20	–28 to –19	–23 to –14	8 to 14	6 to 12	3 to 9	–66 to –51
Maximum of daily maximum temperatures (°C)	4°C	32 to 37	32 to 38	28 to 33	35 to 40	36 to 43	40 to 47	41 to 49	–12 to –5
	3°C	31 to 39	31 to 38	28 to 34	35 to 41	35 to 44	39 to 51	41 to 54	–12 to –3
	2°C	30 to 37	30 to 36	26 to 33	33 to 39	34 to 43	38 to 50	39 to 53	–13 to –4
	1.5°C	29 to 36	29 to 35	25 to 31	32 to 39	33 to 42	38 to 49	39 to 52	–14 to –5
Number of days with maximum temperature above 35°C—bias adjusted	4°C	81 to 106	36 to 50	11 to 22	57 to 77	138 to 194	153 to 210	140 to 168	0 to 0
	3°C	66 to 87	27 to 40	6 to 15	44 to 59	100 to 153	131 to 183	124 to 147	0 to 0
	2°C	52 to 68	19 to 29	4 to 8	33 to 45	61 to 106	116 to 151	102 to 124	0 to 0
	1.5°C	45 to 58	16 to 24	2 to 5	30 to 39	43 to 85	107 to 133	94 to 115	0 to 0
Near-surface total precipitation (mm/d)	4°C	2 to 3	2 to 3	2 to 2	2 to 3	4 to 5	2 to 3	1 to 2	1 to 1
	3°C	2 to 3	2 to 3	2 to 2	2 to 3	3 to 5	2 to 3	1 to 2	1 to 1
	2°C	2 to 3	2 to 3	2 to 2	2 to 3	3 to 5	2 to 3	1 to 2	1 to 1
	1.5°C	2 to 3	2 to 3	2 to 2	2 to 3	3 to 5	2 to 3	1 to 2	1 to 1
Maximum 5-day precipitation amount (mm)	4°C	79 to 99	75 to 93	53 to 71	81 to 105	118 to 168	68 to 113	81 to 124	20 to 29
	3°C	66 to 99	68 to 87	48 to 68	70 to 101	97 to 165	60 to 118	76 to 129	19 to 27
	2°C	64 to 93	65 to 84	47 to 65	66 to 95	93 to 162	55 to 107	73 to 122	18 to 26
	1.5°C	63 to 91	63 to 83	46 to 64	64 to 93	92 to 160	52 to 105	74 to 119	18 to 25

Table 18.5 | Projected sea surface temperature change ranges by global warming level and ocean biome (°C). Ranges are 5th and 95th percentiles from SSP5-8.5 WGI CMIP6 ensemble results. There is little variation in the 5th and 95th percentile values by GWL across the SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5 projections. Source: WGI AR6 Interactive Atlas (Gutiérrez et al., 2021).

Global warming level	All ocean biomes	Northern Hemisphere; high latitudes	Northern Hemisphere; Subtropics	Equatorial	Southern Hemisphere; Subtropics	Southern Hemisphere; high latitudes	Gulf of Mexico	Eastern Boundaries	Amazon River	Arabian Sea	Indonesian flowthrough
4°C	1.9 to 2.4	2.0 to 3.3	2.2 to 2.8	2.1 to 3.0	1.8 to 2.4	1.3 to 2.0	2.1 to 2.8	2.1 to 2.7	1.7 to 2.5	2.3 to 2.9	1.9 to 2.7
3°C	1.3 to 1.7	1.2 to 2.2	1.4 to 2.4	1.4 to 2.2	1.2 to 1.7	0.7 to 1.4	1.5 to 2.3	1.4 to 2.1	1.2 to 2.0	1.6 to 2.2	1.3 to 1.9
2°C	0.6 to 1.0	0.5 to 1.4	0.7 to 1.4	0.7 to 1.3	0.5 to 1	0.3 to 0.8	0.6 to 1.4	0.6 to 1.3	0.6 to 1.3	0.6 to 1.3	0.5 to 1.2
1.5°C	0.2 to 0.7	0.1 to 0.9	0.2 to 1.0	0.2 to 0.8	0.2 to 0.6	0.1 to 0.5	0.2 to 1.0	0.2 to 0.9	0.2 to 0.9	0.2 to 0.9	0.1 to 0.8



Figure 18.6 | This figure presents National Gini coefficients (most recent year available; n = 141 (World Bank, 2021), the Fragile States Index (2021; n = 163; (Fund for Peace, 2021), and per capita CO2 emissions (2018; n = 169), Human Development Report Office, 2020) plotted against the Planetary Pressures-Adjusted Human Development Index (2020, n = 163 (Human Development Report Office, 2020)

or social equity. Despite variation in development context, regional assessments suggest CRD efforts will be associated with some common features. For example, in all regions, existing vulnerability and inequality exacerbate climate risk and therefore pose challenges to CRD (*very high confidence*). Furthermore, low prioritisation of sustainability and climate action in government decision making, low perceptions of climate risk, and path dependence in governance systems and decision-making processes all pose barriers to system transitions, transformation and CRD (*very high confidence*).

18.5.2 Sectoral Synthesis of Climate Resilient Development

The sectoral chapters of the WGII report provide insights regarding how development processes interact with sectors to shape the potential for CRD. Similar to global regions, each sector is associated with various challenges, opportunities and options that enable or constrain CRD (Table 18.7). A number of challenges are common across sectors and mirror those associated with different regions. For example, issues associated with natural resource dependency, access to information for decision making, access to human and financial capital, and path dependence of institutions represent barriers that must be overcome if sectors are to support transitions that enable CRD. These challenges are more acute within vulnerable communities or nations where capacity to innovate and invest are constrained and social inequities reinforce the status quo (*very high confidence*). At the same time, a number of sector-specific opportunities for mitigation, adaptation and sustainable development can be used to integrate sectors into CRDPs. This could include policies and planning initiatives to enhance sector sustainability and resilience, as well as capacity building and greater inclusion of different actors and groups in decision making including capitalising on local and Indigenous knowledge as a mechanism for more representative and equitable action.

In addition, the sectoral assessments identify a broad range of specific adaptation, mitigation and sustainable development options that could play a role in facilitating CRD. Many of these options appear initially to be specific to a given sector. For example, options for the water sector (Chapter 4) are assessed independently from those for health and well-being (Chapter 7). In practice, however, evidence suggests the importance of thinking about sectoral options as cross-cutting, mutually supportive and synergistic packages rather than singular options. First, each of the sectoral chapters has links to multiple SDGs (Table 18.7), implying each sector is important for achieving a range of sustainability goals that extend beyond sectoral boundaries. Moreover, progress across multiple sectors simultaneously creates opportunities for synergies for achieving the SDGs, but also enhances the risk of potential trade-offs (*very high confidence*). Second, a number of options are common to multiple sectors. For example, options associated with ecosystem-based adaptation and nature-based approaches to environmental management appear in multiple sectors (Table 18.7). Similarly, climate-smart agriculture and agroecological approaches to food systems create opportunities for food security, but those same options also benefit land-based ecosystems, water, poverty and livelihoods, and human well-being.

18.5.3 Feasibility and Efficacy of Options for Climate Resilient Development

While both the sectoral and regional assessments indicate a rich toolkit of management options is available to decision makers to facilitate CRD, two key uncertainties undermine efforts to implement those options. The first is the feasibility of implementation. Options that seem promising could nevertheless encounter implementation barriers due to cost, absence of necessary capacity, lack of public acceptance or competition with alternative options. Progress in the literature since the AR5 and SR1.5 reports enables improved consideration

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Table 18.6 | Regional synthesis of dimensions of climate resilient development. For each region, quantitative information is provided on common development indicators including the planetary pressures-adjusted human development index (PPHDI, 2020, n = 169 (Human Development Report Office, 2020), Gini coefficients (GINI, most recent year available; n = 156 (World Bank, 2021), Fragile States Index (FRAGILITY; 2021; n = 173 (Fund for Peace, 2021), and per capita CO_2 emissions production (CO_2/PC, 2018; n = 169 (Human Development Report Office, 2020). Each indicator is associated with a mean value among nations within a specific region as well as the range (minimum to maximum) value. In addition, the table contains evidence of sustainable development challenges and opportunities as well as adaptation/sustainable development options and potential synergies and trade-offs associated with their implementation. Synergies and trade-offs are categorised as follows: (T) Trade-off among policies and practices; (S+) Synergy among policies and practices that enhances sustainability; (S-) Synergy among policies and practices that undermines sustainability.

Region	*Development indicators* mean (range)		*Challenges*	*Opportunities*	*Options*	*Synergies and trade-offs*
Africa	PPAHDI	0.53 (0.39–0.72)	– Institutional and financial challenges in programming and implementing activities to support concrete adaptation measures (Section 9.14.5) – High debt levels exacerbate fiscal challenges and undermine economic resilience (Section 9.14) – Insufficient development and adaptation finance and accessibility of finance (Section 9.14.5) – Complexity of estimating the costs and benefits for adaptation measures in specific contexts (Section 9.14.2) – Exclusions of migrants and other vulnerable populations from social programmes (Section 9.9.4) – Mismatch between the supply of, and demand for, climate services (Section 9.5)	– Climate change literacy can enable the mainstreaming of climate change into national and sub-national developmental agendas (Section 9.4.2) – Adaptive responses can be used as an opportunity for comprehensive, transformative change (Section 9.6.2) – Investments in human capital can facilitate socioeconomic development and poverty reduction (Section 9.9.1) – Strengthening the participation of women in decision making as well as advancing traditional and local knowledge can support climate action and sustainable livelihoods (Section 9.9.3)	– Strengthening climate services (Section 9.4.2) – Ecosystem-based adaptation (Section 9.11.4.2) – Economic diversification (Section 9.12.3) – Intensive irrigation (Section 9.15.2) – Agricultural and livelihood diversification (Section 9.12.3) – Drought-resistant crop varieties (Section 9.15.2) – Soil and water conservation (Section 9.15.2)	– (T) competing uses for water such as hydropower generation, irrigation and ecosystem requirements create trade-offs among different management objectives (Section 9.7.3) – (T) migration in response to unfavourable environmental conditions provides opportunities for farmers but puts pressure on the provision of social services and reduces farm labour (Section 9.15.2) – (T) intensive irrigation contributes to the development of agriculture but has come at a cost to ecosystem integrity and human well-being (Section 9.15.2)
	GINI	42.8 (27.6–63.4)				
	FRAGILITY	87.3 (57.0–110.9)				
	CO2/PC	1.1 (0.0–8.1)				
Asia	HPAHDI	0.65 (0.47–0.78)	– Migration and displacement (Box 10.6) – Uneven economic development (Section 10.4.6) – Rapid land use change (Section 10.4.6) – Increasing inequality (Section 10.4.6) – Large, socially differentiated vulnerable populations (Section 10.4.6)	– Investing in climate-resilient and sustainable infrastructure can be a source of green jobs as well as a means of reducing climate vulnerability (Section 10.6.2) – Sustainable development pathways that connect climate change adaptation and disaster risk reduction efforts can reduce climate vulnerability and increase resilience (Section 10.6.2) – Social protection programmes can develop risk management strategies to address loss and damage from climate change (Section 10.5.6)	– Risk insurance (Section 10.5.5) – Climate-smart agriculture (10.4.5.5, Table 10.6) – Wetland protection and restoration (Table 10.6) – Aquifer storage and recovery (Table 10.6) – Integrated smart water grids (Table 10.6) – Disaster risk management (Table 10.6) – Early warning systems (Table 10.6) – Resettlement and migration (Table 10.6) – Nature-based solutions in urban areas – Coastal green infrastructure (Table 10.6)	– (S+) nature-based adaptation solutions, wetland protection, and climate-smart agriculture enhance carbon sequestration (Table 10.6) – (S+) disaster risk reduction and capacity building have synergistic interactions with climate adaptation when the two are effectively integrated (Section 10.6.2) – (S+) environmental sustainability has benefits for relieving poverty and promoting social equity (Section 10.6.4) – (T) intensive irrigation and other forms of water consumption can have a negative effect on water quality and aquatic ecosystems (Section 10.6.3)
	GINI	34.9 (26.6–43.9)				
	FRAGILITY	73.6 (32.3–111.7)				
	CO_2/PC	6.3 (0.3–38.0)				

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Region	*Development indicators* mean (range)		*Challenges*	*Opportunities*	*Options*	*Synergies and trade-offs*
Australasia	PPAHDI	0.75 (0.70–0.81)	– Underinvestment in adaptation, particularly in public health systems, given current and projected risks (Section 11.3.6.3) – Underlying social and economic vulnerabilities exacerbate disadvantage among particular social groups (Section 11.8.2) – Competing policy and planning objectives within governments (Section 11.7.2) – Limits to adaptation across the region and among neighbours (Section 11.7.2) – Fear of litigation and demands for compensation create disincentives for climate adaptation (Section 11.7.2) – Different climate change risk perceptions among different groups (Section 11.7.2)	– Implementation of national policies and guidance on climate adaptation and resilience (Box 11.5) – Cooperation among individual farmers for adaptation and regional innovation (Section 11.7.1) – Enhancing understanding of Indigenous knowledge and practices (Table 11.11)	– Climate adaptation services, planning and tools from government and private sector providers (Section 11.7.1) – Enhancing governance frameworks (Table 11.17) – Building capacity for adaptation (Table 11.17) – Community partnership and collaborative engagement (Table 11.17) – Flexible decision making (Table 11.17) – Reducing systemic vulnerabilities (Table 11.17) – Providing adaptation funding and compensation mechanisms (Table 11.17) – Addressing social attitudes and engagement in adaptation and climate action (Table 11.17)	– (T) adapting to fire risk in peri-urban zones introduces potential trade-offs among ecological values and fuel reduction in treed landscapes (Section 11.3.5)
	GINI	34.4 (34.4–34.4)				
	FRAGILITY	20.1 (18.4–21.8)				
	CO_2/PC	12.1 (7.3–16.9)				
Central and South America	PPAHDI	0.71 (0.62–0.78)	– Vulnerability of informal settlements with chronic exposure to everyday, non-climate risks – Limited political influence of poor and most vulnerable groups – Poor market access of rural households – Little consideration of the implications of NDCs for poverty and livelihoods – Corruption, particularly in the construction and infrastructure sector – Gender inequities in labour markets – Limits to adaptation	– Address existing development deficits, particularly the needs of informal settlements and economies – Adopt collaborative approaches to decision making that integrate civic groups and communities as well as the private sector – Enhance adoption of sustainable tourism and livelihood diversification	– Upgrading of informal and vulnerable settlements – Capacity building in national and city level government institutions – Enhancing social protection programmes – Integrated land use planning and risk-sensitive zoning – Infrastructure greening – disaster risk mitigation and management – Emergency medical and public health preparedness – Improving insurance mechanisms and climate financing – Ecosystem conservation, protection and restoration – Appropriate use of climate information and development of climate services	– (S+) conservation and restoration of natural ecosystems have synergies with mitigation, adaptation and sustainable development (Section 12.7.1)
	GINI	47.2 (38.6–57.9)				
	FRAGILITY	65.9 (35.9–92.6)				
	CO_2/PC	2.2 (0.9–4.8)				
Europe	PPAHDI	0.76 (0.52–0.83)	– Mitigation and adaptation remain siloed around sectoral approaches (Box 13.3) – Institutional, policy and behavioural lock-ins constrain the rate of system transitions (Section 13.11.4) – Legislative and decision making process constraints on climate action (Section 13.11.4) – High adaptation costs and concerns about effectiveness and feasibility (Section 13.3.2, Table 13.A.5) – Competition for land use among adaptation and other uses (Section 13.3.2) – Perceptions of climate change as irrelevant or not urgent (Section 13.3.2) – Public budget and human capital limitations (Section 13.3.2)	– Engagement in climate change knowledge, policy and practice networks (Box 13.3) – National policies can lead to more ambitious and integrated climate planning and action with associated co-benefits (Box 13.3) – System transformations towards more adaptive and climate-resilient systems (Section 13.11.4, Box 13.3)	– Ecological restoration of habitats agroforestry and reforestation (Section 13.8.2) – 'Smart farming' and knowledge training (Section 13.5.2.1) – Soil management practices (Section 13.5.2.1) – Changing sowing dates and changes in cultivars (Section 13.5.2.1) – Stricter enforcement of existing health regulations (Section 13.7.2) – Integrated coastal zone management and marine spatial planning (Section 13.4.2) – Nature-based solutions (Section 13.4.2) – Climate services (Section 13.6.2.3) – Tailored insurance products for specific physical climate risks (Section 13.6.2.5) – Protection of world heritage sites (Section 13.8.2)	– (T) wind farms support greenhouse gas mitigation but have ecosystem implications and impacts (Section 13.4.2) – (T) adapting and mitigating climate change through afforestation and forest management may be hampered by biophysical and land use trade-offs (Section 13.3.2)
	GINI	31.9 (24.6–41.3)				
	FRAGILITY	41.1 (16.2–72.9)				
	CO_2/PC	6.8 (1.3–21.3)				

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Region	*Development indicators* mean (range)		*Challenges*	*Opportunities*	*Options*	*Synergies and trade-offs*
North America	PPAHDI	0.72 (0.72–0.73)	– Lack of representation of all groups and communities in politics and decision making (Section 14.6.3) – Economic and financial constraints on adaptation within communities (Section 14.6.2) – Persistent social vulnerability and inequities (Sections 14.6.3, 14.4.7.3) – Adaptation actions that are maladaptive and exacerbate existing inequities (Section 14.6.2.1) – Constraints on capacity for data collection (Table 14.8) – Limited organisational willingness to implement new and untested solutions (Table 14.8)	– Increased focus on building adaptive capacity in small towns and rural areas (Section 14.6.3) – Greater use of SDGs as a framework for equitable adaptation measures (Section 14.6.3) – Broader and deeper recognition of the role of Indigenous knowledge and local knowledge systems in adaptation (Section 14.6.3) – Greater emphasis on participatory governance and co-production of knowledge in adaptation decision making (Section 14.6.2.2) – Enhanced use of risk-based decision analysis frameworks and flexible adaptation pathways (Section 14.6.2.2) – Coordination of policies to support transformational adaptation (Section 14.6.2.2)	– Indigenous knowledge-based land and resource management (Section 14.4.4) – Adaptive co-management of agriculture and freshwater resources (Section 14.4.3) – Ecosystem-based management and nature-based solutions (Box 14.3, Sections 14.4.2, 14.4.3, 14.4.4, Table 14.9) – Increased efficiency and equity of water management and allocation (Section 14.4.3.3) – Energy conservation measures (Section 14.6.1.3) – Guidelines, codes, standards and specifications for infrastructure (Section 14.6.1.6) – Modifying zoning and buying properties in floodplains (Section 14.6.1.3) – Web-based tools for visualising and exploring climate information scenario planning and risk analyses (Section 14.6.1.6)	– (S+) post-fire ecosystem recovery measures, restoration of habitat connectivity, and managing for carbon storage enhance adaptation potential and offers co-benefits with carbon mitigation (Box 14.1) – (T) REDD+ represents a trade-off between carbon mitigation and the ability of communities to improve their food security (Section 14.4.7) – (T) new coastal and alpine developments generate economic activity but enhance local social inequalities (Section 15.4.10)
	GINI	40.0 (33.3–45.4)				
	FRAGILITY	45.4 (21.7–69.9)				
	CO_2/PC	11.9 (3.8–16.6)				
Small Islands	PPAHDI	0.68 (0.51–0.76)	– High dependence of economic activity on tourism (Section 15.3.4.5) – Lack of coordination among government departments (Section 15.6.1) – Limited regional cooperation (Section 15.6.1) – Absence of planning frameworks (Section 15.6.1) – Corruption and corrupt people in political and public life (Section 15.6.1) – Insufficient human capital (Section 15.6.1) – Competing development priorities (Section 15.5.5) – Lack of education and awareness around climate change (Section 15.6.4) – Failure of externally driven adaptation (Section 15.6.5) – Constraints on economic, legislative and technical capacity of local governments (Section 15.7)	– Increasing women's access to climate change funding and support from organisations (Section 15.6.5) promoting agroecology, food sovereignty and regenerative economies (Section 15.7) – Expanding sustainable tourism economies (Section 15.7) – Integrating climate change and disaster management with broader development planning and implementation (Section 15.7) – Using climate risk insurance as a way to support development and adaptation processes (Section 15.7) – Improving cross sectoral and cross agency coordination (Section 15.7) – Enhanced integration between development assistance, public financial management, and climate finance (Section 15.5.7)	– Raising dwellings and other infrastructure (Section 15.5.2) – Land reclamation (Section 15.5.2) – Migration and planned resettlement (Section 15.5.2) – Ecosystem-based adaptation including Indigenous and local knowledge (Section 15.5.2) – protected areas (Section 15.5.2) – Ecosystem restoration and improved agroforestry practices (Sections 15.5.2, 15.5.4) – Community-based adaptation (Section 15.5.5) – Livelihood diversification and use of improved technologies and equipment (Section 15.5.6) – Diversifying cropping patterns, expanding or prioritising other cash crops (Section 15.5.6) – Small-scale livestock husbandry (15.5.6) – Irrigation technologies (Section 15.5.6) – Diversification away from coastal tourism – Disaster risk management (DRM) (Section 15.5.7) – Early warning systems and climate services (Section 15.5.7)	– (S+) development decisions and outcomes are strengthened by consideration of climate and disaster risk (Section 15.7) – (S-) impacts of invasive alien species on islands are projected to increase with time due to synergies between climate change and other drivers (Section 15.3.3) – (S-) synergies between changing climate and other natural and anthropogenic stressors could lead to disproportionate impacts on biodiversity (Section 15.3.3)
	GINI	40.2 (28.7–56.3)				
	FRAGILITY	64.6 (38.1–97.5)				
	CO_2/PC	3.7 (0.3–31.3)				

Table 18.7 | Sectoral synthesis of dimensions of climate resilient development. For each sectoral chapter of the WGII report, this table identifies those SDGs that are discussed in the relevant chapter as being particularly relevant to the sector. In addition, the table contains evidence of sustainable development challenges and opportunities as well as adaptation/sustainable development options and potential synergies and trade-offs associated with their implementation. Synergies and trade-offs are categorised as follows: (T) Trade-off among policies and practices; (S+) Synergy among policies and practices that enhances sustainability; (S-) Synergy among policies and practices that undermines sustainability.

Sector	*Relevant SDGs*	*Challenges*	*Opportunities*	*Options*	*Trade-offs*
Terrestrial and freshwater ecosystems and their services	SDG 1, SDG 2, SDG 3, SDG 6, SDG 7, SDG 9, SDG 10, SDG 11, SDG 12, SDG 13, SDG 15, SDG 17	– Low capacity for dispersal limits range shifts to match climate (Section 2.6.1) – Constraints on the evolution of greater stress tolerance among species (Sections 2.4.2, 2.6.1) – Altered peatland drainage and repeated disturbances pose barriers to restoration of tropical peatlands (Section 2.4.3) – Demonstrating the efficacy of natural flood management efforts poses challenges to its deployment (Section 2.6.5) – Uncertainties in climate and socioeconomic projections constrain adaptation planning and implementation (Section 2.7)	– Nature-based solutions offer the opportunity to address climate change and biodiversity problems in an integrated way (Section 2.6) – Adaptation can be integrated with the protection of biodiversity and land-based climate change mitigation initiatives (Section 2.6.2)	– Habitat restoration, connectivity and creation of protected areas (Table 2.5) – Integrated landscape management (Table Cross-Chapter Box NATURAL.1 in Chapter 2) – Community-based natural resource management (Section 2.6.5.7) – Maintain or restore natural species and structural diversity (Table Cross-Chapter Box NATURAL.1 in Chapter 2) – Restoration of hydrological flows and catchment vegetation (Table Cross-Chapter Box NATURAL.1 in Chapter 2) – Control of feral herbivores Table Cross-Chapter Box NATURAL.1 in Chapter 2) – Reduce non-climatic stressors to land-based ecosystems (Table 2.6)	– (S+) ecosystem-based adaptation measures, such as restoration of forests and wetlands for flood and erosion control help maintain freshwater supply and quality (Section 2.2.2) – (S-) over grazing/stocking of pastures and grasslands can result in soil erosion and the loss of biodiversity (Table Cross-Chapter BoxNATURAL1 in Chapter 2) – (T) planting non-native monocultures for mitigation can reduce biodiversity and resilience – (T) inappropriate hydrological restoration can result in increased methane emissions (Table Cross-Chapter Box NATURAL1 in Chapter 2) – (T) afforestation/reforestation and bioenergy initiatives can conflict with other land uses such as food and timber production (Table Cross-Chapter Box BECCS, Section 2.2.2, Box 2.2)
Ocean and coastal ecosystems and their services	SDG 1, SDG 2, SDG 3, SDG 5, SDG 7, SDG 8, SDG 9, SDG 10, SDG 11, SDG 12, SDG 13, SDG 14	– Shifts in the distribution of fish species across exclusive economic zones present governance, ecological and conservation challenges (Section 3.4.3) – Resource constraints impede the implementation of ecosystem-based and community-based adaptation for low- to middle-income nations (Section 3.6.2) – Governance in marine social-ecological systems is highly complex with poorly defined legal frameworks (Section 3.6.2) – 'Coastal squeeze' challenges adaptation, creating tensions between coastal development and coastal habitat management (Section 3.6.3)	– Development assistance can help address resource constraints associated with marine ecosystem management (Section 3.6.3) – Improving coordination among actors and projects will contribute to achieving SDGs (Section 3.6.3) – Private finance can support restoration of blue carbon systems (Section 3.6.3) – Joint implementation of coastal and marine management initiatives can address governance challenges across scales and sectors (Section 3.6.3) – Ocean-based renewable energy options can reduce reliance on imported fuel (Section 3.6.3)	– Maritime spatial planning and integrated coastal management (Section 3.6.2; Figure 3.2.6) – Adaptive and sustainable fisheries management (Section 3.6.2) – Habitat restoration (Section 3.6.2) – fishery mobility (Figure 3.6.2) – Assisted evolution (Figure 3.2.6) – Increase participation in management and governance (Figure 3.2.6) – Nature-based solutions (Section 3.6.2) – Hard and soft infrastructure (Figure 3.2.6) – Livelihood diversification (Figure 3.6.2) – Disaster mitigation and response (Figure 3.2.6) – Finance and market mechanisms (Figure 3.2.6)	– (S+) adaptation in ocean and coastal systems can be designed in ways that substantially contribute to the SDGs and not only support but allow the attainment of social, environmental and economic targets (Section 3.6.4) – (S+) blue/green economies can reduce emissions and finance adaptation pathways (Section 3.6.3) – (T) built infrastructure conflicts with mitigation goals and can create potential ecological, social and cultural impacts that undermine ecosystem health (Section 3.6.2)

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Sector	Relevant SDGs	Challenges	Opportunities	Options	Trade-offs
Water	SDG 1, SDG 2, SDG 3, SDG 6, SDG 7, SDG 10, SDG 11, SDG 13	– Uncertainty in future water availability (Box 4.1, Box 4.4) – Lack of sufficient data, information and knowledge in understanding the water–energy–food nexus (Box 4.6) – Increasing urbanisation is creating new and difficult demands for urban water management. (Section 4.3.4) – Barriers to adapting water-dependent livelihoods in rural communities (Section 4.3.1) – Mainstreaming water management across sectors and enhancing finance for adaptation (Section 4.3.5) – Path-dependency of institutions, (and contingencies on decision-making processes (Section 4.5.3)	– A resilient circular economy delivers access to water, sanitation, wastewater and ecological flows (Box 4.7) – Adaptive sanitation systems and sustainable urban drainage contribute to a 'one health approach' which can prevent water and sanitation contamination risks during floods and droughts. (Box 4.7) – Climate-proof infrastructure would reduce infection risks in flood-prone areas (Box 4.7) – Governance can derive legitimacy from inclusion of multiple stakeholders, including women, Indigenous communities and young people (Section 4.6.6) – Indigenous and local knowledge can help ensure solutions align with the interests of communities (FAQ 4.5)	– Changes in crop cultivars and agronomic practices (Section 4.5) – Changes in irrigation and water management practices (Section 4.5) – Water and soil conservation (Section 4.5) – Migration and off-farm livelihood diversification (Section 4.5) – Collective action, policies and institutions (Section 4.5) – Economic and financial incentives (Section 4.5) – Training and capacity building (Section 4.5) – Flood risk reduction measures (Section 4.5) – Urban water management (Section 4.5) – Water, sanitation and hygiene adaptations (Section 4.5) – Agro-forestry and forestry responses (Section 4.5) – Livestock and fishery responses (Section 4.5) – Indigenous and local knowledge (Section 4.5) – Energy-related adaptations (Section 4.5)	– (S+) increasing the proportion of sewerage, treated wastewater, recycling and safe reuse would help reach climate and water targets (Box 4.7) – (S+) solar irrigation pumps provide for income diversification for small and marginal farmers while also generating renewable energy (Box 4.7) – (T) desalination of seawater or brackish inland water is energy intensive, with high salinity brine and other contaminants (Section 4.5.5) – (T) negative-emission technologies, such as direct air capture can result in a net increase in water consumption (Section 4.5.5)
Food, fibre, and other ecosystem products	SDG 1, SDG 2, SDG 3, SDG 4, SDG 5, SDG 6, SDG 7, SDG 9, SDG 9, SDG 10, SDG 11, SDG 12, SDG 13, SDG 14, SDG 15, SDG 16	– Increased cost and management challenges of providing safe food (Section 5.2.2) – Warming-induced shifts of species create resource allocation challenges among different fishing fleets (Section 5.2.1) – Challenges related to REDD+ implementation and forest use (Section 5.6.3) – Differences in perceptions about the validity of different forms of knowledge (Section 5.8.4) – Inequality in access to climate services (Section 5.14.1) – Lack of support, policies and incentives for the adoption of agro-ecological approaches (BIOECO.1) – Financial barriers limit implementation of adaptation options in agriculture, fisheries, aquaculture and forestry (Section 5.14.3)	– Integrated approaches to food, water, health, biodiversity and energy that involve vulnerable groups can help to address current and future food security challenges, reduce vulnerability of Indigenous People, small-scale landholders and pastoralists, and promote resilient ecosystems. (Sections 5.12.3, 5.13.2; 5.14) – Agro-forestry delivers benefits for climate change mitigation, adaptation, desertification, land degradation and food security, and is considered to have broad adaptation and moderate mitigation potential (Section 5.10.4) – Partnerships between key stakeholders such as researchers, forest managers, and local actors can lead to a shared understanding of climate-related challenges and more effective decisions. (Section 5.6.3)	– Livelihood diversification (Section 5.4.4) – Social protection policies and programmes (Section 5.4.4) – Changes in crop management including irrigation, fertilizers, planting schedules and crop varieties (Section 5.4.4.1) – Adjusting water management for forage production (Section 5.5.4) – Rotational grazing of livestock (Section 5.5.4) – Fire management to control woody thickening of grass (Section 5.5.4) – Using more suitable livestock breeds or species (Section 5.5.4) – Migratory pastoralist activities (Section 5.5.4) – Monitor and manage the spread of pests, weeds, and diseases (Section 5.5.4) – Nature- or ecosystem-based strategies (Section 5.12.5.2)	– (S+) agricultural production systems that integrate crops, livestock, forestry, fisheries and aquaculture can increase food production per unit of land, reduce climatic risk and reduce emissions (Chapter 5 Executive Summary) – (S+) integrated approaches to food, water, health, biodiversity and energy can help address current and future food security challenges, reduce vulnerability of Indigenous People, small-scale landholders and pastoralists, and promote resilient ecosystems (Sections 5.12.3, 5.13.2, 5.14) – (T) growing biomass demand for producing sustainable bio products competes with food production, with potential effects on food prices and knock-on effects related to civil unrest (BIOECO.1)

Sector	Relevant SDGs	Challenges	Opportunities	Options	Trade-offs
Cities, settlements and key infrastructure	SDG 11, SDG 13, SDG 17	– Poor municipal funding, data collection and collaboration hinders sustainable development initiatives, capacity building and climate action (Sections 6.1.5, 6.4.5, 6.4.9) – High urbanisation rates pose challenges to areas that already have high levels of poverty, unemployment, informality and housing and service backlogs (Section 6.2.1) – Limited capacity for early warning systems in low-income countries (Section 6.3.2) – Lack of administrative capacities, coordination across sectors and efforts, transparency and accountability slows sustainability transitions and disaster risk reduction (Case Study 6.4)	– Urban ecological infrastructure including green, blue, turquoise and others can be a source of nature-based solutions that can improve both adaptation and mitigation in urban areas (Section 6.1.2) – Transition architecture movements can drive urban adaptation (Section 6.4.1) – Transformative capacities support adaptation efforts and systemic change processes (Section 6.4.4) – Incorporating Indigenous and local knowledge help generate more people-oriented and place-specific adaptation policies (Section 6.4.7) – Climate finance offers the opportunity to overcome structural impediments to climate action (Box 6.5) – Urban ecological infrastructure can be a source of nature-based solutions that can improve both adaptation and mitigation in urban areas (Cross-Chapter Box URBAN in Chapter 6) – High-density environments coupled with other design measures can provide mitigation and adaptation benefits (Cross-Chapter Box URBAN in Chapter 6)	– Green infrastructure, sustainable land use and planning, and sustainable water management (Section 6.1.2) – Nature-based solutions (Section 6.3.3) – Insurance (Section 6.3.2) – switching to air cooling for thermal power plants (Section 6.3.4) – Increasing the efficiency of hydro- and thermoelectric power plants (Section 6.3.4) – Changing reservoir operation rules (Section 6.3.4) – Upgrading infrastructure and strengthening or relocating (critical) assets (Section 6.3.4) – Including green, blue, turquoise and nature-based solutions (Cross-Chapter Box URBAN in Chapter 6) – Cooling networks (Cross-Chapter Box URBAN in Chapter 6) – Early warning systems (Table 6.4) – Resource demand and supply side management strategies (Table 6.4) – Enhanced monitoring of air quality in rapidly developing cities (Table 6.4) – Investment in air pollution controls (Table 6.4) – Core and shell preservation, elevation and relocation for heritage buildings (Section 6.3.2)	– (S+) sustainable urban energy planning that includes opportunities to avoid and reduce the UHI effect can provide synergies for both climate mitigation and adaptation in urban areas (Cross-Chapter Box URBAN in Chapter 6) – (S+) natural ventilation and passive energy strategies can capture synergies between climate mitigation and adaptation (Cross-Chapter Box URBAN in Chapter 6) – (S+) community-based adaptation has potential to be better integrated to enhance well-being and create synergies with the Sustainable Development Goals – (T) urban mitigation efforts can create trade-offs with adaptation such as intensifying the urban heat island (UHI) effect (Cross-Chapter Box URBAN in Chapter 6) – (T) efforts aimed at increasing adaptation may undermine mitigation objectives by increasing investment in hard infrastructure that increases emissions (Cross-Chapter Box URBAN in Chapter 6) – (T) lack of open and green spaces may induce long-distance leisure trips thereby increasing emissions (Cross-Chapter Box URBAN in Chapter 6)
Health, well-being and the changing structure of communities	SDG 3, SDG 5, SDG 8, SDG 10, SDG 13	– A lack of capacity for adaptation has resulted in only moderate or low levels of adaptation implementation across different countries (Section 7.4.2) – Transitioning to renewable energy sources presents opportunities for realising health co-benefits (Section 7.4.4) – Shifting to healthier plant-rich diets can reduce GHG emissions and reduce land use (Cross-Chapter Box HEALTH in Chapter 7) – Future flows of migration within and between countries are likely to respond strongly to particular combinations of climatic hazards and may present challenges for future adaptation policies and programmes – Climate change disruptions to natural environments can be expected to disrupt livelihood practices, stimulate higher rates of outmigration to urban centres, and in some instances necessitate planned or organised relocations of exposed settlements (Cross-Chapter Box MIGRATE in Chapter 7)	– COVID-19 recovery investments offer an opportunity to contribute to climate resilient development through a green, resilient, healthy and inclusive recovery (Cross-Chapter Box COVID in Chapter 7) – investing in basic infrastructure for all can transform development opportunities, increase adaptive capacity and reduce climate risk (Cross-Chapter Box HEALTH in Chapter 7) – Integrated agroecological systems offer opportunities to increase dietary diversity while building local resilience to climate-related food insecurity (Section 7.4.2) – Incorporating climate change and health considerations into disaster reduction and management strategies could potentially improve funding opportunities (Section 7.4.2) – Adaptive urban design that provides access to healthy natural spaces can promote social cohesion and mitigate mental health challenges (Section 7.4.2)	– Improved building and urban design including use of passive cooling systems (Table 7.2) – Better access to public health systems for the most vulnerable (Table 7.2) – Deployment of renewable energy sources (Table 7.2) – Improved water, sanitation and hygiene conditions (Table 7.2) Early warning system of vector-borne diseases, insecticide treated bed nets and indoor spraying of insecticide (Table 7.2) – Targeted efforts to develop vaccines for infectious diseases exacerbated by climate change (Table 7.2) – Improved personal drinking and eating habits (Table 7.2) – Improved food storage, food processing and food preservation (Table 7.2) – Emergency shelters for people to escape heat (Table 7.2) – Improved funding and access to mental health care (Table 7.2) – Improved education for girls and women (Table 7.2) – Improved maternal and child health services (Table 7.2)	– (T) energy strategies for energy efficiency and GHG emissions reductions can generate health co-benefits through improved air quality but may slow poverty reduction efforts (Sections 7.4.2, 7.4.5) – (S+) investing in adaptation for health and community well-being has the potential to generate considerable co-benefits in terms of reducing impacts of non-climate health challenges – (S+) investments in mitigating greenhouse gas emissions will not only reduce risks associated with dangerous climate change but will increase population health and well-being through a number of pathways. (Section 7.4)

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Sector	Relevant SDGs	Challenges	Opportunities	Options	Trade-offs
Poverty, livelihoods and sustainable development	SDG 1, SDG 2, SDG 3, SDG 5, SDG 10, SDG 14	– Use of political frameworks for decision making that are unfavourable towards adaptation and system transitions (Table 8.4) – Attitudes towards risk and other cultural values limit responses (Table 8.4) – Psychological distress causes insecurity and behaviours that increase vulnerability (Table 8.4) – Limited financial resources to support adaptation projects (Section 8.2.2, Table 8.4) – Small-holder farmers have poor access to markets and land tenure (Section 8.6.1) – Unsuitable infrastructure may increase exposure (Table 8.4) – Lack of access to technologies that can support adaptation (Table 8.4) – Gender-based inequalities constrain women's access to resources for adaptation (Table 8.7) – Poverty constrains livelihood diversification, resilience or adaptive capacity (Table 8.7) – Indigenous Peoples and other populations with strong attachments to place face barriers to adaptation (Table 8.7) – Local institutions face ongoing challenges in gaining support from higher governance levels, particularly in developing countries. (Section 8.5.2)	– Polycentric governance, adaptive governance, multi-level governance, collaborative governance or network governance are increasingly used to understand transitions towards climate-compatible development (Section 8.6.2) – Well coordinated and integrated nexus approaches to adaptation offer opportunities to build resilient systems while harmonising interventions, mitigating trade-offs and improving sustainability (Section 8.6.2) – Income from new livelihood activities can support recovery following disasters linked to climate variability and change (Section 8.4.5) – Improving industrial processes can contribute to the optimised use of energy, reuse of waste, reducing GHG emissions, use of biomass and more efficient equipment (Table 8.3) – Industrialisation and technological innovation in rural areas may assist vulnerable communities through provision of resources, enhanced forecast information or reuse of biowaste (Table 8.3) – Responses to climate change can create significant development opportunities including job creation and livelihood diversification (Section 8.4.3)	– Expanded private sector activity and public–private partnerships (Section 8.6.1) – Credit and insurance (Section 8.6.1) – Use of climate-smart agricultural practices and technologies (Section 8.6.1) – Crop insurance (Section 8.6.1) – Conservation agriculture (Section 8.6.1) – Changing farmers' perception and enhancing farmers' adaptive capacity (Section 8.6.1) – REDD+ (Section 8.6.1) – improving industrial processes (Table 8.3) – Renewable energy and energy efficiency (Table 8.3) – Smart electricity grids (Section 8.6.1) – Green buildings (Section 8.6.1) – Efficient fuels (Section 8.6.1) – Pollution control investments (Section 8.6.1) – Public transit and non-motorised transport with increased use of biofuels (Section 8.6.1) – Integrated natural resource management (Table 8.2) – Disaster risk management (Table 8.2) – Relocation of vulnerable communities (Table 8.2) – Education and communication (Table 8.2) – Land use planning (Table 8.3)	– (S+) agriculture technologies facilitate mitigation to climate change and adaptation such as saving water while maintaining grain yield (Section 8.6.1) – (S+) sustainable pastoralism increases carbon sequestration but can also contribute to adaptation by changing grazing management, livestock breeds, pest management and production structures (Section 8.6.1) – (S+) REDD+ may provide adaptation benefits by enhancing households' economic resilience through positive livelihood impacts (Section 8.6.1) – (S+) solar energy contributes to reducing GHG emissions and improving air quality (Section 8.6.1) – (S+) hydropower contributes to mitigation and adaptation through water resource availability for irrigation and drinking water (Section 8.6.1) – (S+) green roofed buildings contribute to cooler temperatures, thereby reducing energy use for air-conditioning (Section 8.6.1) – (T) mitigation measures such as bioenergy may result in trade-offs with efforts to achieve sustainable development, eradicate poverty and reduce inequalities (Section 8.6.1) – (T) migration to urban centres can be a form of adaptation, but can increase the vulnerability of communities of origin or at destinations (Section 8.2.2)

for options feasibility for both mitigation (SR1.5 ref) and adaptation (Cross-Chapter Box FEASIB). This assessment allows the range of available options to be considered in a more critical light, particularly when considering opportunities for implementation over the near term. Meanwhile, the other challenge is that of option efficacy. Significant uncertainties remain regarding how well a given option will perform in a specific context and whether it is capable of adequately addressing risk (Section 18.6.1). Such uncertainties can undermine the pursuit of CRD or at least efforts to accelerate system transitions that support CRD (*medium evidence*, *medium agreement*) (Section 18.3). Accordingly, closer examination of option implementation in the real world, including within different sectoral and regional contexts, would enhance the knowledge available to decision makers regarding which options will best fit the needs of a given CRD pathway.

18.6 Conclusions and Research Needs

18.6.1 Knowledge Gaps

Research to improve the understanding of CRD currently exists in a nascent state, because, as noted in the AR5, '*integrating climate change mitigation, climate change adaptation, and sustainable development is a relatively new challenge*' (Denton et al., 2014). While a large volume of literature has emerged since the AR5 that spans the nexus of sustainable development, CRD and climate action, the identified research gaps in AR5 (Denton et al., 2014) continue to be priorities for informing CRD. These include enhancing understanding of mainstreaming of climate change into institutional decision making, managing risk under conditions of uncertainty, catalysing system transitions and transformation, and processes for enhancing participation, equity and accountability in sustainable development (*very high confidence*).

The more recent literature adds significant context to the concept of CRD, but also introduces broader perspectives regarding its significance in the arena of climate action. Hence, concepts that are both complementary to, and competitive with, CRD, such as 'climate safe', 'climate compatible' and 'climate smart' development (Huxham et al., 2015; Kim et al., 2017b; Ficklin et al., 2018; Mcleod et al., 2019) (Section 18.1.1). These different framings of the intersection between sustainable development and climate action are used in different communities of research and practice, which complicates efforts to provide clear guidance to decision makers regarding the goals of CRD and how best to achieve it. This is attributable in part to persistent conceptual confusion and disciplinary divides over more fundamental concepts such as resilience and sustainability (Rogers et al., 2020; Zaman, 2021), not to mention contested perspectives regarding development (Lo et al., 2020; Song et al., 2020a; Morton, 2021) (*medium agreement*, *medium evidence*).

Reconciling different perspectives on CRD is not simply a matter of academic debate. Climate action, resilience and sustainable development are all active areas of policy and practice with significant economic, social, environmental and political implications (Section 18.1.3). Hence, enhancing the role of CRD as a practical framework for development and a guide for action may necessitate improving the science–policy discourse regarding CRD (Winterfeldt, 2013; Jones et al., 2014; Ryan and Bustos, 2019). This includes consideration for risk and science communication; decision analysis and decision support systems; and mechanisms for knowledge co-production between scientists and public policy actors (*very high confidence*).

In addition, the AR6 WGII report highlights a number of elements of CRD that are associated with significant knowledge gaps and uncertainties. As a result, enhancing the value of CRD as a unifying concept in development would benefit from further conceptualisation and socialisation of the concept, as well as efforts to address the following knowledge gaps:

- The challenges posed by different levels of global warming to achieving CRD and the magnitude and nature of the adaptation gap (and associated finance needs) that must be addressed to enable climate resilience.
- The efficacy of different adaptation, mitigation and sustainable development interventions in reducing climate risk and/or enhancing opportunities for CRD in the short, medium and long term.
- How different CRD pathways can be designed such that they illustrate opportunities for the practical pursuit of CRD in a manner consistent with principles of inclusion, equity and justice.
- How deliberative, participatory learning can be integrated into approaches to CRD to enhance the representation of diverse actors, forms of knowledge, governance regimes, economic systems and models for decision making in CRD.
- The synergies and trade-offs associated with the implementation of different policy packages and the design principles and development contexts that enhance the ability to successfully manage potential trade-offs.
- The limits of incremental system transitions to achieving CRD on a timeline that reflects the urgency associated with the Paris Agreement and the SDGs.
- The capacity of governments, social institutions and individuals to drive large-scale social transformations that open up the solutions space for CRD.
- Best practices for avoiding maladaptation and ensuring that adaptation interventions are designed so they do not exacerbate vulnerability to climate change to support CRD.

18.6.2 Conclusions

The concept of CRD presents an ambitious agenda for actors at multiple scales—global to local, particularly in the manner in which it reframes climate action to integrate a broader set of objectives than simply reducing GHG emissions or adapting to the impacts of climate change. Specifically, recent literature extends policy goals for climate action beyond avoiding dangerous interference with the climate system to adopt normative goals of meeting basic human needs, eliminating poverty and enabling sustainable development in ways that are just and equitable. This creates a policy landscape for climate action that is not only richer, but also more complex in that it situates responses to climate change squarely within the development arena. Current policy goals associated with the Paris Agreement, Sendai Framework and the SDGs imply aggressive timetables. Yet, as noted

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

in the AR5 and supported by more recent literature (Section 18.2.1), the world is neither on track to achieve all of the SDGs nor fulfil the Paris Agreement's objective of limiting the increase in the global mean temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit warming 1.5°C. (Denton et al., 2014; IPCC, 2018a). This places aspirations for CRD in a precarious position. Transitions will be necessary across multiple systems (Section 18.1.3). While some may be already underway, the pace of those transitions must accelerate, and societal transformations may be necessary to enable CRD (Sections 18.3, 18.4, Box 18.1).

Given the pace of climate change and the inherent challenge of sustainable development, particularly in the face of inevitable disruptions and setbacks such as the COVID-19 pandemic (Cross-Chapter Box COVID in Chapter 7), the feasibility of achieving CRD is an open question. Rapid changes will be required to shift public and private investments, strengthen institutions and orient them towards more sustainable policies and practices, expand the inclusiveness of governance and the equity of decision making, and shift societal and consumer preferences to more climate-resilient lifestyles. Nevertheless, the collective body of recent literature on CRD, system transitions and societal transformation, combined with the assessments within recent IPCC Special Reports (IPCC, 2018a; IPCC, 2019b; IPCC, 2019d) indicate that there are a broad range of opportunities for designing and implementing adaptation and mitigation options that enable the climate goals in the Paris Agreement to be achieved while enhancing resilience and meeting sustainable development objectives. However, options should be considered alongside the mechanisms by which societies can engage to create the conditions that can support the implementation of those options (Section 18.4). This includes formal policy mechanisms pursued by governments, the catalysation of innovation by private firms and entrepreneurship, as well as informal, grassroots interventions by civil society. While there is no 'one-size-fits-all' solution for CRD that will work for all actors at all scales, exploring different pathways by which actors can achieve their development and climate goals can make valuable contributions to developing effective strategies for CRD.

A fundamental challenge for achieving CRD globally is reconciling different perspectives on CRD. As noted in the AR5, '*as policy makers explore what pathways to pursue, they will increasingly face questions about managing discourses about what societal objectives to pursue*' (Denton et al., 2014: 1124). Since the AR5, such discourses have become prominent in policy debates over climate action and sustainable development because of different nations, communities and subpopulations having different understandings of what constitutes CRD. Aggressive efforts to rapidly reduce GHG emissions or enhance resilience to climate change, for example, could have negative externalities for the development objectives of some actors. This potential for trade-offs complicates efforts to build consensus regarding what constitutes appropriate climate and development policies and practices and by whom. The CRD pathways preferred by one actor are likely to be contested by others. This means operationalising concepts such as CRD in practice is likely to necessitate ongoing negotiation.

Ultimately, one of the critical developments within the literature is the emergence of procedural and distributive justice as key criteria for evaluating climate action and CRD more specifically. This trend not only recognises the need to prevent vulnerable human and ecological systems from experiencing disproportionate harm from the changing climate, but also the need to prevent those same systems from being harmed by mitigation, adaptation and sustainable development policies and practices. Failure to adequately engage with equity and justice when designing sustainability transitions could lead to maladaptation, aggravated poverty, reinforcement of existing inequalities, and entrenched gender bias and exclusion of Indigenous and marginalised communities (Jenkins et al., 2018; Fisher et al., 2019; Schipper et al., 2020b). These consequences could ultimately slow, rather than accelerate, CRD. Hence, developing programmes and practices for prioritising equity in effective transition risk management is an important dimension of enabling CRD.

As indicated by the literature assessed within this chapter, keeping windows of opportunity open for CRD will necessitate urgent action, even under diverse assumptions regarding how future mitigation and adaptation interventions evolve. If nations are to collectively limit warming to well below 2°C, for example, unprecedented emissions reductions will be necessary over the next decade (IPCC, 2018a). These reductions would necessitate rapid progression of system transitions (Section 18.3). If, despite the Paris Agreement, future emissions trajectories take the world beyond 2°C, a greater demand will be placed on adaptation as a means of enhancing the resilience of development. Given the long-lived nature of human systems, and the built environment in particular, significant adaptation investments would be needed over the near-term to meet this demand. Yet, it is important to note that, even in the absence of consideration for climate change, substantial development needs exist for communities around the world at present. Hence, a robust strategy for the pursuit of CRDPs is a near-term focus on portfolios of policies and practices that promote human and ecological well-being.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Frequently Asked Questions

FAQ 18.1 | What is a climate resilient development pathway?

A pathway is defined in IPCC reports as a temporal evolution of natural and/or human systems towards a future state. Pathways can range from sets of scenarios or narratives of potential futures to solution-oriented decision-making processes to achieve desirable societal goals. Climate resilient development pathways (CRDPs) are therefore trajectories for the pursuit of climate resilient development (CRD) and navigating its complexities. They involve ongoing processes that strengthen sustainable development, eradicate poverty and reduce inequalities while promoting fair adaptation and mitigation across multiple scales. As the pursuit of CRDPs is contingent on achieving larger-scale societal transformation, CRDPs invariably raise questions of ethics, equity and feasibility of options to drastically reduce emission of greenhouse gasses (mitigation) that limit global warming (e.g., to well below 2°C) and achieve desirable and liveable futures and well-being for all.

There in no one, correct pathway for CRD, but rather multiple pathways depending on factors such as the political, cultural and economic contexts in which different actors find themselves. Some development pathways are more consistent with CRD, while others move society away from CRD. Moreover, CRDPs are not one single decision or action. Rather, CRDPs represent a continuum of coherent, consistent decisions, actions and interventions that evolve within individual communities, nations, and the world. Different actors, the private sector, and civil society, influenced by science, local and Indigenous knowledges, and the media play a role in designing and navigating CRD pathways.

While dependent on past patterns of development and their socio-ethical, political, economic, ecological and knowledge-technology outcomes at any point in time, transformation, ecological tipping points and shocks can create sudden shifts and unexpected nonlinear development pathways. Actions taken today can enable or foreclose some future potential CRDPs. The differentiated impacts of hurricanes and COVID-19 on nations and communities around the world illustrate how the character of societal development such as equity and inclusion have enabled some societies to be more resilient than others.

Frequently Asked Questions

FAQ 18.2 | What is climate resilient development and how can climate change adaptation (measures) contribute to achieving this?

Climate resilient development (CRD) is a process of implementing greenhouse gas mitigation and adaptation options to support sustainable development for all in ways that support human and planetary health and well-being, equity and justice. CRD combines adaptation and mitigation with underlying development choices and everyday actions, carried out by multiple actors within political, economic, ecological, socio-ethical and knowledge-technology arenas. The character of processes within these development arenas are intrinsic to how social choices are made and they determine whether development moves society along pathways toward CRD or away. For example, inclusion, agency and social justice are qualities within the political arena that underpin actions that enable CRD.

CRD addresses the relationship between GHG emissions, levels of warming and related climate risks. However, CRD involves more than just achieving temperature targets. It considers the possible transitions that enable those targets to be achieved as well as the evaluation of different adaptation strategies and how the implementation of these strategies interact with broader sustainable development efforts and objectives. This interdependence between patterns of development, climate risk and the demand for mitigation and adaptation action is fundamental to the concept of CRD. Therefore, climate change and sustainable development cannot be assessed or planned in isolation of one another.

Hence, CRD represents development that deliberately adopts mitigation and adaptation measures to secure a safe climate on earth, meet basic needs for each human being, eliminate poverty and enable equitable, just and sustainable development. It halts practices causing dangerous levels of global warming. CRD may involve deep societal transformation to ensure well-being for all. CRD is now emerging as one of the guiding principles for climate policy, both at the international level, reflected in the Paris Agreement (UNFCCC, 2015), and within specific countries.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Multiple intertwined climate resilient development pathways

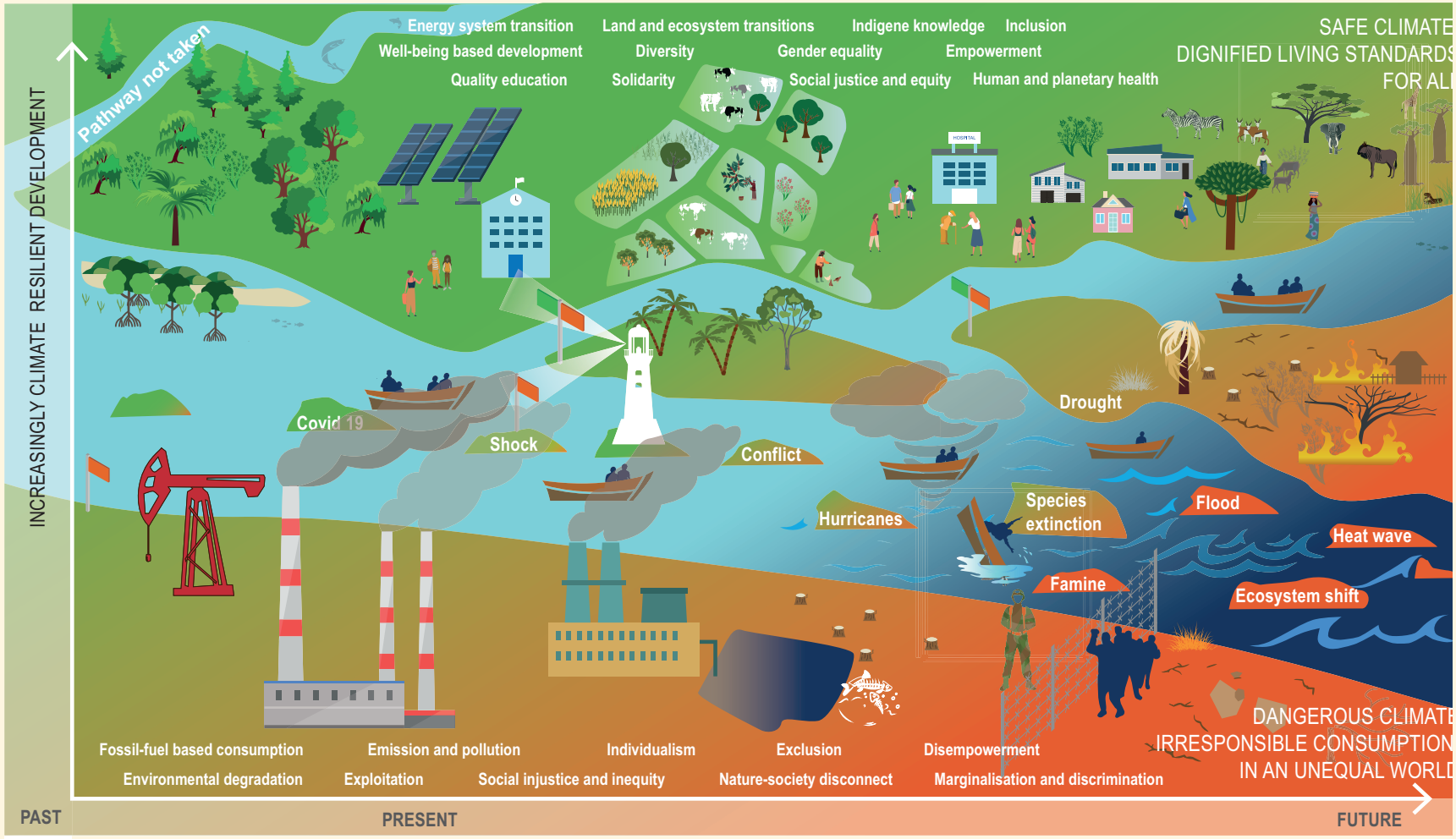


Figure FAQ18.2.1 | Multiple intertwined climate resilient development pathways. Climate change adaptation is one of several climatic and non-climatic measures carried out through decision making by multi actors that may drive a pathway in a CRD or non-CRD direction. Adaptation, mitigation and sustainable development actions can push a society in a CRD direction, but only if these measures are just and equitable. There multiple simultaneous pathways in the past, present and future. Societies (illustrated as boats) move on different pathways, towards CRD and non-CRD, with some pathways more dominant than others. The direction of pathw is emergent, taking place through contestations and social choices, through social transformation as well as through surprises and shocks (illustrated as rocks). Path dependency means it is possible but often turbulent to s from a non-CRD to a CRD pathway. Such a shift becomes more difficult as risks/shocks increase (more rocks) and non-CRD processes and outcomes progress, limiting future options. Low CRD processes and outcomes at bottom are characterised by inequity, exclusion, polarisation, environmental and social exploitation, entrenchment of Business-As-Usual, with increasing risks/shocks. High CRD processes and outcomes (at the top of the figu are characterised by equity, solidarity, justice, human well-being, planetary health, stewardship/care and system transitions.

Frequently Asked Questions

FAQ 18.3 | How can different actors across society and levels of government be empowered to pursue climate resilient development?

CRD entails trade-offs between different policy objectives. Governments as well as political and economic elites may play a key role in defining the direction of development at a national and sub-national scale; but in practice, these pathways can be influenced and even resisted by local people, non-governmental organisations (NGOs) and civil society.

Given such tensions, contestation and debate are inherent to the definition and pursuit of CRD. An active civil society and citizenship create the enabling conditions for deliberation, protest, dissent and pressure, which are fundamental for an inclusive participatory process. These enable a multiplicity of actors to engage across multiple arenas including governmental, economic and financial, political, knowledge, science & technology, and community. Decisions and actions may be influenced by uneven interactions among actors, including socio-political relations of domination, marginalisation, contestation, compliance and resistance, with diverse and often unpredictable outcomes.

In this way, recent social movements and climate protests reflect new modalities of action in response to social, economic, and political inaction. The new climate movement, led mostly by youth, seeks science-based policy and, more importantly, rejects a reformist stance toward climate action in favour of radical climate action. This is mostly pursued through collective disruptive action and non-violent resistance to promote awareness, a regenerative culture and ethics of care. These movements have resulted in notable political successes, such as declarations of climate emergency at the national and local level, as well as in universities. Also, their methods have proven effective to end fossil fuel sponsorship.

The success and importance of recent climate movements also suggest a need to rethink the role of science in society. On one hand, the new climate movements demanding political action were prompted by the findings of scientific reports, mainly the IPCC (2018a) and IPBES (2019) reports. On the other hand, these movements have increased public awareness and stimulated public engagement with climate change at unprecedented levels beyond what the scientific community can do alone.

Frequently Asked Questions

FAQ 18.4 | What role do transitions and transformations in energy, urban and infrastructure, industrial, land and ocean ecosystems, and in society, play in climate resilient development?

The IPCC SR1.5 report identified transitions in four key systems, including energy, land and ocean ecosystems, urban and infrastructure, and industry, as being fundamental to the pursuit of CRD. In addition, this report identifies societal transitions, in terms of values and worldviews that shape aspirations, lifestyles and consumption patterns, as another key component of CRD. Acknowledging societal transitions has implications for how one assesses options and values different outcomes from the perspectives of ethics, equity, justice and inclusion. Collectively, these system transitions can widen the solution space and accelerate and deepen the implementation of sustainable development, adaptation, and mitigation actions by equipping actors and decision-makers with more effective and more equitable options. However, the way they are pursued may not necessarily be perceived as ethical or desirable to all actors. Moreover, system transitions are necessary precursors for more fundamental climate and sustainable-development transformations. Yet, these transitions can themselves be outcomes of transformative actions.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Frequently Asked Questions

FAQ 18.5 | What are success criteria in climate resilient development and how can actors satisfy those criteria?

CRD is not a predefined goal to be achieved at a certain point or stage in the future. It is a constant process of evaluating, valuing, acting and adjusting various options for mitigation, adaptation and sustainable development, shaped by societal values as well as contestations of those values. Any achievement or success is always a work in progress driven by with continuous, directed, intentional actions. These actions will vary according to the priorities and needs of each population or system; therefore, specific criteria for, and indicators of, CRD will vary according to each specific context. This respect for context ensures the pursuit of CRD prioritizes people, planet, prosperity, peace and partnership, per the broad goals of the Agenda 2030 on sustainable development.

If CRD is defined as a process of implementing greenhouse gas mitigation and adaptation options to support sustainable development for all, this implies various potential criteria for success. These include the adoption of mitigation and adaptation measures to secure a safe climate, meet basic needs, eliminate poverty and enable equitable, just and sustainable development for all. Therefore, the 17 United Nations' SDGs provide a good (although limited) measure of progress toward CRD. The SDGs aim at ending poverty and hunger globally and protect life on land and underwater until the year 2030. Although there are proven synergies between the SDGs and mitigation, there remain synergies between the SDGs and adaptation that need to be explored further.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

References

Abrahams, D., 2020: Conflict in abundance and peacebuilding in scarcity: Challenges and opportunities in addressing climate change and conflict. *World Dev*, **132**, 104998, doi:10.1016/j.worlddev.2020.104998.

Abrahams, D. and E. Carr, 2017: Understanding the Connections Between Climate Change and Conflict: Contributions From Geography and Political Ecology. *Curr Clim Change Rep*, **3**, doi:10.1007/s40641-017-0080-z.

Abson, D.J., et al., 2017: Leverage points for sustainability transformation. *Ambio*, **46**(1), 30–39, doi:10.1007/s13280-016-0800-y.

Abu-Rabia-Queder, S. and A. Morris, 2018: Women in Drylands: Barriers and Benefits for Sustainable Livelihood. *J. Arid Environ.*, **149**, 1–3, doi:10.1016/j.jaridenv.2017.11.009.

Acemoglu, D., U. Akcigit, D. Hanley and W. Kerr, 2016: Transition to Clean Technology. *J. Polit. Econ.*, **124**(1), 52–104, doi:10.1086/684511.

Acevedo, S., et al., 2018: The Effects of Weather Shocks on Economic Activity: What are the Channels of Impact? *Imf Work. Pap.*, **18**(144), 1. Available at: https://www.imf.org/en/Publications/WP/Issues/2018/06/22/The-Effects-of-Weather-Shocks-on-Economic-Activity-What-are-the-Channels-of-Impact-45970#: :text=IMF Working Papers&text=In these countries%2C a rise,slower investment%2C and poorer health.

Acosta, M., et al., 2019: Discursive translations of gender mainstreaming norms: the case of agricultural and climate change policies in Uganda. *Womens Stud. Int. Forum*, **74**, 9–19, doi:10.1016/j.wsif.2019.02.010.

Adams, C., T. Ide, J. Barnett and A. Detges, 2018: Sampling bias in climate–conflict research. *Nat. Clim. Chang.*, **8**(3), 200–203, doi:10.1038/s41558-018-0068-2.

Adenle, A.A., et al., 2017: Managing Climate Change Risks in Africa – A Global Perspective. *Ecol. Econ.*, **141**, 190–201.

Adzawla, W., S.B. Azumah, P.Y. Anani and S.A. Donkoh, 2019: Gender perspectives of climate change adaptation in two selected districts of Ghana. *Heliyon*, **5**(11), e2854, doi:10.1016/j.heliyon.2019.e02854.

Agarwal, B., 2020: Does group farming empower rural women? Lessons from India's experiments. *J Peasant Stud*, **47**(4), 841–872, doi:10.1080/03066150.2019.1628020.

Ahlborg, H., 2017: Towards a conceptualization of power in energy transitions. *Environ. Innov. Soc. Transit.*, **25**, 122–141, doi:10.1016/j.eist.2017.01.004.

Ahlborg, H., I. Ruiz-Mercado, S. Molander and O. Masera, 2019: Bringing Technology into Social-Ecological Systems Research—Motivations for a Socio-Technical-Ecological Systems Approach. *Sustainability*, **11**(7), 2009, doi:10.3390/su11072009.

Ahmad, B., 2019: *An Analysis of Climate Change in Pakistan*. Scholars' Press, Chisinau, Republic of Moldova. ISBN 13: 9786138512813.

Åhman, M., L.J. Nilsson and B. Johansson, 2017: Global climate policy and deep decarbonization of energy-intensive industries. *Clim. Policy*, **17**(5), 634–649, doi:10.1080/14693062.2016.1167009.

Aipira, C., A. Kidd and K. Morioka, 2017: Climate change adaptation in pacific countries: fostering resilience through gender equality. In: *Climate Change Adaptation in Pacific Countries* [Leal Filho, W.(ed.)]. Springer International Publishing, Cham, pp. 225–239. ISBN 978-3319500935 978-3-319-50094-2).

Ajibade, I. and M. Egge, 2019: SDGs and climate change adaptation in asian megacities: synergies and opportunities for transformation. In: *Achieving the Sustainable Development Goals*. Routledge, London. ISBN 978-0429029622.

Alam, K., et al., 2011: The political economy of climate resilient development planning in Bangladesh. *IDS Bull.*, **42**(3), 52–61, doi:10.1111/j.1759-5436.2011.00222.x.

Albizua, A., E. Corbera and U. Pascual, 2019: Farmers' vulnerability to global change in Navarre, Spain: large-scale irrigation as maladaptation. *Reg. Environ. Change*, **19**(4), 1147–1158, doi:10.1007/s10113-019-01462-2.

Albrecht, G., et al., 2007: Solastalgia: the distress caused by environmental change. *Australas Psychiatry*, doi:10.1080/10398560701701288.

Aldy, J.E., N. Bento and G. Gianfrate, 2021: National climate policies and corporate internal carbon pricing. *Energy J.*, **42**(5), 87–98.

Aldy, J.E. and G. Gianfrate, 2019: *Future-Proof Your Climate Strategy*. Harvard Business Review, Boston.

Aleluia Reis, L., L. Drouet, R. Van Dingenen and J. Emmerling, 2018: Future global air quality indices under different socioeconomic and climate assumptions. *Sustainability*, **10**(10), doi:10.3390/su10103645.

Alkire, S. and S. Jahan, 2018: *The New Global MPI 2018: Aligning with the Sustainable Development Goals*. UNDP Human Development Report Office, New York.

Allen, C., G. Metternicht and T. Wiedmann, 2018a: Initial progress in implementing the Sustainable Development Goals (SDGs): a review of evidence from countries. *Sustain Sci*, **13**(5), 1453–1467, doi:10.1007/s11625-018-0572-3.

Allen, M.R., O.P. Dube, W. Solecki, F. Aragón-Durand, W. Cramer, S. Humphreys, M. Kainuma, J. Kala, N. Mahowald, Y. Mulugetta, R. Perez, M. Wairiu, and K. Zickfeld, 2018b: Framing and Context. *In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the*. 29–91 pp.

Allwood, G., 2014: Gender mainstreaming and EU climate change policy. *Eur. Integr. Online Pap. (EIoP)*, **18,** 1–26; doi: 10.1695/2014006.

Allwood, G., 2020: Gender equality in European Union development policy in times of crisis. *Polit. Stud. Rev.*, **18**(3), 329–345, doi:10.1177/1478929919863224.

Allwood, J., et al., 2019: *Absolute Zero*. https://www.repository.cam.ac.uk/handle/1810/299414. Accessed 2020.

Allwood, J.M., M.F. Ashby, T.G. Gutowski and E. Worrell, 2013: Material efficiency: providing material services with less material production. *Philos. Trans. A. Math. Phys. Eng. Sci.*, **371**(1986), doi:10.1098/rsta.2012.0496.

Alston, M., 2014: Gender mainstreaming and climate change. *Womens Stud Int Forum*, **47**, 287–294, doi:10.1016/j.wsif.2013.01.016.

Altenburg, T. and D. Rodrik, 2017: Green industrial policy: Accelerating structural change towards wealthy green economies. *Green Ind. Policy*. Available at: https://j.mp/2wULvlo.

Alvaredo, F., et al., 2017: Global inequality dynamics: new findings from WID.world. *Am. Econ. Rev.*, **107**(5), 404–409.

Ambrosio, N., Y.H. Kim, S. Swann and Z. Wang, 2020: Optimizing Community Infrastructure. In: *Chapter 7 – Addressing Climate Risk in Financial Decision Making* [Colker, R.(ed.)]. Butterworth-Heinemann, Oxford, UK, pp. 123–142. ISBN 978-0128162408.

Aminga, V.M. and F. Krampe, 2020: *Climate-related Security Risks and the African Union*. SIPRI. accessed 2021-08-30. Available at: https://www.sipri.org/publications/2020/sipri-policy-briefs/climate-related-security-risks-and-african-union

Enders, J. C., 2016: *Theories of Sustainable Development*. Routledge, London.

Andersson, J.J., 2019: Carbon Taxes and CO₂ Emissions: Sweden as a Case Study. *Am. Econ. Journal: Econ. Policy*, **11**(4), 1–30, doi:10.1257/pol.20170144.

Andonova, L.B., T.N. Hale and C.B. Roger, 2017: National policy and transnational governance of climate change: substitutes or complements? *Int Studies Q*, **61**(2), 253–268.

Andreucci, D., 2019: Populism, emancipation, and environmental governance: insights from Bolivia. *Ann. Am. Assoc. Geogr.*, **109**(2), 624–633, doi:10.1080/24694452.2018.1506696.

Andrijevic, M., et al., 2020a: Overcoming gender inequality for climate resilient development. *Nat Commun*, **11**(1), 6261, doi:10.1038/s41467-020-19856-w.

Andrijevic, M., et al., 2020b: COVID-19 recovery funds dwarf clean energy investment needs. *Science*, **370**(6514), 298–300, doi:10.1126/science.abc9697.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Ansar, A., B. Caldecott and J. Tilbury, 2013: Stranded assets and the fossil fuel divestment campaign: What does divestment mean for the valuation of fossil fuel assets? *Business*. Available at: https://www.semanticscholar.org/paper/Stranded-assets-and-the-fossil-fuel-divestment-What-Ansar-Caldecott/7b3e360b303a7303e80643452d9720e50237abd4

Antal, M. and J. van den Bergh, 2014: Green growth and climate change: conceptual and empirical considerations. *Clim. Policy*, **16**, 1–13, doi:10.1080/14693062.2014.992003.

Antwi-Agyei, P., A.J. Dougill, T.P. Agyekum and L.C. Stringer, 2018: Alignment between nationally determined contributions and the sustainable development goals for West Africa. *Clim. Policy*, **18**(10), 1296–1312, doi:10.1080/14693062.2018.1431199.

Antwi-Agyei, P., A.J. Dougill and L.C. Stringer, 2017: Assessing coherence between sector policies and climate compatible development: opportunities for triple wins. *Sustainability*, **9**(11), 2130, doi:10.3390/su9112130.

Appiah, D.O. and S.E.A. Gbeddy, 2018: A synthesis of the implementation ambivalence of REDD+ in Sub-Saharan Africa and Southeast Asia. *For. Soc.*, 92–111, doi:10.24259/fs.v2i1.2918.

Araos, M., J. Ford, L. Berrang-ford and R. Biesbroek, 2017: Climate change adaptation planning for Global South megacities : the case of Dhaka. *J. Environ. Policy Plan.*, **19**(6), 1–15.

Ari, İ., 2017: Tthe interconnection between sustainable development goals and the climate change negotiations: the Paris Agreement case. *Altern. Polit.*, **9**(Special), 27–45.

Arifeen, A. and I. Nyborg, 2021: How humanitarian assistance practices exacerbate vulnerability: Knowledges, authority and legitimacy in disaster interventions in Baltistan, Pakistan. *Int. J. Disaster Risk Reduct.*, **54**, 102027, doi:10.1016/j.ijdrr.2020.102027.

Arku, G. and L. Marais, 2021: Global South Urbanisms and Urban Sustainability—Challenges and the Way Forward. *Front. Sustain. Cities*, doi:10.3389/frsc.2021.692799.

Arneth, A., F. Denton, F. Agus, A. Elbehri, K. Erb, B. Osman Elasha, M. Rahimi, M. Rounsevell, A. Spence, R. Valentini, 2019: Framing and context. In: *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* [Shukla, P. R., J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi and J. Malley (eds.)], In press.

Arneth, A., N. Unger, M. Kulmala and M.O. Andreae, 2009: Clean the Air, Heat the Planet? *Science*, **326**(5953), 672–673, doi:10.1126/science.1181568.

Arora-Jonsson, S., 2011: Virtue and vulnerability: Discourses on women, gender and climate change. *Glob. Environ. Chang.*, **21**(2), 744–751, doi:10.1016/j.gloenvcha.2011.01.005.

Arora-Jonsson, S., 2019: *Indigeneity and Climate Justice in Northern Sweden*. Vol. 9781786997821. eBook ePub: 9781786997852 eBook Kindle: 9781786997845 Library Edition: 9781786997814.

Arora-Jonsson, S. and B.B. Sijapati, 2018: Disciplining gender in environmental organizations: the texts and practices of gender mainstreaming. *Gend. Work. Organ.*, **25**(3), 309–325, doi:10.1111/gwao.12195.

Arora-Jonsson, S., L. Westholm, B.J. Temu and A. Petitt, 2016: Carbon and cash in climate assemblages: the making of a new global citizenship. *Antipode*, **48**(1), 74–96, doi:10.1111/anti.12170.

Arslan, A., et al., 2015: Climate smart agriculture? Assessing the adaptation implications in Zambia. *J. Agric. Econ.*, **66**(3), 753–780, doi:10.1111/1477-9552.12107.

Asefi-Najafabady, S., et al., 2018: Climate change, population, and poverty: vulnerability and exposure to heat stress in countries bordering the Great Lakes of Africa. *Clim. Change*, **148**(4), 561–573, doi:10.1007/s10584-018-2211-5.

Asfaw, S., G. Pallante and A. Palma, 2018: Diversification strategies and adaptation deficit: evidence from rural communities in Niger. *World Dev*, **101**, 219–234, doi:10.1016/j.worlddev.2017.09.004.

ASSAR, 2018: *What global warming of 1.5°C and higher means for Kenya*. University of Cape Town, (ASSAR), A. a. S. i. S. A. R. Available at: https://www.weadapt.org/sites/weadapt.org/files/kenya_1.5_infographic_and_climate-by-zones_table.pdf (accessed 20/01/2022).

Atsiaya, G.O., O.I. Ayuya, L.W. Nakhone and J.K. Lagat, 2019: Drivers and responses to climate variability by agro-pastoralists in Kenya: the case of Laikipia County. *Sn Appl. Sci.*, **1**(8), 827.

Atteridge, A. and E. Remling, 2018: Is adaptation reducing vulnerability or redistributing it? *WIREs Clim. Chang.*, **9**(1), e500, doi:10.1002/wcc.500.

Auffhammer, M., P. Baylis and C.H. Hausman, 2017: Climate change is projected to have severe impacts on the frequency and intensity of peak electricity demand across the United States. *Proc. Natl. Acad. Sci.*, **114**(8), 1886–1891, doi:10.1073/pnas.1613193114.

Aung, T.S., B. Saboori and E. Rasoulinezhad, 2017: Economic growth and environmental pollution in Myanmar: an analysis of environmental Kuznets curve. *Environ. Sci. Pollut. Res.*, **24**(25), 20487–20501, doi:10.1007/s11356-017-9567-3.

Austin, S., et al., 2015: Public health adaptation to climate change in Canadian jurisdictions. *IJERPH*, **12**(1), 623–651.

Avelino, F. and J. Grin, 2017: Beyond deconstruction. a reconstructive perspective on sustainability transition governance. *Environ. Innov. Soc. Transit.*, **22**, 15–25, doi:10.1016/j.eist.2016.07.003.

Avelino, F., J. Grin, B. Pel and S. Jhagroe, 2016: The politics of sustainability transitions. *J. Environ. Policy Plan.*, **18**(5), 557–567, doi:10.1080/1523908X.2016.1216782.

Avelino, F. and J.M. Wittmayer, 2016: Shifting power relations in sustainability transitions: a multi-actor perspective. *J. Environ. Policy Plan.*, **18**(5), 628–649, doi:10.1080/1523908X.2015.1112259.

Avila, S., 2018: Environmental justice and the expanding geography of wind power conflicts. *Sustain Sci*, **13**(3), 599–616, doi:10.1007/s11625-018-0547-4.

Avriel-Avni, N. and J. Dick, 2019: Chapter Five – Differing perceptions of socio-ecological systems: Insights for future transdisciplinary research. In: *Advances in Ecological Research* [Bohan, D.A. and A.J. Dumbrell(eds.)]. Academic Press, Cambridge, MA , pp. 153–190.

Ayers, J.M. and S. Huq, 2009: Supporting adaptation to climate change: what role for official development assistance? *Dev Policy Rev*, **27**(6), 675–692, doi:10.1111/j.1467-7679.2009.00465.x.

Babcicky, P., 2013: A conflict-sensitive approach to climate change adaptation. *Peace Rev.*, **25**(4), 480–488, doi:10.1080/10402659.2013.846131.

Bai, Y., et al., 2019: Does climate adaptation of vulnerable households to extreme events benefit livestock production? *J Clean Prod*, **210**, 358–365, doi:10.1016/j.jclepro.2018.10.250.

Baker, L., P. Newell and J. Phillips, 2014: The political economy of energy transitions: the case of South Africa. *New Polit. Econ.*, **19**(6), 791–818, doi:10.1080/13563467.2013.849674.

Balehey, S., G. Tesfay and M. Balehegn, 2018: Traditional gender inequalities limit pastoral women's opportunities for adaptation to climate change: Evidence from the Afar pastoralists of Ethiopia. *Pastoralism*, **8**(1), 23, doi:10.1186/s13570-018-0129-1.

Bamzai-Dodson, A., A. E. Cravens, A. A. Wade and R. A. McPherson, 2021: Engaging with stakeholders to produce actionable science: a framework and guidance. *Weather, Climate, and Society*, **13**(4), 1027–1041.

Bandura, A. and L. Cherry, 2020: Enlisting the power of youth for climate change. *Am. Psychol.*, **75**(7), 945–951, doi:10.1037/amp0000512.

Banerjee, O., M. Cicowiez, R. Vargas and M. Horridge, 2019: The SEEA-based integrated economic-environmental modelling framework: an illustration with Guatemala's forest and fuelwood sector. *Environ. Resour. Econ.*, **72**(2), 539–558.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Bangura, Y., 2019: Convergence is not equality. *Development & Change*, **50**(2), 394–409, doi:10.1111/dech.12489.

Bank of England, 2019: *The 2021 biennial exploratory scenario on the financial risks from climate change*. Available at: https://www.bankofengland.co.uk/paper/2019/biennial-exploratory-scenario-climate-change-discussion-paper

Baranzini, A., et al., 2017: Carbon pricing in climate policy: seven reasons, complementary instruments, and political economy considerations. *WIREs Clim. Chang.*, **8**(4), e462, doi:10.1002/wcc.462.

Barata, M. M. L., P. L. Kinney, K. Dear, E. Ligeti, K. L. Ebi, J. Hess, T. Dickinson, A. K. Quinn, M. Obermaier, D. Silva Sousa, D. Jack 2018: Urban Health. In: *Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network*. Cambridge University Press, New York, NY, pp. 363–398.

Bárcena-Martín, E., S. Medina-Claros and S. Pérez-Moreno, 2021: Economic regulation, opportunity-driven entrepreneurship and gender gap: emerging versus high-income economies. *Int. J. Entrepreneurial Behav. Res.*, **27**(5), 1311–1328, doi:10.1108/IJEBR-05-2020-0321.

Barker, A.J. and J. Pickerill, 2020: Doings with the land and sea: Decolonising geographies, Indigeneity, and enacting place-agency. *Prog Hum Geogr*, **44**(4), 640–662, doi:10.1177/0309132519839863.

Barnes, P.W., et al., 2019: Ozone depletion, ultraviolet radiation, climate change and prospects for a sustainable future. *Nat. Sustain.*, **2**(7), 569–579, doi:10.1038/s41893-019-0314-2.

Barnett, J., 2019: Global environmental change I: Climate resilient peace? *Prog Hum Geogr*, **43**(5), 927–936.

Barnett, J., 2020: Global environmental change II: Political economies of vulnerability to climate change. *Prog Hum Geogr*, doi:10.1177/0309132519898254.

Barnett, J., et al., 2014: A local coastal adaptation pathway. *Nat. Clim. Chang.*, **4**(12), 1103–1108, doi:10.1038/nclimate2383.

Barnett, J. and C. McMichael, 2018: The effects of climate change on the geography and timing of human mobility. *Popul. Environ.*, **39**(4), 339–356, doi:10.1007/s11111-018-0295-5.

Barnett, J. and S. O'Neill, 2010: Maladaptation. *Glob. Environ. Chang.*, **20**, 211–213, doi:10.1016/j.gloenvcha.2009.11.004.

Barnhardt, R. and O.K. Angayuqaq, 2005: Indigenous knowledge systems and alaska native ways of knowing. *Anthropol. Educ. Q.*, **36**(1), 8–23, doi:10.1525/aeq.2005.36.1.008.

Bartos, M.D. and M.V. Chester, 2015: Impacts of climate change on electric power supply in the Western United States. *Nat. Clim. Change*, **5**(8), 748–752, doi:10.1038/nclimate2648.

Bassett, T.J. and C. Fogelman, 2013: Déjà vu or something new? The adaptation concept in the climate change literature. *Geoforum*, **48**, 42–53, doi:10.1016/j.geoforum.2013.04.010.

Bataille, C., et al., 2018: A review of technology and policy deep decarbonization pathway options for making energy-intensive industry production consistent with the Paris Agreement. *J Clean Prod*, **187**, 960–973, doi:10.1016/j.jclepro.2018.03.107.

Batten, S., 2018: *Climate change and the macro-economy: a critical review*. Staff Working Paper, Vol. 706. Bank of England.

Battiston, S., et al., 2017: A climate stress-test of the financial system. *Nat. Clim. Chang.*, **7**(4), 283–288, doi:10.1038/nclimate3255.

Bauer, N., et al., 2018: Global energy sector emission reductions and bioenergy use: overview of the bioenergy demand phase of the EMF-33 model comparison. *Clim Change*, doi:10.1007/s10584-018-2226-y.

Beck, U., 2015: Emancipatory catastrophism: What does it mean to climate change and risk society? *Curr. Sociol.*, **63**(1), 75–88, doi:10.1177/0011392114559951.

Becker, S., T. Blanchet and C. Kunze, 2016: Social movements and urban energy policy: Assessing contexts, agency and outcomes of remunicipalisation processes in Hamburg and Berlin. *Util. Policy*, **41**, 228–236, doi:10.1016/j.jup.2016.02.001.

Beddoe, R., et al., 2009: Overcoming systemic roadblocks to sustainability: the evolutionary redesign of worldviews, institutions, and technologies. *Proc. Natl. Acad. Sci. U.S.A.*, **106**(8), 2483–2489.

Bell, K., 2013: Post-conventional approaches to gender, climate change and social justice. In: *Research, Action and Policy: Addressing the Gendered Impacts of Climate Change* [Alston, M. and K. Whittenbury(eds.)]. Springer Netherlands, Dordrecht, pp. 53–61. ISBN 978-9400755185.

Béné, C., et al., 2018: Resilience as a policy narrative: potentials and limits in the context of urban planning. *Clim. Dev.*, **10**(2), 116–133, doi:10.1080/17565529.2017.1301868.

Benjaminsen, G. and R. Kaarhus, 2018: Commodification of forest carbon: REDD+ and socially embedded forest practices in Zanzibar. *Geoforum*, **93**, doi:10.1016/j.geoforum.2018.04.021.

Bento, N. and G. Gianfrate, 2020: Determinants of internal carbon pricing. *Energy Policy*, **143**, 111499, doi:10.1016/j.enpol.2020.111499.

Bento, N., G. Gianfrate and M.H. Thoni, 2019: Crowdfunding for sustainability ventures. *J Clean Prod*, **237**, 117751, doi:10.1016/j.jclepro.2019.117751.

Berga, L., 2016: The role of hydropower in climate change mitigation and adaptation: a review. *Engineering*, **2**(3), 313–318, doi:10.1016/J.ENG.2016.03.004.

Berglund, O., & Schmidt, D. (2020). A Theory of Change: The Civil Resistance Model. *Extinction Rebellion and Climate Change Activism*, 79–95. doi:10.1007/978-3-030-48359-3_6

Berkhout, E., J. Bouma, N. Terzidis and M. Voors, 2018: Supporting local institutions for inclusive green growth: developing an evidence gap map. *NJAS - Wageningen J. Life Sci.*, **84**, 51–71, doi:10.1016/j.njas.2017.10.001.

Bernauer, W. and G. Slowey, 2020: COVID-19, extractive industries, and indigenous communities in Canada: Notes towards a political economy research agenda. *Extr. Ind. Soc.*, **7**(3), 844–846, doi:10.1016/j.exis.2020.05.012.

Berrang-Ford, L., et al., 2014: What drives national adaptation? A global assessment. *Clim Change*, **124**(1), 441–450, doi:10.1007/s10584-014-1078-3.

Berry, P.M., et al., 2015: Cross-sectoral interactions of adaptation and mitigation measures. *Clim Change*, **128**(3), 381–393, doi:10.1007/s10584-014-1214-0.

Bethel, B.J., Y. Buravleva and D. Tang, 2021: Blue economy and blue activities: opportunities, challenges, and recommendations for the Bahamas. *Water*, **13**(10), 1399, doi:10.3390/w13101399.

Beuchelt, T.D. and L. Badstue, 2013: Gender, nutrition- and climate-smart food production: opportunities and trade-offs. *Food Sec.*, **5**(5), 709–721, doi:10.1007/s12571-013-0290-8.

Beveridge, R. and P. Koch, 2016: The post-political trap? Reflections on politics, agency and the city. *Urban Stud.*, doi:10.1177/0042098016671477.

Bezner Kerr, R., et al., 2019: Participatory agroecological research on climate change adaptation improves smallholder farmer household food security and dietary diversity in Malawi. *Agric. Ecosyst. Environ.*, **279**, 109–121, doi:10.1016/j.agee.2019.04.004.

Bhamidipati, P.L., J. Haselip and U. Elmer Hansen, 2019: How do energy policies accelerate sustainable transitions? Unpacking the policy transfer process in the case of GETFiT Uganda. *Energy Policy*, **132**, 1320–1332, doi:10.1016/j.enpol.2019.05.053.

Bhavnani, K.-K., J. Foran, P.A. Kurian and D. Munshi, 2019: *Climate futures: Re-imagining global climate justice*. Zed Books Ltd., London. ISBN 978-1786997852.

Bherwani, H., S. Gautam and A. Gupta, 2021: Qualitative and quantitative analyses of impact of COVID-19 on sustainable development goals (SDGs) in Indian subcontinent with a focus on air quality. *Int. J. Environ. Sci. Technol.*, **18**, doi:10.1007/s13762-020-03122-z.

Biagini, B. and A. Miller, 2013: Engaging the private sector in adaptation to climate change in developing countries: importance, status, and challenges. *Clim. Dev.*, **5**(3), 242–252.

Bindoff, N.L., W.W.L. Cheung, J.G. Kairo, J. Arístegui, V.A. Guinder, R. Hallberg, N. Hilmi, N. Jiao, M.S. Karim, L. Levin, S. O'Donoghue, S.R. Purca Cuicapusa,

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

B. Rinkevich, T. Suga, A. Tagliabue, and P. Williamson, 2019: Changing Ocean, Marine Ecosystems, and Dependent Communities. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [Pörtner, H.-O., D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama and N. M. Weyer (eds.)], In press.

Birkmann, J., et al., 2021: New methods for local vulnerability scenarios to heat stress to inform urban planning—case study City of Ludwigsburg/Germany. *Clim Change*, **165**(1), 37, doi:10.1007/s10584-021-03005-3.

Bistline, J.E. and S.K. Rose, 2018: Social cost of carbon pricing of power sector CO 2 : accounting for leakage and other social implications from subnational policies. *Environ. Res. Lett.*, **13**(1), 14027, doi:10.1088/1748-9326/aa9c89.

Biswas, A.K. and C. Tortajada, 2016: Water security, climate change and sustainable development: an introduction. In: *Water Security, Climate Change and Sustainable Development* [Biswas, A.K. and C. Tortajada(eds.)]. Springer Singapore, Singapore, pp. 1–5. ISBN 978-9812879745 978-981-287-976-9).

Bizikova, L., J.-E. Parry, J. Karami and D. Echeverria, 2015: Review of key initiatives and approaches to adaptation planning at the national level in semi-arid areas. *Reg Environ Change*, **15**(5), 837–850.

Blanco G., R. Gerlagh, S. Suh, J. Barrett, H. C. de Coninck, C. F. Diaz Morejon, R. Mathur, N. Nakicenovic, A. Ofosu Ahenkora, J. Pan, H. Pathak, J. Rice, R. Richels, S. J. Smith, D. I. Stern, F. L. Toth, and P. Zhou, 2014: Drivers, Trends and Mitigation. In: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J. C. Minx (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 351–411. ISBN 9781107058217.

Blanford, G.J., S.K. Rose and M. Tavoni, 2012: Baseline projections of energy and emissions in Asia. *Energy Econ.*, **34**, 284–S292, doi:10.1016/j.eneco.2012.08.006.

Bleischwitz, R., et al., 2018: Extrapolation or saturation – Revisiting growth patterns, development stages and decoupling. *Glob. Environ. Chang.*, **48**, 86–96, doi:10.1016/j.gloenvcha.2017.11.008.

Bloemen, P., M.V.D. Steen and Z.V.D. Wal, 2019: Designing a century ahead: climate change adaptation in the Dutch Delta. *Policy Soc.*, **38**(1), 58–76, doi :10.1080/14494035.2018.1513731.

Blühdorn, I. and M. Deflorian, 2021: Politicisation beyond post-politics: new social activism and the reconfiguration of political discourse. *Soc. Mov Stud.*, **20**(3), 259–275, doi:10.1080/14742837.2021.1872375.

Blythe, J., et al., 2018: The Dark Side of Transformation: Latent Risks in Contemporary Sustainability Discourse. *Antipode*, **50**(5), 1206–1223, doi:10.1111/anti.12405.

Bocquillon, P., 2018: (De-)Constructing coherence? Strategic entrepreneurs, policy frames and the integration of climate and energy policies in the European Union. *Environ. Policy Gov.*, **28**(5), 339–349, doi:10.1002/eet.1820.

Bodnar, S., 2008: Wasted and Bombed: Clinical Enactments of a Changing Relationship to the Earth. *Psychoanal. Dialogues.*, **18**(4), 484–512.

Boeckmann, M. and H. Zeeb, 2014: Using a social justice and health framework to assess European climate change adaptation strategies. *Int. J. Environ. Res. Public Health*, **11**(12), 12389–12411, doi:10.3390/ijerph111212389.

Boermans, M. A. and R. Galema, 2019: Are pension funds actively decarbonizing their portfolios? *Ecol. Econ.*, **161**, 50–60, doi:10.1016/j.ecolecon.2019.03.008.

Bohoslavsky, J.P., 2019: *The impact of economic reforms and austerity measures on women's human rights*. Center for Women's Global Leadership – OHCHR. Available at: https://www.ohchr.org/EN/Issues/Development/IEDebt/Pages/ImpactEconomicReformPoliciesWomen.aspx

Bond, S. and J. Barth, 2020: Care-full and just: Making a difference through climate change adaptation. *Cities*, **102**, 102734, doi:10.1016/j.cities.2020.102734.

Bosomworth, K., P. Leith, A. Harwood and P.J. Wallis, 2017: What's the problem in adaptation pathways planning? The potential of a diagnostic problem-structuring approach. *Environ. Sci. Policy*, **76**, 23–28, doi:10.1016/j.envsci.2017.06.007.

Boulton, E., 2016: Climate change as a 'hyperobject': a critical review of Timothy Morton's reframing narrative. *WIREs Clim. Chang.*, **7**(5), 772–785, doi:10.1002/wcc.410.

Bourgeois, R., 2015: *A Glossary of Terms commonly used in Futures Studies*. Doi: 10.13140/RG.2.1.1600.2008

Bowen, K.J., et al., 2017: Implementing the "Sustainable Development Goals": towards addressing three key governance challenges—collective action, trade-offs, and accountability. *Curr. Opin. Environ. Sustain.*, **26-27**, 90–96, doi:10.1016/j.cosust.2017.05.002.

Boyce, J.K., 2018: Carbon pricing: effectiveness and equity. *Ecol. Econ.*, **150**, 52–61, doi:10.1016/j.ecolecon.2018.03.030.

Boyd, J., 2007: Nonmarket benefits of nature: What should be counted in green GDP? *Ecol. Econ.*, **61**(4), 716–723.

Bradley, K. and J. Hedrén, 2014: Utopian Thought in the Making of Green Futures. In: *Green Utopianism: Perspectives, Politics and Micro-Practices* [Bradley, K. & Hedrén, J. (eds.)], pp. 1–20. ISBN 978-0415814447.

Brand, U., C. Görg and M. Wissen, 2020: Overcoming neoliberal globalization: social-ecological transformation from a Polanyian perspective and beyond. *Globalizations*, **17**(1), 161–176, doi:10.1080/14747731.2019.1644708.

Brandi, C. and A. Dzebo, 2017: *The case for connecting the implementation of the Paris Climate Agreement and the 2030 Agenda for Sustainable Development*. German Development Institute. Available at: https://www.die-gdi.de/uploads/media/BP_21.2017.pdf

Brasseur, G. P. and L. Gallardo, 2016: Climate services: Lessons learned and future prospects. *Earth's Future*, **4**(3), 79–89.

Brattland, C. and T. Mustonen, 2018: How traditional knowledge comes to matter in atlantic salmon governance in Norway and Finland. *Arct. Inst. N. Am.*, **71**(4), 375–392, doi:10.14430/arctic4751.

Brattland, C. and S. Nilsen, 2011: Reclaiming indigenous seascapes. Sami place names in Norwegian sea charts. *Polar Geogr.*, **34**, 275–297, doi:10.1080/1088937x.2011.644871.

Brechin, S. and M. Espinoza, 2017: A case for further refinement of the Green Climate Fund's 50:50 ratio climate change mitigation and adaptation allocation framework: toward a more targeted approach. *Clim Change*, **142**, doi:10.1007/s10584-017-1938-8.

Brink, E. and C. Wamsler, 2019: Citizen engagement in climate adaptation surveyed: The role of values, worldviews, gender and place. *J Clean Prod*, **209**, 1342–1353, doi:10.1016/j.jclepro.2018.10.164.

Brooks, N., et al., 2014: *Tracking Adaptation and Measuring Development: a step-by-step guide*. International Institute for Environment and Development. Available at: https://pubs.iied.org/10100iied

Broto, V.C., E. Boyd and J. Ensor, 2015: Participatory urban planning for climate change adaptation in coastal cities: lessons from a pilot experience in Maputo, Mozambique. *Curr. Opin. Environ. Sustain.*, **13**, 11–18, doi:10.1016/j.cosust.2014.12.005.

Brown, K., 2013: Global environmental change I: A social turn for resilience? *Prog Hum Geogr*, doi:10.1177/0309132513498837.

Brulle, R.J. and K.M. Norgaard, 2019: Avoiding cultural trauma: climate change and social inertia. *Env Polit*, **28**(5), 886–908.

Brundiers, K., 2018: Disasters as opportunities for sustainability: the case of Christchurch, Aotearoa New Zealand. *Sustain Sci*, **13**(4), 1075–1091, doi:10.1007/s11625-017-0523-4.

Brundiers, K., 2020: Leveraging disasters for sustainable development. *Environ. Sci. Policy Sustain. Dev.*, **62**(1), 15–27, doi:10.1080/00139157.2020.1687226.

Brundiers, K. and H.C. Eakin, 2018: Leveraging post-disaster windows of opportunities for change towards sustainability: a framework. *Sustainability*, **10**(5), 1390.

Brundtland, C., 1987: *Our Common Future*. Oxford University Press, Oxford, UK.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Bryant, L. and B. Garnham, 2015: The fallen hero: masculinity, shame and farmer suicide in Australia. *Gend. Place Cult.*, **22**(1), 67–82, doi:10.1080/0966369X.2013.855628.

Brzoska, M. and C. Fröhlich, 2016: Climate change, migration and violent conflict: vulnerabilities, pathways and adaptation strategies. *Migr. Dev.*, **5**(2), 190–210, doi:10.1080/21632324.2015.1022973.

Buckwell, A., et al., 2020: Social benefit cost analysis of ecosystem-based climate change adaptations: a community-level case study in Tanna Island, Vanuatu. *Clim. Dev.*, **12**(6), 495–510, doi:10.1080/17565529.2019.1642179.

Buggy, L. and K.E. McNamara, 2016: The need to reinterpret "community" for climate change adaptation: a case study of Pele Island, Vanuatu. *Clim. Dev.*, **8**(3), 270–280, doi:10.1080/17565529.2015.1041445.

Buhaug, H., 2015: Climate–conflict research: some reflections on the way forward. *WIREs Clim. Chang.*, **6**(3), 269–275, doi:10.1002/wcc.336.

Burch, S., et al., 2016: Governing and accelerating transformative entrepreneurship: exploring the potential for small business innovation on urban sustainability transitions. *Curr. Opin. Environ. Sustain.*, **22**, 26–32, doi:10.1016/j.cosust.2017.04.002.

Burke, M., S. Heft-Neal and E. Bendavid, 2016: Sources of variation in under-5 mortality across sub-Saharan Africa: a spatial analysis. *Lancet Glob. Health*, **4**(12), e936–e945, doi:10.1016/S2214-109X(16)30212-1.

Burke, M., S.M. Hsiang and E. Miguel, 2015: Global non-linear effect of temperature on economic production. *Nature*, **527**(7577), 235–239, doi:10.1038/nature15725.

Burman, A., 2017: The political ontology of climate change: moral meteorology, climate justice, and the coloniality of reality in the Bolivian Andes. *J. Polit. Ecol.*, **24**(1), 921–930, doi:10.2458/v24i1.20974.

Busby, J.W., 2021: Beyond internal conflict: The emergent practice of climate security. *J Peace Res*, **58**(1), 186–194, doi:10.1177/0022343320971019.

Busch, T., M. Johnson and T. Pioch, 2020: Corporate carbon performance data: Quo vadis? *J Ind Ecol*, doi:10.1111/jiec.13008.

Busscher, T., M. v. d. Brink and S. Verweij, 2019: Strategies for integrating water management and spatial planning: Organising for spatial quality in the Dutch "Room for the River" program. *J. Flood Risk Manag.*, **12**(1), e12448, doi:10.1111/jfr3.12448.

Butler, C.D., 2017: Limits to growth, planetary boundaries, and planetary health. *Curr. Opin. Environ. Sustain.*, **25**, 59–65, doi:10.1016/j.cosust.2017.08.002.

Butler, J.R.A., et al., 2016: Priming adaptation pathways through adaptive co-management: Design and evaluation for developing countries. *Clim. Risk Manag.*, **12**, 1–16.

Byers, E., et al., 2018: Global exposure and vulnerability to multi-sector development and climate change hotspots. *Environ. Res. Lett.*, **13**(5), 55012, doi:10.1088/1748-9326/aabf45.

Cai, Y. and T.S. Lontzek, 2018: The social cost of carbon with economic and climate risks. *J. Polit. Econ.*, **127**(6), 2684–2734, doi:10.1086/701890.

Calkins, J., 2015: Moving forward after Sendai: how countries want to use science, evidence and technology for disaster risk reduction. *PLoS Curr*, **7**, doi:10.1371/currents.dis.22247d6293d4109d09794890bcda1878.

Camargo, A. and D. Ojeda, 2017: Ambivalent desires: State formation and dispossession in the face of climate crisis. *Polit Geogr*, **60**, 57–65, doi:10.1016/j.polgeo.2017.04.003.

Campbell, B.M., et al., 2016: Reducing risks to food security from climate change. *Glob Food Sec*, **11**, 34–43, doi:10.1016/j.gfs.2016.06.002.

Caniglia, G., et al., 2021: A pluralistic and integrated approach to action-oriented knowledge for sustainability. *Nat. Sustain.*, **4**(2), 93–100, doi:10.1038/s41893-020-00616-z.

Cannon, T. and D. Müller-Mahn, 2010: Vulnerability, resilience and development discourses in context of climate change. *Nat. Hazards*, **55**(3), 621–635, doi:10.1007/s11069-010-9499-4.

Capaldi, C.A., et al., 2015: Flourishing in nature: A review of the benefits of connecting with nature and its application as a wellbeing intervention. *Intnl. J. Wellbeing*, **5**(4), doi:10.5502/ijw.v5i4.449.

Carabine, E., M. Jouanjean and J. Tsui, 2015: Kenya ending drought emergencies policy review: Scenarios for building resilience in the ASALs. Oversees Development Institute. Available at: https://odi.org/en/publications/kenya-ending-drought-emergencies-policy-review-scenarios-for-building-resilience-in-asals/

Carino, J. and L. Tamayo, 2019: *Global Report on the Situation of Lands, Territories and Resources of Indigenous Peoples*. Indigenous Peoples Major Group for Sustainable Development, www.indigenouspeoples-sdg.org (accessed 20/01/2022).

Carmin, J., N. Nadkarni and C. Rhie, 2012: Progress and challenges in urban climate adaptation planning: results of a global. MIT Press, Cambridge, MA.

Carpenter, S.R., C. Folke, M. Scheffer and F.R. Westley, 2019: Dancing on the volcano: social exploration in times of discontent. *Ecol. Soc.*, **24**(1), art23.

Carr, C., 2013: Discourse yes, implementation maybe: an immobility and paralysis of sustainable development policy. *Eur. Plan. Stud.*, **22**(9), 1824–1840.

Carr, E., 2019: Properties and projects: reconciling resilience and transformation for adaptation and development. *World Dev*, **122**, 70–84, doi:10.1016/j.worlddev.2019.05.011.

Carr, E.R., 2020: Resilient livelihoods in an era of global transformation. *Glob. Environ. Chang.*, **64**, 102155, doi:10.1016/j.gloenvcha.2020.102155.

Carr, E.R. and M.C. Thompson, 2014: Gender and climate change adaptation in agrarian settings: current thinking, new directions, and research frontiers: gender and climate change adaptation in agrarian settings. *Geogr. Compass*, **8**(3), 182–197. Doi: 10.1111/gec3.12121

Casas Varez, M., 2017: *La transversalización del enfoque de género en las políticas públicas frente al cambio climático en América Latina*. Economic Commission for Latin America and the Caribbean. Available at: https://www.cepal.org/es/publicaciones/41101-la-transversalizacion-enfoque-genero-politicas-publicas-frente-al-cambio

Casey, G., 2019: *Energy Efficiency and Directed Technical Change: Implications for Climate Change Mitigation*. Department of Economics, Williams College, https://ideas.repec.org/p/wil/wileco/2019-17.html. Accessed 2020 . (Department of Economics Working Papers).

Cash, D.W., et al., 2003: Knowledge systems for sustainable development. *Proc. Natl. Acad. Sci. U. S. A.*, **100**(14), 8086–8091, doi:10.1073/pnas.1231332100.

Castán Broto, V., et al., 2020: Spatiotemporal perspectives on urban energy transitions: a comparative study of three cities in China. *Urban Transform.*, **2**(1), 11, doi:10.1186/s42854-020-00015-9.

Castañeda Carney, I., et al., 2020: *Gender-based violence and environment linkages*. IUCN, Gland, Switzerland, ISBN 978-2831720340.

Castells-Quintana, D., M.P. Lopez-Uribe and T.K.J. McDermott, 2018: Adaptation to climate change: a review through a development economics lens. *World Dev*, **104I**, 183–196.

Catalano, M., L. Forni and E. Pezzolla, 2020: Climate-change adaptation: the role of fiscal policy. *Resour. Energy Econ.*, **59**, 101111, doi:10.1016/j.reseneeco.2019.07.005.

Catley, A., J. Lind and I. Scoones, 2013: *Pastoralism and development in Africa: dynamic change at the margins*. Routledge, London. ISBN 978-1136255854.

Cavaliere, P., 2019: Electrolysis of iron ores: most efficient technologies for greenhouse emissions abatement. In: *Clean Ironmaking and Steelmaking Processes: Efficient Technologies for Greenhouse Emissions Abatement* [Cavaliere, P.(ed.)]. Springer International Publishing, Cham, pp. 555–576. ISBN 978-3030212094.

Ceballos, G., P.R. Ehrlich and R. Dirzo, 2017: Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. *Proc. Natl. Acad. Sci.*, **114**(30), E6089–E6096, doi:10.1073/pnas.1704949114.

Cervigni, R. and M. Morris, 2016: *Confronting Drought in Africa's Drylands: Opportunities for Enhancing Resilience*. World Bank; and Agence Française de Développement, Washington, DC, ISBN 978-1464808173.

Cervigni, R., et al., 2016: *Vulnerability in Drylands Tomorrow: Business as Usual Raising Ominous Prospects*. World Bank Group.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Chae, Y., S.H. Choi and Y.J. Kim, 2020: Climate change policy implications of sustainable development pathways in korea at sub-national scale. *Sustainability*, **12**(10), doi:10.3390/su12104310.

Chakraborty, R. and P.Y. Sherpa, 2021: From climate adaptation to climate justice: critical reflections on the IPCC and himalayan climate knowledges. *Clim Change*, **167**, 49, doi:10.1007/s10584-021-03158-1.

Chambers, R., 2012: *Revolutions in Development Inquiry*, 1st edn., Routledge, London. 258 pp.

Chaminade, C. and F. Randelli, 2020: The role of territorially embedded innovation ecosystems accelerating sustainability transformations: a case study of the transformation to organic wine production in Tuscany (Italy). *Sustainability*, **12**(11), 4621.

Chancel, L. and T. Piketty, 2019: Indian income inequality, 1922-2015: from British Raj to billionaire Raj? *Rev Income Wealth*, **65**(S1), 33–S62, doi:10.1111/roiw.12439.

Chen, A.A., et al., 2020a: Pathways to climate change mitigation and stable energy by 100% renewable for a small island: Jamaica as an example. *Renew. Sustain. Energy Rev.*, **121**, 109671, doi:10.1016/j.rser.2019.109671.

Chen, C., et al., 2016: Measuring the adaptation gap: A framework for evaluating climate hazards and opportunities in urban areas. *Environ. Sci. Policy*, **66**, 403–419, doi:10.1016/j.envsci.2016.05.007.

Chen, G., et al., 2020b: Global projections of future urban land expansion under shared socioeconomic pathways. *Nat Commun*, **11**(1), 537, doi:10.1038/s41467-020-14386-x.

Chen, K., et al., 2018: Future ozone-related acute excess mortality under climate and population change scenarios in China: A modeling study. *PLoS Med*, **15**(7), e1002598, doi:10.1371/journal.pmed.1002598.

Chen, K., et al., 2017: Impact of climate change on heat-related mortality in Jiangsu Province, China. *Environ. Pollut.*, **224**, 317–325, doi:10.1016/j.envpol.2017.02.011.

Chen, Q. and D. Taylor, 2020: Economic development and pollution emissions in Singapore: evidence in support of the environmental Kuznets curve hypothesis and its implications for regional sustainability. *J Clean Prod*, **243**, 118637, doi:10.1016/j.jclepro.2019.118637.

Chen, Y., et al., 2019: Tele-connecting China's future urban growth to impacts on ecosystem services under the shared socioeconomic pathways. *Sci. Total. Environ.*, **652**, 765–779, doi:10.1016/j.scitotenv.2018.10.283.

Chenery, H., 1974: *Redistribution with growth: Policies to improve income distribution in developing countries in the context of economic growth : a joint stul... of Development Studies*. University of Sussex, London, ISBN 978-0199200696. 304 pp.

Chi, Y.F. and J.N. Rauch, 2010: The Plight of Green GDP in China. The Journal of Sustainable Development, doi: 10.7916/D8FX794J

Chome, N., 2020: Land, livelihoods and belonging: negotiating change and anticipating LAPSSET in Kenya's Lamu county. *J. East. African Stud.*, **14**(2), 310–331.

Chowdhooree, I., 2019: Indigenous knowledge for enhancing community resilience: An experience from the south-western coastal region of Bangladesh. *Int. J. Disaster Risk Reduct.*, **40**, 101259, doi:10.1016/j.ijdrr.2019.101259.

Chu, E. and K. Michael, 2019: Recognition in urban climate justice: marginality and exclusion of migrants in Indian cities. *environ urban*, **31**(1), 139–156, doi:10.1177/0956247818814449.

Chu, E.K., 2018: Urban climate adaptation and the reshaping of state–society relations: the politics of community knowledge and mobilisation in Indore, India. *Urban Stud.*, **55**(8), 1766–1782.

Tiam Fook, C., 2017: Transformational processes for community-focused adaptation and social change: a synthesis. *Clim. Dev.*, **9**(1), 5–21.

Ciwmb, 2003: *Plastics White Paper—optimizing plastics use, recycling, and disposal in California*. California Integrated Waste Management Board. Available at: https://www2.calrecycle.ca.gov/Publications/Details/1010 (accessed 20/01/2022).

Clapp, C. and J. Sillmann, 2019: Facilitating climate-smart investments. *One Earth*, **1**(1), 57–61, doi:10.1016/j.oneear.2019.08.009.

Clark, W.C., et al., 2016: Boundary work for sustainable development: Natural resource management at the Consultative Group on International Agricultural Research (CGIAR). *Proc. Natl. Acad. Sci. USA*, **113**(17), 4615–4622, doi:10.1073/pnas.0900231108.

Clarke L., K. Jiang, K. Akimoto, M. Babiker, G. Blanford, K. Fisher-Vanden, J.-C. Hourcade, V. Krey, E. Kriegler, A. Löschel, D. McCollum, S. Paltsev, S. Rose, P. R. Shukla, M. Tavoni, B. C. C. van der Zwaan, and D.P. van Vuure, 2014: Assessing Transformation Pathways. In: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J. C. Minx (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 413–510. ISBN 9781107058217.

Clay, L., M. Papas, K. Gill and D. Abramson, 2018: Factors associated with continued food insecurity among households recovering from hurricane Katrina. *IJERPH*, **15**(8), 1647.

Clayton, S., et al., 2015: Psychological research and global climate change. *Nat. Clim. Chang.*, **5**(7), 640–646.

Clayton, S., C. Manning, K. Krygsman and M. Speiser, 2017: Mental health and our changing climate: impacts. Washington, D.C.: American Psychological Association, and ecoAmerica. Available at: https://www.apa.org/news/press/releases/2017/03/mental-health-climate.pdf (accessed 20/01/2022).

Cloutier, G., et al., 2015: Planning adaptation based on local actors' knowledge and participation: a climate governance experiment. *Clim. Policy*, **15**(4), 458–474.

Clucas, B., I.D. Parker and A.M. Feldpausch-Parker, 2018: A systematic review of the relationship between urban agriculture and biodiversity. *Urban Ecosyst*, **21**(4), 635–643, doi:10.1007/s11252-018-0748-8.

Cobb, C.W. and H. Daly, 1989: *For the common good: redirecting the economy towards community, the environment, and a sustainable future*. Beacon Press, Boston. 482 pp.

Cohen, M.J., 2020: Does the COVID-19 outbreak mark the onset of a sustainable consumption transition? *Sustain. Sci. Pract. Policy*, **16**(1), 1–3, doi:10.1080/15487733.2020.1740472.

Cole, P. and G. Banks, 2017: Renewable energy programmes in the South Pacific – Are these a solution to dependency? *Energy Policy*, **110**, 500–508, doi:10.1016/j.enpol.2017.08.048.

Collins, A.M., J.A. Grant and P. Ackah-Baidoo, 2019a: The glocal dynamics of land reform in natural resource sectors: Insights from Tanzania. *Land Use Policy*, **81**, 889–896.

Collins, S.M., et al., 2019b: 'I know how stressful it is to lack water!' Exploring the lived experiences of household water insecurity among pregnant and postpartum women in western Kenya. *Glob Public Health*, **14**(5), 649–662.

Colloff, M.J., et al., 2021: Adapting transformation and transforming adaptation to climate change using a pathways approach. *Environ. Sci. Policy*, **124**, 163–174, doi:10.1016/j.envsci.2021.06.014.

Collste, D., M. Pedercini and S.E. Cornell, 2017: Policy coherence to achieve the SDGs: using integrated simulation models to assess effective policies. *Sustain Sci*, **12**(6), 921–931, doi:10.1007/s11625-017-0457-x.

Conway, D., et al., 2015: Climate and southern Africa's water–energy–food nexus. *Nat. Clim. Chang.*, **5**(9), 837–846, doi:10.1038/nclimate2735.

Cormack, Z., 2016: The promotion of pastoralist heritage and alternative 'visions' for the future of Northern Kenya. *J. East. African Stud.*, **10**(3), 548–567.

Cormack, Z. and A. Kurewa, 2018: The changing value of land in Northern Kenya: the case of Lake Turkana Wind Power. *Crit. African Stud.*, **10**(1), 89–107.

Cornell, S. et al., 2013: Opening up knowledge systems for better responses to global environmental change. *Environ. Sci. Policy*, **28**, 60–70.

Costantini, V., A. Markandya, E. Paglialunga and G. Sforna, 2018: Impact and distribution of climatic damages: a methodological proposal with a dynamic

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

CGE model applied to global climate negotiations. *Econ Polit*, **35**(3), 809–843, doi:10.1007/s40888-018-0129-z.

Cote, M. and A.J. Nightingale, 2011: Resilience thinking meets social theory: Situating social change in socio-ecological systems (SES) research. *Prog Hum Geogr*, doi:10.1177/0309132511425708.

Country, B., et al., 2018: *Intercultural Communication Handbook*. http://bawakacollective.com/handbook/.

Country, B., et al., 2016: Co-becoming Bawaka:towards a relational understanding of place/space. *Prog Hum Geogr*, **40**(4), 455–475, doi:10.1177/0309132515589437.

Cretney, R., 2014: Resilience for whom? Emerging critical geographies of Socio-ecological resilience. *Geogr. Compass*, **8**(9), 627–640, doi:10.1111/gec3.12154.

Crippa, M., et al., 2019: *Fossil CO2 and GHG emissions of all world countries*. Publications Office of the European Union, https://publications.jrc.ec.europa.eu/repository/handle/111111111/57649. Accessed 2020.

Cubillo-Guevara, A.P., A.L. Hidalgo-Capitán and J.A. Domínguez-Gómez, 2014: El pensamiento sobre el Buen Vivir. Entre el indigenismo, el socialismo y el posdesarrollismo. *Revista Del Clad Reforma Y Democr.*, **60**, 27–58.

Cumming, D.J., G. Leboeuf and A. Schwienbacher, 2017: Crowdfunding cleantech. *Energy Econ.*, **65**, 292–303, doi:10.1016/j.eneco.2017.04.030.

Cundill, G., et al., 2014: *Social Learning for Adaptation: a Descriptive Handbook for Practitioners and Action Researchers*. IDRC/Rhodes University, Ruliv. ISBN 9780868104805.

D'Alessandro, S., A. Cieplinski, T. Distefano and K. Dittmer, 2020: Feasible alternatives to green growth. *Nat. Sustain.*, **3**(4), 329–335, doi:10.1038/s41893-020-0484-y.

Dabelko, G., L. Risi and S. Null, 2013: *Backdraft: The Conflict Potential of Climate Change Adaptation and Mitigation*. Woodrow Wilson International Center for Scholars, Washington, DC.

Daigneault, A., et al., 2019: Developing detailed shared socioeconomic pathway (SSP) narratives for the global forest sector. *J. For. Econ.*, **34**(1-2), 7–45, doi:10.1561/112.00000441.

Daly, H. and J. Cobb, 1989: *For the Common Good. Redirecting the Economy Toward Community, the Environment and a Sustainable Future*. Beacon Press, Boston, Massachusetts.

Danilina, V. and Trionfetti, 2019: *Green Public Procurement vs Environmental Taxation: implications for the EU-MENA environmental policy*. Available at: https://planbleu.org/en/publications/green-public-procurement-v-s-environmental-taxation-implications-for-the-eu-mena-environmental-policy/ (accessed 20/01/2022).

Daron, J., et al., 2021: Integrating seasonal climate forecasts into adaptive social protection in the Sahel. *Clim. Dev.*, **13**(6), 543–550, doi:10.1080/17565529.2020.1825920.

Davelaar, D., 2021: Transformation for sustainability: a deep leverage points approach. *Sustain Sci*, **16**(3), 727–747, doi:10.1007/s11625-020-00872-0.

David, M., 2017: Moving beyond the heuristic of creative destruction: Targeting exnovation with policy mixes for energy transitions. *Energy Res. Soc. Sci.*, **33**, 138–146, doi:10.1016/j.erss.2017.09.023.

Tàbara, D., et al., 2018: Positive tipping points in a rapidly warming world. *Curr. Opin. Environ. Sustain.*, **31**, 120–129, doi:10.1016/j.cosust.2018.01.012.

Davidson, K., T.M.P. Nguyen, R. Beilin and J. Briggs, 2019: The emerging addition of resilience as a component of sustainability in urban policy. *Cities*, **92**, 1–9, doi:10.1016/j.cities.2019.03.012.

Davidsson, Å., 2020: Disasters as an opportunity for improved environmental conditions. *Int. J. Disaster Risk Reduct.*, **48**, 101590, doi:10.1016/j.ijdrr.2020.101590.

de Coninck, H., A. Revi, M. Babiker, P. Bertoldi, M. Buckeridge, A. Cartwright, W. Dong, J. Ford, S. Fuss, J.-C. Hourcade, D. Ley, R. Mechler, P. Newman, A. Revokatova, S. Schultz, L. Steg, and T. Sugiyama, 2018: Strengthening and Implementing the Global Response. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor and T. Waterfield (eds.)]. In press. ISBN 9789291691517.

de Coninck, H. and A. Sagar, 2015: Making sense of policy for climate technology development and transfer. *Clim. Policy*, **15**(1), 1–11.

De Juan, A., 2015: Long-term environmental change and geographical patterns of violence in Darfur, 2003–2005. *Polit Geogr*, **45**, 22–33, doi:10.1016/j.polgeo.2014.09.001.

de la Torre-Castro, M., et al., 2017: Gender analysis for better coastal management – Increasing our understanding of social-ecological seascapes. *Mar. Policy.*, **83**, 62–74, doi:10.1016/j.marpol.2017.05.015.

de Vries, G.W., W.P.C. Boon and A. Peine, 2016: User-led innovation in civic energy communities. *Environ. Innov. Soc. Transit.*, **19**, 51–65, doi:10.1016/j.eist.2015.09.001.

de Witt, A., 2015: Climate change and the clash of Worldviews: an exploration of how to move forward in a polarized debate. *Zygon*, **50**(4), 906–921, doi:10.1111/zygo.12226.

De Witt, A., J. de Boer, N. Hedlund and P. Osseweijer, 2016: A new tool to map the major worldviews in the Netherlands and USA, and explore how they relate to climate change. *Environ. Sci. Policy*, **63**, 101–112, doi:10.1016/j.envsci.2016.05.012.

Deaconu, A., G. Mercille and M. Batal, 2019: The agroecological farmer's pathways from agriculture to nutrition: a practice-based case from Ecuador's highlands. *Ecol. Food. Nutr.*, **58**(2), 142–165.

Dearing, J.A., et al., 2014: Safe and just operating spaces for regional social-ecological systems. *Glob. Environ. Chang.*, **28**, 227–238.

DeCaro, D.A., C.A. Arnold, E. Frimpong Boamah and A.S. Garmestani, 2017: Understanding and applying principles of social cognition and decision making in adaptive environmental governance. *Ecol. Soc.*, **22**(1), art33.

Dekker, S., 2020: Responding to climate change : the role of local government in ireland. *Irel. Clim. Crisis*, 109–127. Doi: 10.1007/978-3-030-47587-1_7.

Delina, L.L. and B.K. Sovacool, 2018: Of temporality and plurality: an epistemic and governance agenda for accelerating just transitions for energy access and sustainable development. *Curr. Opin. Environ. Sustain.*, **34**, 1–6, doi:10.1016/j.cosust.2018.05.016.

Dellink, R., E. Lanzi and J. Chateau, 2019: The sectoral and regional economic consequences of climate change to 2060. *Environ. Resour. Econ.*, **72**(2), 309–363, doi:10.1007/s10640-017-0197-5.

Dellmuth, L.M., M.-T. Gustafsson, N. Bremberg and M. Mobjörk, 2018: Intergovernmental organizations and climate security: advancing the research agenda. *WIREs Clim. Chang.*, **9**(1), e496, doi:10.1002/wcc.496.

Demaria, F. and A. Kothari, 2017: The post-development dictionary agenda: paths to the pluriverse. *Third World Q*, **38**(12), 2588–2599, doi:10.1080/01436597.2017.1350821.

Demaria, F., F. Schneider, F. Sekulova and J. Martinez-Alier, 2013: What is degrowth? From an activist slogan to a social movement. *environ values*, **22**(2), 191–215, doi:10.3197/096327113X13581561725194.

Demeritt, D., et al., 2011: Pathways to Sustainability: perspectives and provocations. *Environ. Plan. A.*, **43**(5), 1226–1237, doi:10.1068/a227sym.

Dempsey, J., T.G. Martin and U.R. Sumaila, 2020: Subsidizing extinction? *Conservation Letters*, **13**(1), e12705, doi:10.1111/conl.12705.

Demuzere, M., et al., 2014: Mitigating and adapting to climate change: multi-functional and multi-scale assessment of green urban infrastructure. *J. Environ. Manag.*, **146**, 107–115, doi:10.1016/j.jenvman.2014.07.025.

Deneulin, S. and L. Shahani, 2009: *An Introduction to the Human Development and Capability Approach: Freedom and Agency*. 1st edn. Routledge, London ; Sterling, VA : Ottawa, ON. ISBN 978-1844078066 376 pp).

Denton, F., T.J. Wilbanks, A.C. Abeysinghe, I. Burton, Q. Gao, M.C. Lemos, T. Masui, K.L. O'Brien, and K. Warner, 2014: Climate-Resilient Pathways: Adaptation, Mitigation, and Sustainable Development. In: *Climate Change*

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C. B., V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea and L. L. White (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 1101-1131. ISBN 9781107058071.

Díaz, S., et al., 2015: The IPBES conceptual framework—connecting nature and people. *Curr. Opin. Environ. Sustain.*, **14**, 1–16.

Díaz, S., et al., 2018: Assessing nature's contributions to people. *Science*, **359**(6373), 270–272, doi:10.1126/science.aap8826.

Dietz, S., A. Bowen, C. Dixon and P. Gradwell, 2016: 'Climate value at risk' of global financial assets. *Nat. Clim. Chang.*, **6**(7), 676–679, doi:10.1038/nclimate2972.

Diffenbaugh, N. and M. Burke, 2019: Global warming has increased global economic inequality. *Proc. Natl. Acad. Sci.*, **116**, 201816020, doi:10.1073/pnas.1816020116.

DiGregorio, M., 2015: Bargaining with disaster: flooding, climate change, and Urban growth ambitions in Quy Nhon, Vietnam. *pac aff*, **88**(3), 577–597, doi:10.5509/2015883577.

Dimson, E., O. Karakaş and X. Li, 2015: Active ownership. *Rev Financ Stud*, **28**(12), 3225–3268, doi:10.1093/rfs/hhv044.

Dimson, E., O. Karakaş and X. Li, 2020: *Coordinated Engagements*. European Corporate Governance Institute – Finance Working Paper No. 721/2021. Doi: 10.2139/ssrn.3209072.

Djoudi, H., et al., 2016: Beyond dichotomies: Gender and intersecting inequalities in climate change studies. *Ambio*, **45**(S3), 248–262.

Doczi, J., 2015: *Understanding patterns of climate resilient economic development*. Available at: https://www.odi.org/publications/10101-understanding-patterns-climate-resilient-economic-development (accessed 20/01/2021).

Dodman, D. and D. Mitlin, 2015: The national and local politics of climate change adaptation in Zimbabwe. *Clim. Dev.*, **7**(3), 223–234.

Dolšak, N. and A. Prakash, 2018: The politics of climate change adaptation. *Annu. Rev. Environ. Resour.*, **43**(1), 317–341, doi:10.1146/annurev-environ-102017-025739.

Domingo, A., 2018: Analyzing zombie dystopia as neoliberal scenario: an exercise in emancipatory catastrophism. *Front. Sociol.*, **3**, 20, doi:10.3389/fsoc.2018.00020.

Donner, S.D., M. Kandlikar and S. Webber, 2016: Measuring and tracking the flow of climate change adaptation aid to the developing world. *Environ. Res. Lett.*, **11**(5), 54006.

Dornan, M., 2015: Renewable energy development in small island developing states of the pacific. *Resources*, **4**(3), 490–506, doi:10.3390/resources4030490.

Douxchamps, S., et al., 2016: Linking agricultural adaptation strategies, food security and vulnerability: evidence from West Africa. *Reg Environ Change*, **16**(5), 1305–1317, doi:10.1007/s10113-015-0838-6.

Dresse, A., I. Fischhendler, J.Ø. Nielsen and D. Zikos, 2018: Environmental peacebuilding: towards a theoretical framework. *Coop Confl*, doi:10.1177/0010836718808331.

Dreyer, J.S., 2015: Ubuntu. *Int. J. Pract. Theol.*, **19**(1), 189–209, doi:10.1515/ijpt-2015-0022.

Driver, E., M. Parsons and K. Fisher, 2018: Technically political: The post-politics(?) of the New Zealand Emissions Trading Scheme. *Geoforum*, **97**, 253–267, doi:10.1016/j.geoforum.2018.09.023.

Duan, F., Q. Ji, B.-Y. Liu and Y. Fan, 2018: Energy investment risk assessment for nations along China's Belt & Road Initiative. *J Clean Prod*, **170**, 535–547, doi:10.1016/j.jclepro.2017.09.152.

Duku, C., S.J. Zwart and L. Hein, 2018: Impacts of climate change on cropping patterns in a tropical, sub-humid watershed. *PLoS One*, **13**(3), e192642, doi:10.1371/journal.pone.0192642.

Dumont, E.S., S. Bonhomme, T.F. Pagella and F.L. Sinclair, 2019: Structured stakeholder engagement leads to development of more diverse and inclusive agroforestry options. *Exp. Agric.*, **55**(S1), 252–274.

Dun, O., C. McMichael, K. McNamara and C. Farbotko, 2020: Investing in home: development outcomes and climate change adaptation for seasonal workers living between Solomon Islands and Australia. *Migr. Dev.*, **0**(0), 1–24, doi:10.1080/21632324.2020.1837535.

Dzebo, A., et al., 2017: *Exploring connections between the Paris Agreement and the 2030 Agenda for Sustainable Development*. Stockholm Environment Institute. Available at: https://transparency-partnership.net/system/files/document/SEI_2017_Exploring%20Paris%20Agreement%20and%20SDG%20connections.pdf (accessed 20/0/2022)

Dzebo, A., H. Janetschek, C. Brandi and G. Iacobuta, 2019: *Connections between the Paris Agreement and the 2030 Agenda: the case for policy coherence*. Stockholm Environment Institute. Available at: https://www.sei.org/publications/connections-between-the-paris-agreement-and-the-2030-agenda/ (accessed 20/01/2021).

Eakin, H.C., M.C. Lemos and D.R. Nelson, 2014: Differentiating capacities as a means to sustainable climate change adaptation. *Glob. Environ. Chang.*, **27**(1), 1–8.

Eastin, J., 2018: Climate change and gender equality in developing states. *World Dev*, **107**, 289–305.

Ebi, K.L., N.H. Ogden, J.C. Semenza and A. Woodward, 2017: Detecting and attributing health burdens to climate change. *Environ. Health Perspect.*, **125**(8), 85004, doi:10.1289/EHP1509.

ECB, 2020: *Guide on Climate-Related and Environmental Risks*. European Central Bank. Available at: https://www.bankingsupervision.europa.eu/legalframework/publiccons/pdf/climate-related_risks/ssm.202005_draft_guide_on_climate-related_and_environmental_risks.en.pdf (accessed 20/01/2022).

Economides, G. and A. Xepapadeas, 2018: *Monetary Policy under Climate Change*. CESifo Working Paper, CESifo, Munich, Vol. 7021.

Ehnert, F., et al., 2018: Urban sustainability transitions in a context of multi-level governance: A comparison of four European states. *Environ. Innov. Soc. Transit.*, **26**, 101–116, doi:10.1016/j.eist.2017.05.002.

Eisenmenger, N., et al., 2020: The Sustainable Development Goals prioritize economic growth over sustainable resource use: a critical reflection on the SDGs from a socio-ecological perspective. *Sustain Sci*, **15**(4), 1101–1110, doi:10.1007/s11625-020-00813-x.

Elliott, A. and J. Cullis, 2017: The importance of the humanities to the climate change debate. In: *Climate Change and the Humanities: Historical, Philosophical and Interdisciplinary Approaches to the Contemporary Environmental Crisis* [Elliott, A., J. Cullis and V. Damodaran(eds.)]. Palgrave Macmillan UK, London, pp. 15–42. ISBN 978-1137551245.

Ellis, N.R. and P. Tschakert, 2019: Triple-wins as pathways to transformation? A critical review. *Geoforum*, **103**, 167–170, doi:10.1016/j.geoforum.2018.12.006.

Emmerling, J. and M. Tavoni, 2021: Representing inequalities in integrated assessment modeling of climate change. *One Earth*, **4**(2), 177–180, doi:10.1016/j.oneear.2021.01.013.

Enns, C., 2018: Mobilizing research on Africa's development corridors. *Geoforum*, **88**, 105–108.

Enns, C. and B. Bersaglio, 2020: On the coloniality of "new" mega-infrastructure projects in east africa. *Antipode*, **52**(1), 101–123.

Ensor, J., 2016: *Adaptation and resilience in Vanuatu: Interpreting community perceptions of vulnerability, knowledge and power for community-based adaptation programming*. Report by SEI for Oxfam Australia, Carlton. Stockhom Environment Institute, Stockholm.

Eriksen, S., R. Grøndahl and A.-M. Sæbønes, 2021a: On CRDP and CRPD: Why the rights of persons with disabilities are critical for understanding climate resilient development pathways. *Lancet Planet. Health*.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Eriksen, S., et al., 2021b: Adaptation interventions and their effect on vulnerability in developing countries: help, hindrance or irrelevance? *World Dev*, **141**, 105383, doi:10.1016/j.worlddev.2020.105383.

Eriksen, S.H., L.K. Cramer, I. Vetrhus and P. Thornton, 2019: Can climate interventions open up space for transformation? Examining the case of climate-smart agriculture (CSA) in Uganda. *Front. Sustain. Food Syst.*, **3**.

Eriksen, S.H., A.J. Nightingale and H. Eakin, 2015: Reframing adaptation: the political nature of climate change adaptation. *Glob. Environ. Chang.*, **35**, 523–533, doi:10.1016/j.gloenvcha.2015.09.014.

Escobar, A., 1995: Imagining a post-development era. *Power Dev.*, 211–227. Doi: 10.2307/466217

Escobar, A., 2016: Thinking-feeling with the earth; territorial struggles and the ontological dimension of the epistemologies of the south. *AIBR Revista De Antropología Iberoamericana*, **11**(1), 11–32.

Esquivel-Muelbert, A., et al., 2019: Compositional response of Amazon forests to climate change. *Glob. Change Biol.*, **25**(1), 39–56, doi:10.1111/gcb.14413.

Estoque, R., et al., 2018: A review of quality of life (QOL) assessments and indicators: Towards a "QOL-Climate" assessment framework. *Ambio*, **48**, doi:10.1007/s13280-018-1090-3.

Etchart, L., 2017: The role of indigenous peoples in combating climate change. *Palgrave Commun*, **3**(1), 1–4, doi:10.1057/palcomms.2017.85.

Ewuoso, C. and S. Hall, 2019: Core aspects of ubuntu: a systematic review. *S Afr J BL*, **12**(2), 93–103, doi:10.7196/SAJBL.2019.v12i2.679.

Fadrique, B., et al., 2018: Widespread but heterogeneous responses of Andean forests to climate change. *Nature*, **564**(7735), 207–212, doi:10.1038/s41586-018-0715-9.

Faist, T., 2018: The Socio-natural question: how climate change adds to social inequalities. *J. Intercult. Stud.*, **39**(2), 195–206, doi:10.1080/07256868.2018.1446670.

Fankhauser, S. and T. McDermott, 2016: *The Economics of Climate Resilient Development*. Edward Elgar Publishing, Cheltenham, UK, ISBN 978-1785360312.

Fankhauser, S. and T.K.J. McDermott, 2014: Understanding the adaptation deficit: why are poor countries more vulnerable to climate events than rich countries? *Glob. Environ. Chang.*, **27**, 9–18, doi:10.1016/j.gloenvcha.2014.04.014.

FAO, 2014: *Walking the Nexus Talk: Assessing the Water-Energy-Food Nexus in the Context of the Sustainable Energy for All Initiative*. Food and Agriculture Organization of the United Nations, Rome.

Fao, 2016: *Base de datos Género y derecho a la tierra*. FAO, Available at: http://www.fao.org/gender-landrights-database (accessed 20/01/2022).

Farrell, N., 2015: 'Conscience capitalism'and the neoliberalisation of the non-profit sector. *New Polit. Econ.*, **20**(2), 254-272.

Faruque, M.O., 2017: Neoliberal resource governance and counter-hegemonic social movement in Bangladesh. *Soc. Mov Stud.*, **16**(2), 254–259, doi:10.1080/14742837.2016.1268957.

Favretto, N., et al., 2018: Links between climate change mitigation, adaptation and development in land policy and ecosystem restoration projects: lessons from South Africa. *Sustainability*, **10**(3), 779, doi:10.3390/su10030779.

Fazey, I., et al., 2018a: Transformation in a changing climate: a research agenda. *Clim. Dev.*, **10**(3), 197–217.

Fazey, I., et al., 2018b: Ten essentials for action-oriented and second order energy transitions, transformations and climate change research. *Energy Res. Soc. Sci.*, **40**, 54–70.

Fazey, I., et al., 2016: Past and future adaptation pathways. *Clim. Dev.*, **8**(1), 26–44.

Fedele, G., et al., 2019: Transformative adaptation to climate change for sustainable social-ecological systems. *Environ. Sci. Policy*, **101**, 116–125, doi:10.1016/j.envsci.2019.07.001.

Feodoroff, P., 2020: Indigenous Female Bodies as Indicators of Change. *Global Report of Indigenous Knowledge and Local Knowledge on Climate Change 2020*. Available at: https://arcticpassion.eu/blog/Paulina (accessed 20/01/2022).

Feola, G., 2015: Societal transformation in response to global environmental change: a review of emerging concepts. *Ambio*, **44**(5), 376–390, doi:10.1007/s13280-014-0582-z.

Feola, G., O. Koretskaya and D. Moore, 2021: (Un)making in sustainability transformation beyond capitalism. *Glob. Environ. Chang.*, **69**, 102290, doi:10.1016/j.gloenvcha.2021.102290.

Fergnani, A. and Z. Song, 2020: The six scenario archetypes framework: A systematic investigation of science fiction films set in the future. *Futures*, **124**, 102645, doi:10.1016/j.futures.2020.102645.

Fernandez, G. and I. Ahmed, 2019: "build back better" approach to disaster recovery: research trends since 2006. *Prog. Disaster Sci.*, **1**, 100003, doi:10.1016/j.pdisas.2019.100003.

Ferragina, E., A. Arrigoni and T.F. Spreckelsen, 2020: The rising invisible majority. *Rev. Int. Polit. Econ.*, **0**(0), 1–38, doi:10.1080/09692290.2020.1797853.

Few, R., et al., 2017: Transformation, adaptation and development: relating concepts to practice. *Palgrave Commun*, **3**(1), 1–9, doi:10.1057/palcomms.2017.92.

Ficklin, L., L.C. Stringer, A.J. Dougill and S.M. Sallu, 2018: Climate compatible development reconsidered: calling for a critical perspective. *Clim. Dev.*, **10**(3), 193–196, doi:10.1080/17565529.2017.1372260.

Fioramonti, L., L. Coscieme and L.F. Mortensen, 2019: From gross domestic product to wellbeing: How alternative indicators can help connect the new economy with the Sustainable Development Goals. *Anthropocene Rev.*, doi:10.1177/2053019619869947.

Fischedick M., J. Roy, A. Abdel-Aziz, A. Acquaye, J. M. Allwood, J.-P. Ceron, Y. Geng, H. Kheshgi, A. Lanza, D. Perczyk, L. Price, E. Santalla, C. Sheinbaum and K. Tanaka, 2014: Industry. In: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J. C. Minx (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 739–810. ISBN 9781107058217.

Fischer, J. and M. Riechers, 2019: A leverage points perspective on sustainability. *People Nat.*, **1**(1), 115–120, doi:10.1002/pan3.13.

Fisher, B. S. et al., 2007: Issues related to mitigation in the long term context. In: *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Metz, B., O. R. Davidson, P. R. Bosch, R. Dave and L. A. Meyer (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 169-250. ISBN 9780521880114.

Fisher, E., J. Hellin, H. Greatrex and N. Jensen, 2019: Index insurance and climate risk management: addressing social equity. *Dev Policy Rev*, **37**(5), 581–602, doi:10.1111/dpr.12387.

Flammer, C., 2020: *Green Bonds: Effectiveness and Implications for Public Policy*. National Bureau of Economic Research, Cambridge, MA, https://www.nber.org/papers/w25950. Accessed 2020.

Fleurbaey M., S. Kartha, S. Bolwig, Y. L. Chee, Y. Chen, E. Corbera, F. Lecocq, W. Lutz, M. S. Muylaert, R. B. Norgaard, C. Oker-eke, and A. D. Sagar, 2014: Sustainable Development and Equity. In: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C. B., V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea and L. L. White (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA.

Folke, C., et al., 2016: Social-ecological resilience and biosphere-based sustainability science. *Ecology and Society* 21(3):41. Doi: 10.5751/ES-08748-210341

Ford, J., et al., 2016: Including indigenous knowledge and experience in IPCC assessment reports. *Nat. Clim. Chang.*, **64**(4), 349.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Ford, J., W. Vanderbilt and L. Berrang-Ford, 2012: Authorship in IPCC AR5 and its implications for content: climate change and Indigenous populations in WGII. *Clim Change*, **113**(2), 201–213, doi:10.1007/s10584-011-0350-z.

Ford, J.D., et al., 2015: The status of climate change adaptation in Africa and Asia. *Reg Environ Change*, **15**(5), 801–814.

Ford, J.D., et al., 2020: The resilience of Indigenous Peoples to environmental change. *One Earth*, **2**, 532–543.

Forsyth, T., 2018: Is resilience to climate change socially inclusive? Investigating theories of change processes in Myanmar. *World Dev*, **111**, 13–26, doi:10.1016/j.worlddev.2018.06.023.

Foster-Fishman, P.G., B. Nowell and H. Yang, 2007: Putting the system back into systems change: a framework for understanding and changing organizational and community systems. *Am J Community Psychol*, **39**(3-4), 197–215, doi:10.1007/s10464-007-9109-0.

Fougère, L. and S. Bond, 2016: Legitimising activism in democracy: a place for antagonism in environmental governance. *Plan. Theory*, doi:10.1177/1473095216682795.

Fragkias, M. and C.G. Boone, 2016: Modern political economy, global environmental change and urban sustainability transitions. *Curr. Opin. Environ. Sustain.*, **22**, 63–68, doi:10.1016/j.cosust.2017.04.007.

Frainer, A., et al., 2020: Cultural and linguistic diversities are underappreciated pillars of biodiversity. *Proc. Natl. Acad. Sci.*, **117**(43), 26539–26543, doi:10.1073/pnas.2019469117.

Franco-Torres, M., B.C. Rogers and R. Harder, 2020: Articulating the new urban water paradigm. *Crit Rev Environ Sci Technol*, **0**(0), 1–47, doi:10.1080/10643389.2020.1803686.

Frank, S., et al., 2017: Reducing greenhouse gas emissions in agriculture without compromising food security? *Environ. Res. Lett.*, **12**(10), 105004, doi:10.1088/1748-9326/aa8c83.

Frank, T.D., et al., 2019: Global, regional, and national incidence, prevalence, and mortality of HIV, 1980-2017, and forecasts to 2030, for 195 countries and territories: a systematic analysis for the Global Burden of Diseases, Injuries, and Risk Factors Study 2017. *Lancet HIV*, **6**(12), e831–e859, doi:10.1016/s2352-3018(19)30196-1.

Frantzeskaki, N., et al., 2017: Nature-based solutions accelerating urban sustainability transitions in cities: lessons from Dresden, Genk and Stockholm cities. In: *Nature-Based Solutions to Climate Change Adaptation in Urban Areas* [Korn, H. & Kabisch, N. (eds).]. Springer, Cham, pp. 65–88.

Fresnillo Sallan, I., 2020: Debt and climate: entangled emergencies derailing women's rights and gender justice. *Gend. Dev.*, **28**(3), 499–513, doi:10.1080/13552074.2020.1838168.

Friedman, S., S. Schmer-Galunder, A. Chen and J. Rye (eds.), 2019: *Relating Word Embedding Gender Biases to Gender Gaps: A Cross-Cultural Analysis*. Association for Computational Linguistics, Florence, Italy, 18–24.

Froehlich, H.E., J.C. Afflerbach, M. Frazier and B.S. Halpern, 2019: Blue Growth Potential to Mitigate Climate Change through Seaweed Offsetting. *Curr. Biol.*, **29**(18), 3087–3093.e3083, doi:10.1016/j.cub.2019.07.041.

Fudge, S., M. Peters and B. Woodman, 2016: Local authorities as niche actors: the case of energy governance in the UK. *Environ. Innov. Soc. Transit.*, **18**, 1–17. Doi: 10.1016/j.eist.2015.06.004.

Fund for Peace, 2021: *Fragile States Index Annual Report 2021*. Fund for Peace, Peace, F. f., Washington, DC. 51 pp.

Fuso Nerini, F., et al., 2018: Mapping synergies and trade-offs between energy and the Sustainable Development Goals. *Nat. Energy*, **3**(1), 10–15, doi:10.1038/s41560-017-0036-5.

Gaddy, B.E., V. Sivaram, T.B. Jones and L. Wayman, 2017: Venture Capital and Cleantech: The wrong model for energy innovation. *Energy Policy*, **102**, 385–395, doi:10.1016/j.enpol.2016.12.035.

Galvin, K. A., 2009: Transitions: pastoralists living with change. *Annu. Rev. Anthropol.*, **38**(1), 185–198.

Gambrel, J.C. and P. Cafaro, 2009: The virtue of simplicity. *J. Agric. Environ. Ethics.*, **23**(1), 85, doi:10.1007/s10806-009-9187-0.

Garcia, A., P. Tschakert and N.A. Karikari, 2020: 'Less able': how gendered subjectivities warp climate change adaptation in Ghana's Central Region. *Gend. Place Cult.*, **27**(11), 1602–1627, doi:10.1080/0966369X.2020.1786017.

Garcia, D.J. and F. You, 2017: Introducing green GDP as an objective to account for changes in global ecosystem services Due to Biofuel production. In: *Computer Aided Chemical Engineering* [Espuña, A., M. Graells and L. Puigjaner(eds.)]. Elsevier, Amsterdam, pp. 505–510.

Garg, A. and K. Halsnæs, 2007: *Sustainable development to enhance resilience to climate change vulnerability. From vulnerability to resilience: The challenge of adaptation to climate change*, 17–25. United Nations Environment Programme. Available at: https://www.researchgate.net/publication/228466265_From_Vulnerability_to_Resilience_The_Challenge_of_Adaptation_to_Climate_Change (accessed 20/01/2022).

Garschagen, M., et al., 2021: The consideration of future risk trends in national adaptation planning: conceptual gaps and empirical lessons. *Clim. Risk Manag.* In press. Doi: 10.1016/j.crm.2021.100357

Gaur, M. and V.R. Squires, 2018: *Climate Variability Impacts on Land Use and Livelihoods in Drylands*. Springer International Publishing, Cham. ISBN 978-3319566801.

Gay-Antaki, M., 2020: Feminist geographies of climate change: negotiating gender at climate talks. *Geoforum*, **115**, 1–10.

Gay-Antaki, M. and D. Liverman, 2018: Climate for women in climate science: women scientists and the intergovernmental panel on climate change. *Proc. Natl. Acad. Sci.*, **115**(9), 2060–2065.

Gazzotti, P., et al., 2021: Persistent inequality in economically optimal climate policies. *Nat Commun*, **12**(1), 3421, doi:10.1038/s41467-021-23613-y.

Gebreyes, M., 2018: 'Producing' institutions of climate change adaptation and food security in north eastern Ethiopia. *NJAS - Wageningen J. Life Sci.*, **84**, 123–132, doi:10.1016/j.njas.2017.10.007.

Geere, J.-A.L. and P.R. Hunter, 2020: The association of water carriage, water supply and sanitation usage with maternal and child health. A combined analysis of 49 Multiple Indicator Cluster Surveys from 41 countries. *Int J Hyg Environ Health*, **223**(1), 238–247.

Geradts, T.H. and N.M. Bocken, 2019: Driving sustainability-oriented innovation. *MIT Sloan Manage. Rev.*, **60**(2), 1.

Gernert, M., H. El Bilali and C. Strassner, 2018: Grassroots initiatives as Sustainability transition pioneers: implications and lessons for urban food systems. *Urban Sci.*, **2**(1), 23.

Gerst, M., P. Raskin and J. Rockström, 2013: Contours of a resilient global future. *Sustainability*, **6**, 123–135, doi:10.3390/su6010123.

Ghisetti, C., S. Mancinelli, M. Mazzanti and M. Zoli, 2017: Financial barriers and environmental innovations: evidence from EU manufacturing firms. *Clim. Policy*, **17**(sup1), 131–S147, doi:10.1080/14693062.2016.1242057.

Gianfrate, G. and M. Peri, 2019: The green advantage: exploring the convenience of issuing green bonds. *J Clean Prod*, **219**, 127–135, doi:10.1016/j.jclepro.2019.02.022.

Gibon, T., et al., 2020: Shades of green: life cycle assessment of renewable energy projects financed through green bonds. *Environ. Res. Lett.*, **15**, 104045, doi:10.1088/1748-9326/abaa0c.

Gibson-Graham, J.K., 2006: *A Postcapitalist Politics*, 1st edn., University of Minnesota Press, Minneapolis, ISBN 978-0816648047. 316 pp.

Gibson-Graham, J.K., 2005: Surplus possibilities: postdevelopment and community economies. *Singap J Trop Geogr*, **26**(1), 4–26.

Gielen, D., et al., 2019: The role of renewable energy in the global energy transformation. *Energy Strategy Rev.*, **24**, 38–50, doi:10.1016/j.esr.2019.01.006.

Gill, S.R. and S.R. Benatar, 2020: Reflections on the political economy of planetary health. *Rev. Int. Polit. Econ.*, **27**(1), 167–190, doi:10.1080/09692290.2019.1607769.

Gillard, R., et al., 2016: Transformational responses to climate change: beyond a systems perspective of social change in mitigation and adaptation. *Wiley Interdiscip. Rev. Clim. Chang.*, **7**, 251–265.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Gills, B. and J. Morgan, 2020: Global Climate Emergency: after COP24, climate science, urgency, and the threat to humanity. *Globalizations*, **17**(6), 885–902, doi:10.1080/14747731.2019.1669915.

Gleditsch, N.P. and R. Nordås, 2014: Conflicting messages? The IPCC on conflict and human security. *Polit Geogr*, **43**, 82–90, doi:10.1016/j.polgeo.2014.08.007.

Gliedt, T., C.E. Hoicka and N. Jackson, 2018: Innovation intermediaries accelerating environmental sustainability transitions. *J Clean Prod*, **174**, 1247–1261.

Goda, T., Ö. Onaran and E. Stockhammer, 2017: Income inequality and wealth concentration in the recent crisis. *Development & Change*, **48**(1), 3–27, doi:10.1111/dech.12280.

Goddard, G. and M. A. Farrelly, 2018: Just transition management: Balancing just outcomes with just processes in Australian renewable energy transitions. *Appl Energy*, **225**, 110–123, doi:10.1016/j.apenergy.2018.05.025.

Godfrey-Wood, R. and O. Naess, 2016: *Adapting to climate change: Transforming development?* Available at: https://bulletin.ids.ac.uk/index.php/idsbo/article/view/2717 (accessed 21/01/2022).

Goldman, M.J., M.D. Turner and M. Daly, 2018: A critical political ecology of human dimensions of climate change: Epistemology, ontology, and ethics. *WIREs Clim. Chang.*, **9**(4), e526, doi:10.1002/wcc.526.

Gonçalves-Souza, D., P.H. Verburg and R. Dobrovolski, 2020: Habitat loss, extinction predictability and conservation efforts in the terrestrial ecoregions. *Biol. Conserv.*, **246**, 108579, doi:10.1016/j.biocon.2020.108579.

Gonda, N., 2017: Revealing the patriarchal sides of climate change adaptation through intersectionality: a case study from Nicaragua. In: *Understanding Climate Change through Gender Relations* [Buckingham, S. & Le Masson, V. (eds.)] 173–189. Routledge, London. ISBN 978-1315661605.

Goodrich, C.G., A. Prakash and P.B. Udas, 2019: Gendered vulnerability and adaptation in Hindu-Kush Himalayas: Research insights. Environ. Dev., 31, 1–8, doi:10.1016/j.envdev.2019.01.001.

Göpel, M., 2016: *The Great Mindshift: How a New Economic Paradigm and Sustainability Transformations Go Hand in Hand*. Springer, Berlin.

Gorddard, R., et al., 2016: Values, rules and knowledge: adaptation as change in the decision context. *Environ. Sci. Policy*, **57**, 60–69.

Görg, C., et al., 2017: Challenges for social-ecological transformations: contributions from social and political ecology. *Sustainability*, **9**, 1045, doi:10.3390/su9071045.

Gorissen, L., et al., 2018: Moving towards systemic change? Investigating acceleration dynamics of urban sustainability transitions in the Belgian City of Genk. *J Clean Prod*, **173**, 171–185.

Gotham, K.F., 2016: Antinomies of risk reduction: climate change and the contradictions of coastal restoration. *Environ. Sociol.*, **2**(2), 208–219, doi:10.1080/23251042.2016.1177363.

Government of Kenya, 2008: About Vision 2030. Available at: https://vision2030.go.ke/about-vision-2030/ (accessed 21/01/2022).

Government of Kenya, 2012: *Vision 2030 Development Strategy for Northern Kenya and other Arid Lands*. Available at: https://www.adaconsortium.org/images/publications/Vision2030-2011.pdf (accessed 21/01/2022).

Government of Kenya, 2016: *Brief on LAPSSET corridor project*. Available at: https://s3-eu-west-1.amazonaws.com/s3.sourceafrica.net/documents/118442/LAPSSET-Project-Report-July-2016-1.pdf (accessed 21/01/2022).

Government of Kenya, 2018: *Ministry Of Devolution And ASALs, State Department For Development Of The Arid And Semi Arid Lands Strategic Plan (2018 – 2022)*. Available at: https://www.asals.go.ke/wp-content/uploads/2019/05/ASAL-Report-Final-for-printing.pdf (accessed 21/01/2022).

Graham, N.T., et al., 2018: Water sector assumptions for the shared socioeconomic pathways in an integrated modeling framework. *Water Resour. Res.*, **54**(9), 6423–6440, doi:10.1029/2018WR023452.

Gram-Hanssen, I., N. Schafenacker and J. Bentz, 2021: Decolonizing transformations through 'right relations. *Sustain Sci*, doi:10.1007/s11625-021-00960-9.

Gratani, M., et al., 2011: Is validation of Indigenous ecological knowledge a disrespectful process? A case study of traditional fishing poisons and invasive fish management from the wet tropics, Australia. *Ecol. Soc.*, **16**(3), doi:10.5751/es-04249-160325.

Green, A.S., et al., 2020: An interdisciplinary framework for using archaeology, history and collective action to enhance India's agricultural resilience and sustainability. *Environ. Res. Lett.*, **15**(10), 105021, doi:10.1088/1748-9326/aba780.

Green, R., et al., 2013: The effect of rising food prices on food consumption: systematic review with meta-regression. *BMJ*, **346**(1), f3703–f3703.

Greiner, C., 2016: Land-use change, territorial restructuring, and economies of anticipation in dryland Kenya. *J. East. African Stud.*, **10**(3), 530–547.

Griscom, B.W., et al., 2017: Natural climate solutions. *Proc. Natl. Acad. Sci.*, **114**(44), 11645–11650.

Grove, K., 2018: *Resilience*. Routledge, London.

Grydehøj, A. and I. Kelman, 2017: The eco-island trap: climate change mitigation and conspicuous sustainability. *Area*, **49**(1), 106–113.

Guido, Z., C. Knudson, D. Campbell and J. Tomlinson, 2020: Climate information services for adaptation: what does it mean to know the context? *Clim. Dev.*, **12**(5), 395-407.

Gumucio, T., M. A. Alves, N. Orentlicher and M.C. Hernández Ceballo, 2018: Analysis of gender research on forest, tree and agroforestry value chains in Latin America. *For. Trees Livelihoods*, **27**(2), 69–85.

Gundimeda, H., P. Sukhdev, R.K. Sinha and S. Sanyal, 2007: Natural resource accounting for Indian states - Illustrating the case of forest resources. *Ecol. Econ.*, **61**(4), 635–649, doi:10.1016/j.ecolecon.2006.07.035.

Güneralp, B., et al., 2017: Urbanization in Africa: challenges and opportunities for conservation. *Environ. Res. Lett.*, **13**(1), 15002, doi:10.1088/1748-9326/aa94 fe.

Gupta, J. and N. Pouw, 2017: Towards a trans-disciplinary conceptualization of inclusive development. *Curr. Opin. Environ. Sustain.*, **24**, 96–103. Doi: 10.1016/j.cosust.2017.03.004

Haasnoot, M., J.H. Kwakkel, W.E. Walker and J. ter Maat, 2013: Dynamic adaptive policy pathways: a method for crafting robust decisions for a deeply uncertain world. *Glob. Environ. Chang.*, **23**(2), 485–498, doi:10.1016/j.gloenvcha.2012.12.006.

Haines, A., et al., 2017: Short-lived climate pollutant mitigation and the Sustainable Development Goals. *Nat. Clim. Chang.*, **7**(12), 863–869, doi:10.1038/s41558-017-0012-x.

Hajer, M., et al., 2015: Beyond cockpit-ism: four insights to enhance the transformative potential of the sustainable development goals. *Sustainability*, **7**(2), 1651–1660.

Hale, T., 2016: "All hands on deck": the Paris Agreement and nonstate climate action. *Glob. Environ. Polit.*, **16**(3), 12–22, doi:10.1162/GLEP_a_00362.

Hall, S.M., 2020: The personal is political: feminist geographies of/in austerity. *Geoforum*, **110**, 242–251, doi:10.1016/j.geoforum.2018.04.010.

Hallam, R., 2019: *Common sense for the 21st century: only nonviolent rebellion can now stop climate breakdown and social collapse*. Chelsea Green Publishing, Hartford. ISBN 978-1527246744.

Hallegatte, S., C. Brandon, et al., 2018: *The economics of (and obstacles to) aligning development and climate change adaptation: A World Bank Group Contribution to the Global Commission on Adaptation*. Available at: https://gca.org/reports/the-economics-of-and-obstacles-to-aligning-development-and-climate-change-adaptation/ (accessed 21/01/2022).

Hallegatte, S., J. Rentschler and J. Rozenberg, 2019: *Lifelines: The Resilient Infrastructure Opportunity*. World Bank, Washington, DC, ISBN 978-1464814303.

Hallegatte, S. and J. Rozenberg, 2017: Climate change through a poverty lens. *Nat. Clim. Change*, **7**(4), 250–256, doi:10.1038/nclimate3253.

Han, H. and S.W. Ahn, 2020: Youth mobilization to stop global climate change: narratives and impact. *Sustainability*, **12**(10), 4127, doi:10.3390/su12104127.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Han, S.-J., 2015: Emancipatory catastrophism from an East Asian perspective: feedback from the dialogue organizer. *Curr. Sociol.*, **63**(1), 115–120, doi:10.1177/0011392114559851.

Hansen, L., 2021: *Central Banking Challenges Posed by Uncertain Climate Change and Natural Disasters*. Available at: https://www.frbsf.org/economic-research/files/hansen-vsce-061021-paper.pdf (accessed 21/01/2022).

Hansen, L., et al., 2013: *The state of adaptation in the United States: an overview. A report for the John D. and Catherine T. MacArthur Foundation*. Ecoadapt, Bainbridge Island, WA, USA.

Hansen, U. E. and R. Lema, 2019: The co-evolution of learning mechanisms and technological capabilities: Lessons from energy technologies in emerging economies. *Technol Forecast Soc Change*, **140**, 241–257, doi:10.1016/j.techfore.2018.12.007.

Hardee, K., et al., 2018: Family planning and resilience: associations found in a population, health, and environment (PHE) project in western Tanzania. *Popul Environ*, **40**(2), 204–238, doi:10.1007/s11111-018-0310-x.

Hardoy, J., E. Gencer and M. Winograd, 2019: Participatory planning for climate resilient and inclusive urban development in Dosquebradas, Santa Ana and Santa Tomé. *environ urban*, **31**(1), 33–52, doi:10.1177/0956247819825539.

Harnphatananusorn, S., S. Santipolvut and C. Sonthi, 2019: Concepts and empirical calculation of the green GDP for Thailand. *Int. J. Green Econ.*, **13**, 68, doi:10.1504/IJGE.2019.10023001.

Harper, S., J.S. Kaufman and R.S. Cooper, 2017: Declining US life expectancy. *Epidemiology*, **28**(6), e54–e56.

Harrington, L.J. and F.E.L. Otto, 2018: Changing population dynamics and uneven temperature emergence combine to exacerbate regional exposure to heat extremes under 1.5°C and 2°C of warming. *Environ. Res. Lett.*, **13**(3), 34011, doi:10.1088/1748-9326/aaaa99.

Harris, L.M., E.K. Chu and G. Ziervogel, 2018: Negotiated resilience. *Resilience*, **6**(3), 196–214, doi:10.1080/21693293.2017.1353196.

Harris, P. and L. Clarke, 2017: Maramataka. In: *He Whare Hangarau M?ori-Language, Culture and Technology* [Whaanga, H., T.T. Keegan and M. Apperley].

Harrison, P., et al., 2019: Synthesizing plausible futures for biodiversity and ecosystem services in Europe and Central Asia using scenario archetypes. *Ecol. Soc.*, **24**(2), doi:10.5751/ES-10818-240227.

Harvey, B., L. Cochrane and M.V. Epp, 2019: Charting knowledge co-production pathways in climate and development. *Environ. Policy Gov.*, **29**(2), 107–117, doi:10.1002/eet.1834.

Hasegawa, T., et al., 2018: Risk of increased food insecurity under stringent global climate change mitigation policy. *Nat. Clim. Change*, **8**(8), 699–703, doi:10.1038/s41558-018-0230-x.

Hasegawa, T., S. Fujimori, K. Takahashi and T. Masui, 2015: Scenarios for the risk of hunger in the twenty-first century using shared socioeconomic pathways. *Environ. Res. Lett.*, **10**(1), 14010, doi:10.1088/1748-9326/10/1/014010.

Haukkala, T., 2018: A struggle for change—the formation of a green-transition advocacy coalition in Finland. *Environ. Innov. Soc. Transit.*, **27**, 146–156, doi:10.1016/j.eist.2017.12.001.

Hay, J.E., P. Hartley and J. Roop, 2019: Climate risk assessments and management options for redevelopment of the Parliamentary Complex in Samoa, South Pacific. *Weather. Clim. Extrem.*, **25**, 100214, doi:10.1016/j.wace.2019.100214.

Häyhä, T., et al., 2016: From planetary boundaries to national fair shares of the global safe operating space — how can the scales be bridged? *Glob. Environ. Chang.*, **40**, 60–72.

Healey, P., 2006: Transforming governance: Challenges of institutional adaptation and a new politics of space. *Eur. Plan. Stud.*, **14**(3), 299–320, doi:10.1080/09654310500420792.

Hegre, H., K. Petrova and N. von Uexkull, 2020: Synergies and trade-offs in reaching the sustainable development goals. *Sustainability*, **12**(20), doi:10.3390/su12208729.

Heigl, F., et al., 2019: Opinion: toward an international definition of citizen science. *Proc. Natl. Acad. Sci.*, **116**(17), 8089–8092.

Heinrichs, H., 2020: Artful sustainability governance—foundational considerations on sensory-informed policymaking for sustainable development. *Sustain. Dev.*, **28**(4), 791–799, doi:10.1002/sd.2029.

Hémous, D., 2016: The dynamic impact of unilateral environmental policies. *J Int Econ*, **103**, 80–95, doi:10.1016/j.jinteco.2016.09.001.

Hepburn, C., et al., 2020: Will COVID-19 fiscal recovery packages accelerate or retard progress on climate change? *Oxf. Rev. Econ. Policy*, **36**. Doi: 10.1093/oxrep/graa015.

Herrero, M., et al., 2016: Climate change and pastoralism: impacts, consequences and adaptation: -EN- -FR- Le changement climatique et le pastoralisme : effets, conséquences et adaptation -ES- Cambio climático y pastoreo: efectos directos, repercusiones y adaptación. *Revue Sci. Et Tech. De L'oie*, **35**(2), 417–433.

Hewitt, C.D., et al., 2020: Making society climate resilient: international progress under the global framework for climate services. *Bull. Am. Meteorol. Soc.*, **101**(2), E237–E252.

Heyen, A., L. Hermwille and T. Wehnert, 2017: Out of the comfort zone! Governing the exnovation of unsustainable technologies and practices. *GAIA - Ecol. Perspect. Sci. Soc.*, **26**(4), 326–331, doi:10.14512/gaia.26.4.9.

Hickel, J., 2017: Is global inequality getting better or worse? A critique of the World Bank's convergence narrative. *Third World Q*, **38**(10), 2208–2222, doi :10.1080/01436597.2017.1333414.

Hickel, J., 2019: Is it possible to achieve a good life for all within planetary boundaries? *Third World Q*, **40**(1), 18–35, doi:10.1080/01436597.2018.1535895.

Hickel, J., et al., 2021: Urgent need for post-growth climate mitigation scenarios. *Nat. Energy*, **6**(8), 766–768, doi:10.1038/s41560-021-00884-9.

Hickel, J. and G. Kallis, 2020: Is green growth possible? *New Polit. Econ.*, **25**(4), 469–486, doi:10.1080/13563467.2019.1598964.

Hildingsson, R., A. Kronsell and J. Khan, 2019: The green state and industrial decarbonisation. *Env Polit*, **28**(5), 909–928, doi:10.1080/09644016.2018.1488484.

Hilmi, N., et al., 2017: The effects of energetic transition on economic growth in Iran. *Marmara İktisat Dergisi*, **1**(1), 77–93.

Hilmi, N. and A. Safa, 2010: The economic and financial policies to fight against climate change: the case of Maghreb. *MEEA Online J.*, **12**. Available at: https://ecommons.luc.edu/meea/120/.

Hilmi, N., A. Safa, N. Peridy and M. Zemouri, 2015: Taking into account sustainable development for MENA countries: The calculation of a modified HDI index. *Top. Middle eastern North African Econ.*, **17**. Available at: https://meea.sites.luc.edu/volume17/pdfs/Hilmi-Safa-Peridy-Zemouri.pdf.

Hirpa, F.A., et al., 2018: Finding sustainable water futures in data-sparse regions under climate change: Insights from the Turkwel River basin, Kenya. *J. Hydrol. Reg. Stud.*, **19**, 124–135. Doi: 10.1016/j.ejrh.2018.08.005

Hjerpe, M., S. Storbjörk and J. Alberth, 2015: "There is nothing political in it": triggers of local political leaders' engagement in climate adaptation. *Local Environ*, **20**(8), 855–873, doi:10.1080/13549839.2013.872092.

Hoagland, S.J., 2017: Integrating traditional ecological knowledge with western science for optimal natural resource management. *IK: Other Ways Knowing*, **3**(1), 1–15, doi:10.18113/P8ik359744.

Hoegh-Guldberg, O., R. Cai, E.S. Poloczanska, P.G. Brewer, S. Sundby, K. Hilmi, V.J. Fabry, and S. Jung, 2014: The Ocean. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects: Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Barros, V. R., C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea and L. L. White (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 1655–1731. ISBN 9781107058163.

Hoegh-Guldberg, O., et al., 2019: *The Ocean as a Solution to Climate Change: Five Opportunities for Action*. Available at: https://www.oceanpanel.org/climate (accessed 21/01/2022).

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Hoekstra, A., M. Steinbuch and G. Verbong, 2017: Creating agent-based energy transition management models that can uncover profitable pathways to climate change mitigation. *Complexity*. Doi: 10.1155/2017/1967645.

Holden, E., et al., 2017: *The Imperatives of Sustainable Development*. Routledge, ISBN 978-0203022177.

Hölscher, K., N. Frantzeskaki and D. Loorbach, 2019: Steering transformations under climate change: capacities for transformative climate governance and the case of Rotterdam, the Netherlands. *Reg Environ Change*, **19**(3), 791–805, doi:10.1007/s10113-018-1329-3.

Hölscher, K., J.M. Wittmayer and D. Loorbach, 2018: Transition versus transformation: What's the difference? *Environ. Innov. Soc. Transit.*, **27**, 1–3, doi:10.1016/j.eist.2017.10.007.

Holvoet, N. and L. Inberg, 2014: Gender sensitivity of sub-saharan africa national adaptation programmes of action: findings from a desk review of 31 countries. *Clim. Dev.*, **6**(3), 266–276.

Holzer, J.M., N. Carmon and D.E. Orenstein, 2018: A methodology for evaluating transdisciplinary research on coupled socio-ecological systems. *Ecol Indic*, **85**, 808–819, doi:10.1016/j.ecolind.2017.10.074.

Honohan, P., 2019: *Should Monetary Policy Take Inequality and Climate Change into Account?* Working Paper Series, Peterson Institute for International Economics , Accessed 2021-08-26.

Hopkins, P., 2019: Social geography I: intersectionality. *Prog Hum Geogr*, **43**(5), 937–947, doi:10.1177/0309132517743677.

Horcea-Milcu, A.-I., et al., 2019: Values in transformational sustainability science: four perspectives for change. *Sustain Sci*, **14**(5), 1425–1437, doi:10.1007/s11625-019-00656-1.

Houser, M., R. Gunderson and D. Stuart, 2019: Farmers' perceptions of climate change in context: toward a political economy of relevance. *Sociol Ruralis*, **59**(4), 789–809, doi:10.1111/soru.12268.

Hov, Ø., et al., 2017: Five priorities for weather and climate research. *Nature*, **552**(7684), 168–170.

Howells, M., et al., 2013: Integrated analysis of climate change, land-use, energy and water strategies. *Nat. Clim. Chang.*, **3**(7), 621–626, doi:10.1038/nclimate1789.

Howlett, M.P. and K. Saguin, 2018: *Policy Capacity for Policy Integration: Implications for the Sustainable Development Goals*. Available at: https://www.researchgate.net/profile/Kidjie-Saguin/publication/324660470_Policy_Capacity_for_Policy_Integration_Implications_for_the_Sustainable_Development_Goals/links/5b43ec5c458515f71cb88d56/Policy-Capacity-for-Policy-Integration-Implications-for-the-Sustainable-Development-Goals.pdf (accessed 21/01/2022).

Huaman, E.S. and B. Sriraman, 2015: *Indigenous Innovation: Universalities and Peculiarities*. Springer, Berlin, 214. ISBN 978-9463002264.

Huang, P., V. Castán Broto, Y. Liu and H. Ma, 2018: The governance of urban energy transitions: A comparative study of solar water heating systems in two Chinese cities. *J Clean Prod*, **180**, 222–231, doi:10.1016/j.jclepro.2018.01.053.

Huang, R. and X. Sun, 2020: Dual mediation and success of environmental protests in China: a qualitative comparative analysis of 10 cases. *Soc. Mov Stud.*, **19**(4), 408–425, doi:10.1080/14742837.2019.1682539.

Huitema, D., et al., 2016: The governance of adaptation: choices, reasons, and effects. Introduction to the Special Feature. *Ecol. Soc.*, **21**(3), doi:10.5751/ES-08797-210337.

Hulme, M., 2018: "Gaps" in climate change knowledge. *Environ. Humanit.*, **10**, 330–337, doi:10.1215/22011919-4385599.

Hulme, M., 2019: *Climate Emergency Politics Is Dangerous*. *Issues in Science and Technology,* **36**(1), 23–25.

Human Development Report Office, 2020: *Human Development Report 2020: The Next Frontier Human development and the Anthropocene*. United Nations Development Programme, New York, http://hdr.undp.org/sites/default/files/hdr2020.pdf (accessed 21/01/2022). (412 pp).

Hunt, D., et al., 2012: Scenario archetypes: converging rather than diverging themes. *Sustainability*, **4**, 740–772, doi:10.3390/su4040740.

Huntington, H.P., et al., 2017: How small communities respond to environmental change: patterns from tropical to polar ecosystems. *Ecol. Soc.*, **22**(3).

Huntjens, P. and T. Zhang, 2016: *Climate justice: equitable and inclusive governance of climate action*. Working Paper, Vol. 16. The Hague Institute, The Hague, Netherlands.

Hurlbert, M., J. Krishnaswamy, E. Davin, F.X. Johnson, C.F. Mena, J. Morton, S. Myeong, D. Viner, K. Warner, A. Wreford, S. Zakieldeen, Z. Zommers, 2019: Risk management and decision-making in relation to sustainable development. In: *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* [Shukla, P. R., J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi and J. Malley (eds.)], In press.

Huxham, M., et al., 2015: Applying climate compatible development and economic valuation to coastal management: a case study of Kenya's mangrove forests. *J. Environ. Manag.*, **157**, 168–181, doi:10.1016/j.jenvman.2015.04.018.

Ide, T., 2020: The dark side of environmental peacebuilding. *World Dev*, **127**, 104777, doi:10.1016/j.worlddev.2019.104777.

IEA, 2015: *Energy and climate change, world energy outlook special report*. International Energy Agency, Paris. Available at: https://www.actu-environnement.com/media/pdf/news-24754-rapport-aie.pdf (accessed 21/01/2022).

IEA, 2017: *Energy Technology Perspectives 2017*. International Energy Agency (IEA), Available at: https://www.iea.org/reports/energy-technology-perspectives-2017 (accessed 21/01/2022).

IEA, 2019: *Material efficiency in clean energy transitions*. International Energy Agency (IEA).

IEA, 2020: *Global Energy Review 2020: The impacts of the Covid-19 crisis on global energy demand and CO2 emissions*. International Energy Agency (IEA), Paris.

IEA, et al., 2019: *Tracking SDG 7: The Energy Progress Report 2019*. https://trackingsdg7.esmap.org/ (accessed 21/01/2022).

Ikeda, S. and S. Managi, 2019: Future inclusive wealth and human well-being in regional Japan: projections of sustainability indices based on shared socioeconomic pathways. *Sustain Sci*, **14**(1), 147–158, doi:10.1007/s11625-018-0589-7.

ILO, 1989: *Indigenous and Tribal Peoples Convention, C169*. International Labour Organisation, Geneva.

IMF, 2017: Reigniting growth in low-income and emerging market economies: what role can structural reforms play? *World Economic Outlook.* Available at: https://www.imf.org/~/media/Files/Publications/WEO/2019/October/English/Ch3.ashx (accessed 21/01/2022). .

IMF, 2019: *Fiscal Monitor: How to Mitigate Climate Change*. International Monetary Fund, Washington, DC.

IMF, 2021: *Fiscal Policies to Address Climate Change in Asia and the Pacific*. International Monetary Fund, Washington, DC.

IMF and OECD, 2021: *Tax Policy and Climate Change: IMF/OECD Report for the G20 Finance Ministers and Central Bank Governors*. Available at: https://www.oecd.org/tax/tax-policy/imf-oecd-g20-report-tax-policy-and-climate-change.htm (accessed 21/01/2022).

Inaotombi, S. and P.C. Mahanta, 2019: Pathways of socio-ecological resilience to climate change for fisheries through indigenous knowledge. *Hum. Ecol. Risk Assessment: Int. J.*, **25**(8), 2032–2044, doi:10.1080/10807039.2018.1482197.

Iñigo, E.A. and L. Albareda, 2016: Understanding sustainable innovation as a complex adaptive system: a systemic approach to the firm. *J Clean Prod*, **126**, 1–20, doi:10.1016/j.jclepro.2016.03.036.

IPBES, 2019: *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Secretariat of the

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), Bonn, Germany, ISBN 978-3947851133. 56 pp.

IPCC, 2012: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change* [Field, C. B., V. Barros, T. F. Stocker, Q. Dahe, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G.-K. Plattner, S. K. Allen, M. Tignor and P. M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 582 pp. ISBN 9781107025066.

IPCC, 2014a: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Barros, V. R., C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea and L. L. White (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 688 pp. ISBN 9781107058163.

IPCC, 2014b: Summary for Policymakers. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C. B., V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea and L. L. White (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 1-32. ISBN 9781107058071.

IPCC, 2018a: *Global warming of 1.5 C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson, D., P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor and Waterfield (eds.)]. Organization, W. M., Geneva, Switzerland, 32 pp.

IPCC, 2018b: Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor and T. Waterfield (eds.)]. In press. ISBN 9789291691517.

IPCC, 2019a: Annex I: Glossary [Weyer, N.M. (ed.)]. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [Pörtner, H.-O., D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama and N. M. Weyer (eds.)], In press.

IPCC, 2019b: *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* [Shukla, P. R., J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi and J. Malley (eds.)]. In press.

IPCC, 2019c: *Climate Change and Land: IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse gas fluxes in Terrestrial Ecosystems* [Shukla, P. R., J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H. O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi and J. Malley (eds.)]. Available at: https://www.ipcc.ch/srccl-report-download-page/ (accessed 2019/10/2).

IPCC, 2019d: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [Pörtner, H.-O., D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama and N. M. Weyer (eds.)]. In press.

IPCC, 2019e: *Special Report on the Ocean and Cryosphere in a Changing Climate* [Pörtner, H. O., D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama and N. M. Weyer (eds.)]. Available at: https://www.ipcc.ch/srocc/home/ (accessed 2019/10/2).

IPCC, 2019 f: Summary for Policymakers. In: *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* [Shukla, P. R., J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi and J. Malley (eds.)]. In press.

IPCC, 2019g: Technical Summary. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [Pörtner, H.-O., D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama and N. M. Weyer (eds.)], In press.

IPCC, 2021a: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press.

IPCC, 2021b: Summary for Policymakers. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press.

Isgren, E., C.S. Boda, D. Harnesk and D. O'Byrne, 2019: Science has much to offer social movements in the face of planetary emergencies. *Nat. Ecol. Evol.*, **3**(11), 1498–1498.

Islam, S., C. Chu and J.C.R. Smart, 2020: Challenges in integrating disaster risk reduction and climate change adaptation: Exploring the Bangladesh case. *Int. J. Disaster Risk Reduct.*, **47**, 101540, doi:10.1016/j.ijdrr.2020.101540.

ITK, 2019: *National Inuit Climate Change Strategy, Inuit Tapiriit Kanatami (ITK), Ottawa*. Accessed 2021-09-02.
https://www.itk.ca/wp-content/uploads/2019/06/ITK_Climate-Change-Strategy_English.pdf

Ives, C., R. Freeth and J. Fischer, 2019: Inside-out sustainability: the neglect of inner worlds. *Ambio*, **49**, doi:10.1007/s13280-019-01187-w.

Ives, C.D., et al., 2017: Human–nature connection: a multidisciplinary review. *Curr. Opin. Environ. Sustain.*, **26-27**, 106–113, doi:10.1016/j.cosust.2017.05.005.

Jabeen, H., 2014: Adapting the built environment: the role of gender in shaping vulnerability and resilience to climate extremes in Dhaka. *environ urban*, **26**(1), 147–165, doi:10.1177/0956247813517851.

Jabeen, H. and S. Guy, 2015: Fluid engagements: responding to the co-evolution of poverty and climate change in Dhaka, Bangladesh. *Habitat Int.*, **47**, 307–314, doi:10.1016/j.habitatint.2015.02.005.

Jackson, E.A., 2016: *Ontological and Epistemological Discourse(s) on Sustainable Development: Perspective on Sierra Leone in the Aftermath of a Decade of Civil Unrest*. Social Science Research Network, Rochester, NY, https://papers.ssrn.com/abstract=2811522. Accessed 2020.

Jackson, M., 2014: Composing postcolonial geographies: postconstructivism, ecology and overcoming ontologies of critique. *Singap J Trop Geogr*, **35**(1), 72–87, doi:10.1111/sjtg.12052.

Jackson, T., 2009: *Prosperity Without Growth: Economics for a Finite Planet*. Earthscan, UK, USA, ISBN 978-1-84407-894-3.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Jackson, T., 2021: *Post Growth: Life after Capitalism*, 1st edn., Polity, Cambridge, UK Medford, MA, USA, ISBN 978-1509542529. 256 pp.

Jafry, T., 2016: Making the case for gender sensitive climate policy – lessons from South Asia/IGP. *Int. J. Clim. Change Strateg. Manag.*, **8**(4), 559–577, doi:10.1108/IJCCSM-04-2015-0049.

Jafry, T., M. Mikulewicz and K. Helwig, 2018: Introduction: justice in the era of climate change. In: *Routledge Handbook of Climate Justice*, pp. 1–9. Routledge, London.

Janke, T., 2018: Protecting indigenous cultural expressions in Australia and New Zealand: Two decades after the 'Mataatua Declaration and our culture, our future'. *Intellect. Prop. Forum: J. Intellect. Ind. Prop. Soc. Aust. N. Z.*, **114**, 21–30, doi:10.3316/informit.204204436835200.

Jendrzejewski, B., 2020: Bioeconomic modelling – An application of environmentally adjusted economic accounts and the computable general equilibrium model. *Land Use Policy*, **92**, Mar 1;92:104431.

Jenkins, K., 2017: Women anti-mining activists' narratives of everyday resistance in the Andes: staying put and carrying on in Peru and Ecuador. *Gend. Place Cult.*, **24**(10), 1441–1459, doi:10.1080/0966369X.2017.1387102.

Jenkins, K., B.K. Sovacool and D. McCauley, 2018: Humanizing sociotechnical transitions through energy justice: An ethical framework for global transformative change. *Energy Policy*, **117**, 66–74, doi:10.1016/j.enpol.2018.02.036.

Jernnäs, M. and B.-O. Linnér, 2019: A discursive cartography of nationally determined contributions to the Paris climate agreement. *Glob. Environ. Chang.*, **55**, 73–83, doi:10.1016/j.gloenvcha.2019.01.006.

Joakim, E.P., L. Mortsch and G. Oulahen, 2015: Using vulnerability and resilience concepts to advance climate change adaptation. *Environ. Hazards*, **14**(2), 137–155, doi:10.1080/17477891.2014.1003777.

Johansson, T., A. Patwardhan, N. Nakicenovic and L. Gomez-Echeverri, 2012: *Global Energy Assessment: Toward a Sustainable Future*. Cambridge University Press, Cambridge UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria. ISBN 978-0521182935.

Johnstone, P. and P. Newell, 2018: Sustainability transitions and the state. *Environ. Innov. Soc. Transit.*, 2018 Jun 1;27:72-82.

Jones, L., et al., 2014: *Exploring the role of climate science in supporting long-term adaptation and decision-making in sub-Saharan Africa*. CDKN, 2014.

Jordan, J.C., 2019: Deconstructing resilience: why gender and power matter in responding to climate stress in Bangladesh. *Clim. Dev.*, **11**(2), 167–179, doi:10.1080/17565529.2018.1442790.

Jørgensen, M.S., U. Jørgensen and J.S. Jensen, 2017: Navigations and governance in the Danish energy transition reflecting changing Arenas of Development, controversies and policy mixes. *Energy Res. Soc. Sci.*, **33**, 173–185, doi:10.1016/j.erss.2017.09.034.

Jørgensen, U., 2012: Mapping and navigating transitions—the multi-level perspective compared with arenas of development. *Res Policy*, **41**(6), 996–1010, doi:10.1016/j.respol.2012.03.001.

Jost, C., et al., 2016: Understanding gender dimensions of agriculture and climate change in smallholder farming communities. *Clim. Dev.*, **8**(2), 133–144.

Juhola, S., E. Glaas, B.-O. Linnér and T.-S. Neset, 2015: Redefining maladaptation. *Environ. Sci. Policy*, **2016**, 135–140, doi:10.1016/j.envsci.2015.09.014.

Kabir, M. and R. Salim, 2019: Valuation of subsoil minerals in Bangladesh: An application of the system of environmental-economic accounting. *Resour. Policy*, **62**, 193–204.

Kabubo-Mariara, M.J., 2009: Adaptation to Climate Change and Livestock Biodiversity: Evidence from Kenya. In: *Conserving and Valuing Ecosystem Services and Biodiversity: Economic, Social and Institutional Challenges in the New Millennium* [Ninan, K.N.(ed.)]. Earthscan, pp. 345–369.

Kakenmaster, W., 2019: Articulating resistance: Agonism, radical democracy and climate change activism. *Millennium*, **47**(3), 373–397, doi:10.1177/0305829819839862.

Kalafatis, S., 2017: Identifying the potential for climate compatible development efforts and the missing links. *Sustainability*, **9**(9), 1642.

Kallis, G., 2011: In defence of degrowth. *Ecol. Econ.*, **70**(5), 873–880.

Kallis, G., 2018: *Degrowth*. Agenda Publishing, Newcastle upon Tyne, UK, ISBN 978-1911116806. 176 pp.

Kallis, G., J. Martinez-Alier and R.B. Norgaard, 2009: Paper assets, real debts: An ecological-economic exploration of the global economic crisis. *Crit. Perspect. Int. Bus.*, **5**(1/2), 14–25.

Kamal Uddin, A.M., et al., 2006: *Climate resilient development: country framework to mainstream climate risk management and adaptation : working paper*. Climate Change Cell, Dept. of Environment, Dhaka, ISBN 978-9843237040.

Kamau, M., P. Chasek and D. O'Connor, 2018: *Transforming Multilateral Diplomacy: The Inside Story of the Sustainable Development Goals*, 1st edn., Routledge, London New York, ISBN 978-0813350868. 366 pp.

Kandlikar, M., C. Reynolds and A. Grieshop, 2009: *A Perspective Paper on Black Carbon Mitigation as a Response to Climate Change*. Copenhagen Consensus Center, 2009.

Karlsson, M., E. Alfredsson and N. Westling, 2020: Climate policy co-benefits: a review. *Clim. Policy*, **20**(3), 292–316, doi:10.1080/14693062.2020.1724070.

Kasdan, M., L. Kuhl and P. Kurukulasuriya, 2021: The evolution of transformational change in multilateral funds dedicated to financing adaptation to climate change. *Clim. Dev.*, **13**(5), 427–442, doi:10.1080/17565529.2020.1790333.

Kattumuri, R., D. Ravindranath and T. Esteves, 2017: Local adaptation strategies in semi-arid regions: study of two villages in Karnataka, India. *Clim. Dev.*, **9**(1), 36–49.

Kaya, H.O. and M. Chinsamy, 2016: Community-based environmental resource management systems for sustainable livelihood and climate change adaptation: a review of best practices in africa. *J. Soc. Sci.*, **46**(2), 123–129, doi:10.1080/09718923.2016.11893519.

Kaza, S., L. Yao, P. Bhada-Tata and F.V. Woerden, 2018: *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*. World Bank Publications, Washington, DCISBN 978-1464813474. 230 pp.
https://openknowledge.worldbank.org/handle/10986/30317

Keith, H., M. Vardon, J.A. Stein and D. Lindenmayer, 2019: Contribution of native forests to climate change mitigation – A common approach to carbon accounting that aligns results from environmental-economic accounting with rules for emissions reduction. *Environ. Sci. Policy*, **93**, 189–199.

Kenis, A. and M. Lievens, 2016: Imagining the carbon neutral city: the (post) politics of time and space. *Environ. Plan. A.*, doi:10.1177/0308518X16680617.

Kenis, A. and E. Mathijs, 2012: Beyond individual behaviour change: the role of power, knowledge and strategy in tackling climate change. *Environ. Educ. Res.*, **18**(1), 45–65, doi:10.1080/13504622.2011.576315.

Kenis, A. and E. Mathijs, 2014: Climate change and post-politics: repoliticizing the present by imagining the future? *Geoforum*, **52**, 148–156, doi:10.1016/j.geoforum.2014.01.009.

Kermoal, N. and I. Altamirano-Jiménez, 2016: *Kermoal and Altamirano-Jiménez, 2016*. Athabasca University Press, Athabasca.

Khanal, U., et al., 2021: Smallholder farmers' adaptation to climate change and its potential contribution to UN's sustainable development goals of zero hunger and no poverty. *J Clean Prod*, **281**, 124999, doi:10.1016/j.jclepro.2020.124999.

Khatri, D.B., 2018: *Climate and development at the third pole*. https://pub.epsilon.slu.se/15564/. Accessed 09 Sep 2020.

Kim, Y., M.V. Chester, D.A. Eisenberg and C.L. Redman, 2019: The infrastructure trolley problem: positioning safe-to-fail infrastructure for climate change adaptation. *Earth's Future*, **7**(7), 704–717, doi:10.1029/2019EF001208.

Kim, Y., et al., 2017a: Fail-safe and safe-to-fail adaptation: decision-making for urban flooding under climate change. *Clim Change*, doi:10.1007/s10584-017-2090-1.

Kim, Y., et al., 2017b: A perspective on climate resilient development and national adaptation planning based on USAID's experience. *Clim. Dev.*, **9**(2), 141–151.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Kingsborough, A., E. Borgomeo and J.W. Hall, 2016: Adaptation pathways in practice: Mapping options and trade-offs for London's water resources. *Sustain. Cities Soc.*, **27**, 386–397, doi:10.1016/j.scs.2016.08.013.

Kirchhoff, C.J., M. Carmen Lemos and S. Dessai, 2013: Actionable knowledge for environmental decision making: broadening the usability of climate science. *Annu. Rev. Environ. Resour.*, **38**(1), 393–414, doi:10.1146/annurev-environ-022112-112828.

Kivimaa, P., W. Boon, S. Hyysalo and L. Klerkx, 2019a: Towards a typology of intermediaries in sustainability transitions: A systematic review and a research agenda. *Res Policy*, **48**(4), 1062–1075, doi:10.1016/j.respol.2018.10.006.

Kivimaa, P., et al., 2019b: Passing the baton: how intermediaries advance sustainability transitions in different phases. *Environ. Innov. Soc. Transit.*, **31**, 110–125, doi:10.1016/j.eist.2019.01.001.

Kivimaa, P. and M. Martiskainen, 2018: Dynamics of policy change and intermediation: the arduous transition towards low-energy homes in the United Kingdom. *Energy Res. Soc. Sci.*, **44**, 83–99, doi:10.1016/j.erss.2018.04.032.

Kivimaa, P., E. Primmer and J. Lukkarinen, 2020: Intermediating policy for transitions towards net-zero energy buildings. *Environ. Innov. Soc. Transit.* https://doi.org/10.1016/j.eist.2020.01.007

Klein, N., 2020: *On fire: the (burning) case for a green new deal*. Simon & Schuster, ISBN 978-1982129927. https://doi.org/10.3197/096327120x15916910310572

Klein, R. J. T. et al., 2007: Inter-relationships between adaptation and mitigation. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Parry, M. L., O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, pp. 745–777. ISBN 9780521880107.

Klepp, S. and J. Herbeck, 2016: The politics of environmental migration and climate justice in the Pacific region. *J. Hum. Rights Environ.*, **7**, 54–73, doi:10.4337/jhre.2016.01.03.

Kleres, J. and Å. Wettergren, 2017: Fear, hope, anger, and guilt in climate activism. *Soc. Mov Stud.*, 1–13, doi:10.1080/14742837.2017.1344546.

Klinsky, S., et al., 2017: Why equity is fundamental in climate change policy research. *Glob. Environ. Chang.*, **44**, 170–173.

Klinsky, S. and H. Winkler, 2018: Building equity in: strategies for integrating equity into modelling for a 1.5°C world. *Philos. Trans. Royal Soc. A: Math. Phys. Eng. Sci.*, **376**(2119), 20160461.

Koch, M., 2020: Structure, action and change: a Bourdieusian perspective on the preconditions for a degrowth transition. *Sustain. Sci. Pract. Policy*, **16**(1), 4–14, doi:10.1080/15487733.2020.1754693.

Kochore, H.H., 2016: The road to Kenya?: Visions, expectations and anxieties around new infrastructure development in Northern Kenya. *J. East. African Stud.*, **10**(3), 494–510.

Köhler, J., et al., 2019: An agenda for sustainability transitions research: State of the art and future directions. *Environ. Innov. Soc. Transit.*, **31**, 1–32, doi:10.1016/j.eist.2019.01.004.

Kohler, P., S. Renggli and C. Lüthi, 2019: WASH and gender in health care facilities: the uncharted territory. *Health. Care. Women. Int.*, **40**(1), 3–12.

Komendantova, N., et al., 2016: Multi-risk approach and urban resilience. *Int. J. Disaster Resil. Built Environ.*, **7**, 114–132, doi:10.1108/IJDRBE-03-2015-0013.

Kookana, R.S., et al., 2016: Groundwater scarcity impact on inclusiveness and women empowerment: Insights from school absenteeism of female students in two watersheds in India. *Int. J. Incl. Educ.*, **20**(11), 1155–1171.

Kothari, A., F. Demaria and A. Acosta, 2014: Buen Vivir, degrowth and ecological Swaraj: alternatives to sustainable development and the green economy. *Development*, **57**(3), 362–375, doi:10.1057/dev.2015.24.

Koubi, V., 2019: Climate change and conflict. *Annu. Rev. Polit. Sci.*, **22**(1), 343–360, doi:10.1146/annurev-polisci-050317-070830.

Krampe, F., E.S. Smith and M.D. Hamidi, 2021: Security implications of climate development in conflict-affected states implications of local-level effects of rural hydropower development on farmers in Herat. *Polit Geogr*, **90**, 102454, doi:10.1016/j.polgeo.2021.102454.

Kriegler, E., et al., 2018: Pathways limiting warming to 1.5°C: a tale of turning around in no time? *Philos. Trans. Royal Soc. A: Math. Phys. Eng. Sci.*, **376**(2119), 20160457, doi:10.1098/rsta.2016.0457.

Kristjanson, P., et al., 2017: Addressing gender in agricultural research for development in the face of a changing climate: where are we and where should we be going? *Int. J. Agric. Sustain.*, **15**(5), 482–500.

Krogstrup, S. and W. Oman, 2019: *Macroeconomic and Financial Policies for Climate Change Mitigation: A Review of the Literature*. IMF Working Papers, Vol. 19. doi:10.5089/9781513511955.001.

Krueger, P., Z. Sautner and L.T. Starks, Rochester, NY: *The Importance of Climate Risks for Institutional Investors*. Social Science Research Network, https://papers.ssrn.com/abstract=3235190.Accessed 2019.

Krusell, P. and A. Smith, 2018: *Climate Change Around the World*. Slides from ifo Institute Workshop on "Heterogeneous Agents and the Macroeconomics of Climate Change".

Kubiszewski, I., et al., 2013: Beyond GDP: Measuring and achieving global genuine progress. *Ecol. Econ.*, **93**, 57–68.

Kuenkel, P., 2019: *Stewarding Sustainability Transformations: An Emerging Theory and Practice of SDG Implementation*. Springer International Publishing, Switzerland. ISBN 978-3030036904.

Kull, M., 2016: Multi-level governance and structural constructivism–understanding multilevel politics in the European Union. In: *European Integration and Rural Development*. Routledge, London and New York.

Kuokkanen, A., V. Uusitalo and K. Koistinen, 2019: A framework of disruptive sustainable innovation: an example of the Finnish food system. *Technol. Analysis Strateg. Manag.*, **31**(7), 749–764, doi:10.1080/09537325.2018.1550254.

Kuper, M., H. Amichi and P.-L. Mayaux, 2017: Groundwater use in North Africa as a cautionary tale for climate change adaptation. *Water Int.*, **42**(6), 725–740, doi:10.1080/02508060.2017.1351058.

Kuzemko, C., A. Lawrence and M. Watson, 2019: New directions in the international political economy of energy. *Rev. Int. Polit. Econ.*, **26**(1), 1–24, doi:10.1080/09692290.2018.1553796.

Labriet, M., et al., 2015: Worldwide impacts of climate change on energy for heating and cooling. *Mitig Adapt Strateg Glob Change*, **20**(7), 1111–1136.

Lacroix, K. and R. Gifford, 2017: Psychological barriers to energy conservation behavior: the role of worldviews and climate change risk perception. *Environ Behav*, doi:10.1177/0013916517715296.

Lahn, B., 2018: In the light of equity and science: scientific expertise and climate justice after Paris. *Int. Environ. Agreements: Polit. Law Econ.*, **18**(1), 29–43.

Lahsen, M. and E. Turnhout, 2021: How norms, needs, and power in science obstruct transformations towards sustainability. *Environ. Res. Lett.*, **16**(2), 25008, doi:10.1088/1748-9326/abdcf0.

Lam, D.P.M., et al., 2020: Indigenous and local knowledge in sustainability transformations research: a literature review. *Ecol. Soc.*, **25**(1), doi:10.5751/ES-11305-250103.

Lamsal, P., L. Kumar, K. Atreya and K.P. Pant, 2017: Vulnerability and impacts of climate change on forest and freshwater wetland ecosystems in Nepal: A review. *Ambio*, **46**(8), 915–930, doi:10.1007/s13280-017-0923-9.

Langlois, A.J., 2014: Social connection & political responsibility: an engagement with Iris Marion Young. *St Antony's Int. Rev.*, **10**(1), 43–63.

Larik, J.E., et al., 2017: Blue growth and sustainable development in Indian ocean governance. *The hague Inst. Glob. Justice Policy Brief*.

Latour, B., D. Milstein, I. Marrero-Guillamón and I. Rodríguez-Giralt, 2018: Down to earth social movements: an interview with Bruno Latour. *Soc. Mov Stud.*, **17**(3), 353–361, doi:10.1080/14742837.2018.1459298.

Lau, J.D., D. Kleiber, S. Lawless and P.J. Cohen, 2021: Gender equality in climate policy and practice hindered by assumptions. *Nat. Clim. Chang.*, **11**(3), 186–192, doi:10.1038/s41558-021-00999-7.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Lawrence, J., et al., 2015: Adapting to changing climate risk by local government in New Zealand : institutional practice barriers and enablers. *Local Environ*, **20**(3), 298–320.

Le Blanc, D., 2015: Towards integration at last? The sustainable development goals as a network of targets: the sustainable development goals as a network of targets. *Sustain. Dev.*, **23**(3), 176–187, doi:10.1002/sd.1582.

Le, T.-H., Y. Chang and D. Park, 2016: Trade openness and environmental quality: international evidence. *Energy Polii*, **92**(C), 45–55.

Leal Filho, W., et al., 2020: COVID-19 and the UN sustainable development goals: threat to solidarity or an opportunity? *Sustainability*, **12**(13), 5343, doi:10.3390/su12135343.

Lee, J.-Y., J. Marotzke, G. Bala, L. Cao, S. Corti, J.P. Dunne, F. Engelbrecht, E. Fischer, J.C. Fyfe, C. Jones, A. Maycock, J. Mutemi, O. Ndiaye, S. Panickal, and T. Zhou, 2021: Future Global Climate: Scenario-Based Projections and Near-Term Information. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Lee, K., N. Gjersoe, S. O'Neill and J. Barnett, 2020: Youth perceptions of climate change: a narrative synthesis. *WIREs Clim. Chang.*
https://doi.org/10.1002/wcc.641

Lee, S.-H. and M. Thiel, 2017: Relations between GDP growth and environmental performance using latent growth curve model applied for environmental Kuznets curve. *Int. J. Sustain. Econ.*, **9**(2), 87–104, doi:10.1504/IJSE.2017.083362.

Lee, S.A., 2020: *Playing the Long Game: The intersection of Climate Change Risk and Financial Regulation*.
Keynote Remarks at PLI's 52nd Annual Institute on Securities Regulation.

Leibenluft, J., 2020: *Rethinking the Intersection of Climate Policy and the Federal Budget*. Center for American Progress.
https://www.americanprogress.org/article/rethinking-intersection-climate-policy-federal-budget/

Leigh, N.G. and H. Lee, 2019: Sustainable and resilient urban water systems: the role of decentralization and planning. *Sustainability*, **11**(3), 918, doi:10.3390/su11030918.

Lele, S., V. Srinivasan, B.K. Thomas and P. Jamwal, 2018: Adapting to climate change in rapidly urbanizing river basins: insights from a multiple-concerns, multiple-stressors, and multi-level approach. *Water Int.*, **43**(2), 281–304, doi:10.1080/02508060.2017.1416442.

Lemke, S. and T. Delormier, 2017: Indigenous Peoples' food systems, nutrition, and gender: Conceptual and methodological considerations. *Matern. Child Nutr.*, (Suppl 3), doi:10.1111/mcn.12499.

Lemoine, D. and C. Traeger, 2014: Watch your step: optimal policy in a tipping climate. *Am. Econ. Journal: Econ. Policy*, **6**, doi:10.1257/pol.6.1.137.

Lenzholzer, S., et al., 2020: Urban climate awareness and urgency to adapt: an international overview. *Urban Clim.*, **33**, 100667, doi:10.1016/j.uclim.2020.100667.

Lertzman, R.A., 2010: *Myth of apathy: psychoanalytic explorations of environmental degradation*. Cardiff University, UK, ISBN 978-1073291229.

Lesnikowski, A., et al., 2017: What does the Paris Agreement mean for adaptation? *Clim. Policy*, **17**(7), 825–831.

Lesutis, G., 2020: How to understand a development corridor? The case of Lamu Port–South Sudan–Ethiopia-Transport corridor in Kenya. *Area*, **52**(3), 600–608.

Leventon, J., D.J. Abson and D.J. Lang, 2021: Leverage points for sustainability transformations: nine guiding questions for sustainability science and practice. *Sustain Sci*, **16**(3), 721–726, doi:10.1007/s11625-021-00961-8.

Ley, D., 2017: Sustainable development, climate change, and renewable energy in rural central america. In: *Evaluating Climate Change Action for Sustainable Development* [Uitto, J.I., J. Puri and R.D. van den Berg(eds.)]. Springer International Publishing, Cham, pp. 187–212. ISBN 978-3319437026.

Ley, D., H.J. Corsair, S. Fuss and C. Singh, 2020: Evaluating the use of renewable energy and communal governance systems for climate change adaptation. *Cent. Eur. Rev. Econ. Manag.*, **4**(1), 53–70, doi:10.29015/cerem.850.

Li, D., et al., 2019a: Challenges and opportunities for the development of MEGACITIES. *Int. J. Digit. Earth*, **12**(12), 1382–1395, doi:10.1080/17538947.2018.1512662.

Li, L., et al., 2018: Service learning, service climate, and service-based social innovation for sustainability. *Sustainability*, **10**(7), 2566.

Li, S., et al., 2017: Integrated modelling of urban spatial development under uncertain climate futures: a case study in Hungary. *Environ. Model. Softw.*, **96**, 251–264, doi:10.1016/j.envsoft.2017.07.005.

Li, X., et al., 2019b: Projecting global urban area growth through 2100 based on historical time series data and future shared socioeconomic pathways. *Earth's Future*, **7**(4), 351–362, doi:10.1029/2019EF001152.

Liem, A., R.B. Natari, Jimmy and B.J. Hall, 2020: Digital health applications in mental health care for immigrants and refugees: a rapid review. *Telemedicine E-health*, doi:10.1089/tmj.2020.0012.

Lillebø, A.I., et al., 2017: How can marine ecosystem services support the Blue Growth agenda? *Mar. Policy.*, **81**, 132–142, doi:10.1016/j.marpol.2017.03.008.

Lind, J., 2018: Devolution, shifting centre-periphery relationships and conflict in northern Kenya. *Polit Geogr*, **63**, 135–147.

Lindoso, D., et al., 2018: Harvesting water for living with drought: insights from the Brazilian human coexistence with semi-aridity approach towards achieving the sustainable development goals. *Sustainability*, **10**(3), 622.

Liobikienė, G. and M. Butkus, 2018: The challenges and opportunities of climate change policy under different stages of economic development. *Sci. Total Environ.*, **642**, 999–1007, doi:10.1016/j.scitotenv.2018.06.140.

Lipper, L., et al., 2014: Climate-smart agriculture for food security. *Nat. Clim. Chang.*, **4**(12), 1068–1072, doi:10.1038/nclimate2437.

Liu, J.-Y., et al., 2019: Identifying trade-offs and co-benefits of climate policies in China to align policies with SDGs and achieve the 2°C goal. *Environ. Res. Lett.*, **14**(12), 124070, doi:10.1088/1748-9326/ab59c4.

Lo, A.Y., S. Liu, L.T.O. Cheung and F.K.S. Chan, 2020: Contested transformations: sustainable economic development and capacity for adapting to climate change. *Ann. Am. Assoc. Geogr.*, **110**(1), 223–241, doi:10.1080/24694452.2019.1625748.

Lo, K. and V. Castán Broto, 2019: Co-benefits, contradictions, and multi-level governance of low-carbon experimentation: Leveraging solar energy for sustainable development in China. *Glob. Environ. Chang.*, **59**, 101993, doi:10.1016/j.gloenvcha.2019.101993.

Lockwood, M., C. Kuzemko, C. Mitchell and R. Hoggett, 2016: Historical institutionalism and the politics of sustainable energy transitions: a research agenda. *Environ. Plan. C: Polit. Space*, doi:10.1177/0263774X16660561.

Löfmarck, E. and R. Lidskog, 2017: Bumping against the boundary: IPBES and the knowledge divide. *Environ Sci Policy*, **69**, 22–28, doi:10.1016/j.envsci.2016.12.008.

Loorbach, D., N. Frantzeskaki and F. Avelino, 2017: Sustainability transitions research: transforming science and practice for societal change. *Annu. Rev. Environ. Resour.*, **42**(1), 599–626, doi:10.1146/annurev-environ-102014-021340.

Loorbach, D., et al., 2020: Transformative innovation and translocal diffusion. *Environ. Innov. Soc. Transit.*, **35**, 251–260, doi:10.1016/j.eist.2020.01.009.

Lopez-Carr, D., *Population-health-environment (phe) synergies ? Evidence from USAID-sponsored programs in african and asian core conservation areas*. Accessed 2021-08-20.

Lorenzoni, I. and L. Whitmarsh, 2014: Climate change and perceptions, behaviors, and communication research after the IPCC 5th Assessment Report - a WIREs Editorial: Climate change and perceptions, behaviors, and communication research. *Wiley Interdiscip. Rev. Clim. Chang.*, **5**(6), 703–708.

Lucas, H., et al., 2017: Critical challenges and capacity building needs for renewable energy deployment in Pacific Small Island Developing States (Pacific SIDS). *Renew. Energy*, **107**, 42–52, doi:10.1016/j.renene.2017.01.029.

Ludwig, D. and L. Poliseli, 2018: Relating traditional and academic ecological knowledge: mechanistic and holistic epistemologies across cultures. *Biol. Philos.*, **33**(5), 43, doi:10.1007/s10539-018-9655-x.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Ludwig, F., E. van Slobbe and W. Cofino, 2014: Climate change adaptation and integrated water resource management in the water sector. *J. Hydrol. Reg. Stud.*, **518**, 235–242, doi:10.1016/j.jhydrol.2013.08.010.

Luederitz, C., D.J. Abson, R. Audet and D.J. Lang, 2017: Many pathways toward sustainability: not conflict but co-learning between transition narratives. *Sustain Sci*, **12**(3), 393–407, doi:10.1007/s11625-016-0414-0.

Luton, L.S., 2015: Climate scientists and the intergovernmental panel on climate change: evolving dynamics of a belief in political neutrality. *Adm. Theory Prax.*, **37**(3), 144–161, doi:10.1080/10841806.2015.1053360.

Lwasa, S., 2015: A systematic review of research on climate change adaptation policy and practice in Africa and South Asia deltas. *Reg Environ Change*, **15**(5), 815–824.

Lyon, C., 2018: Complexity ethics and UNFCCC practices for 1.5°C climate change. *Curr. Opin. Environ. Sustain.*, **31**, 48–55.

MacGregor, S., 2003: Feminist perspectives on sustainability. In: *UNESCO Encyclopedia of Life Support Systems: Introduction to Sustainable Development*, ed. / David V J Bell; Annie Cheung. Oxford : Eolss Publishers, pp. 467–492.

MacGregor, S., 2014: Only resist: feminist ecological citizenship and the post-politics of climate change. *Hypatia*, **29**(3), 617–633.

MacGregor, S., 2019: Finding transformative potential in the cracks? The ambiguities of urban environmental activism in a neoliberal city. *Soc. Mov Stud.*, **0**(0), 1–17, doi:10.1080/14742837.2019.1677224.

MacGregor, S., 2020: Gender matters in environmental justice. In: *Environmental Justice* [Coolsaet, B.(ed).], 1st edn. Key issues in environment and sustainability, Routledge, Abingdon, Oxon ; New York, NY, pp. 234–248. ISBN 978-0429029585.

Mach, K.J., et al., 2019: Climate as a risk factor for armed conflict. *Nature*, **571**(7764), 193–197, doi:10.1038/s41586-019-1300-6.

Mackey, B. and D. Claudie, 2015: Points of contact: integrating traditional and scientific knowledge for Biocultural conservation. *Environ. Ethics.*, (Fall), 37(3), 341–357.

Maes, M.J.A., K.E. Jones, M.B. Toledano and B. Milligan, 2019: Mapping synergies and trade-offs between urban ecosystems and the sustainable development goals. *Environ. Sci. Policy*, **93**, 181–188, doi:10.1016/j.envsci.2018.12.010.

Magnan, A.K. and T. Ribera, 2016: Global adaptation after Paris. *Science*, **352**(6291), 1280–1282.

Magnan, A.K., et al., 2016: Addressing the risk of maladaptation to climate change. *WIREs Clim. Chang.*, **7**(5), 646–665, doi:10.1002/wcc.409.

Magnan, A.K., E.L.F. Schipper and V.K.E. Duvat, 2020: Frontiers in climate change adaptation science: advancing guidelines to design adaptation pathways. *Curr. Clim. Change Rep.*, **6**(4), 166–177, doi:10.1007/s40641-020-00166-8.

Mahoney, J.L. and K. Thelen, 2009: A theory of gradual institutional change. *Explain. Institutional Chang. Ambiguity Agency Power*, 1–37, doi:10.1017/CBO9780511806414.003.

Mahony, M. and M. Hulme, 2016: Modelling and the Nation: Institutionalising Climate Prediction in the UK, 1988–92. *Minerva*, **54**(4), 445–470, doi:10.1007/s11024-016-9302-0.

Mainali, K., et al., 2020: Contrasting responses to climate change at Himalayan treelines revealed by population demographics of two dominant species. *Ecol. Evol.*, **10**(3), 1209–1222, doi:10.1002/ece3.5968.

Major, D.C., M. Lehmann and J. Fitton, 2018: Linking the management of climate change adaptation in small coastal towns and cities to the Sustainable Development Goals. *Ocean. Coast. Manag.*, **163**, 205–208, doi:10.1016/j.ocecoaman.2018.06.010.

Makuvaro, V., et al., 2017: Constraints to crop production and adaptation strategies of smallholder farmers in semi-arid Central and Western Zimbabwe. *African Crop. Sci. J.*, **25**(2), 221–235, doi:10.4314/acsj.v25i2.7.

Mallucci, Enrico (2020). "Natural Disasters, Climate Change, and Sovereign Risk," International Finance Discussion Papers 1291. Washington: Board of Governors of the Federal Reserve System, https://doi.org/10.17016/IFDP.2020.1291.

Manne, A.S. and R.G. Richels, 1992: *Buying Greenhouse Insurance: The Economic Costs of CO2 Emission Limits*. The MIT Press, Cambridge, Mass, 194. ISBN 978-0262132800. New ed.

Maor, M., J. Tosun and A. Jordan, 2017: Proportionate and disproportionate policy responses to climate change: core concepts and empirical applications. *J. Environ. Policy Plan.*, **0**(0), 1–13.

Mapfumo, P., Mtambanengwe, F. and Chikowo, R.2016: Building on indigenous knowledge to strengthen the capacity of smallholder farming communities to adapt to climate change and variability in southern Africa. *Clim. Dev.*, **8**, 72–81, doi:10.1080/17565529.2014.998604.

Marin, A. and L.O. Naess, 2017: Climate change adaptation through humanitarian aid? Promises, perils and potentials of the 'new humanitarianism'. *IDS Bull.* https://doi.org/10.19088/1968-2017.150

Markard, J., F.W. Geels and R. Raven, 2020: Challenges in the acceleration of sustainability transitions. *Environ. Res. Lett.* https://doi.org/10.1088/1748-9326/ab9468

Markkanen, S. and A. Anger-Kraavi, 2019: Social impacts of climate change mitigation policies and their implications for inequality. *Clim. Policy*, **19**(7), 827–844, doi:10.1080/14693062.2019.1596873.

Marmot, M., 2020: The Art of Medicine - Society and the slow burn of inequality. *Inst. Health Equity*, **395**, 1413–1414. https://doi.org/10.1016/s0140-6736(20)30940-5

Marmot, M. and J. Allen, 2020: COVID-19: exposing and amplifying inequalities. *J Epidemiol Community Health*, doi:10.1136/jech-2020-214720.

Marsha, A., et al., 2018: Influences of climatic and population changes on heat-related mortality in Houston, Texas, USA. *Clim Change*, **146**(3), 471–485, doi:10.1007/s10584-016-1775-1.

Martinez-Alier, J., 2021: Mapping ecological distribution conflicts: The EJAtlas. *Extr. Ind. Soc.*, doi:10.1016/j.exis.2021.02.003.

Martínez-Fernández, J., I. Banos-González and M.Á. Esteve-Selma, 2021: An integral approach to address socio-ecological systems sustainability and their uncertainties. *Sci. Total. Environ.*, **762**, 144457, doi:10.1016/j.scitotenv.2020.144457.

Martiskainen, M., et al., 2020: Contextualizing climate justice activism: knowledge, emotions, motivations, and actions among climate strikers in six cities. *Glob. Environ. Chang.*, **65**, 102180, doi:10.1016/j.gloenvcha.2020.102180.

Maru, Y.T., et al., 2014: A linked vulnerability and resilience framework for adaptation pathways in remote disadvantaged communities. *Glob. Environ. Chang.*, **28**, 337–350, doi:10.1016/j.gloenvcha.2013.12.007.

Massarella, K., et al., 2021: Transformation beyond conservation: how critical social science can contribute to a radical new agenda in biodiversity conservation. *Curr. Opin. Environ. Sustain.*, **49**, 79–87, doi:10.1016/j.cosust.2021.03.005.

Massey, E., R. Biesbroek, D. Huitema and A. Jordan, 2014: Climate policy innovation: the adoption and diffusion of adaptation policies across europe. *Glob. Environ. Chang.*, **29**, 434–443.

Material, E., 2019: *Industrial Transformation 2050: Pathways to net-zero emissions from EU Heavy Industry*. https://materialeconomics.com/publications/industrial-transformation-2050. Accessed 25-04-2019.

Mathai, M.V., J.A.P. de Oliveira and G. Dale, 2018: The rise and flaws of green growth. *Apn Sci. Bull.*, doi:10.30852/sb.2018.359.

Matin, N., J. Forrester and J. Ensor, 2018: What is equitable resilience? *World Dev*, **109**, 197–205.

Matos, P., et al., 2019: Modeling the provision of air-quality regulation ecosystem service provided by urban green spaces using lichens as ecological indicators. *Sci. Total. Environ.*, **665**, 521–530, doi:10.1016/j.scitotenv.2019.02.023.

Matsui, K., 2015: Problems of defining and validating traditional knowledge: a historical approach. *Int. Indig. Policy J.*, **6**(2), 2, doi:10.18584/iipj.2015.6.2.2.

Matthew, R., 2014: Integrating climate change into peacebuilding. *Clim Change*, **123**(1), 83–93, doi:10.1007/s10584-013-0894-1.

Mbow, C., C. Rosenzweig, L.G. Barioni, T.G. Benton, M. Herrero, M. Krishnapillai, E. Liwenga, P. Pradhan, M.G. Rivera-Ferre, T. Sapkota, F.N. Tubiello, Y. Xu, 2019:

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Food security. In: *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* [Shukla, P. R., J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi and J. Malley (eds.)]. In press.

McCartney, G., et al., 2017: Regeneration and health: a structured, rapid literature review. *Public Health*, **148**, 69–87. https://doi.org/10.1016/j.puhe.2017.02.022

McCollum, D.L., et al., 2018a: Connecting the sustainable development goals by their energy inter-linkages. *Environ. Res. Lett.*, **13**(3), 33006, doi:10.1088/1748-9326/aaafe3.

McCollum, D.L., et al., 2018b: Energy investment needs for fulfilling the paris agreement and achieving the sustainable development goals. *Nat. Energy*, **3**(7), 589–599, doi:10.1038/s41560-018-0179-z.

McGregor, D., S. Whitaker and M. Sritharan, 2020: Indigenous environmental justice and sustainability. *Curr. Opin. Environ. Sustain.*, **43**, 35–40, doi:10.1016/j.cosust.2020.01.007.

Mcleod, E., et al., 2018: Raising the voices of Pacific Island women to inform climate adaptation policies. *Mar. Policy*, **93**, 178–185.

Mcleod, E., et al., 2019: Lessons from the pacific islands – adapting to climate change by supporting social and ecological resilience. *Front. Mar. Sci.*, **6**(289), doi:10.3389/fmars.2019.00289.

McManamay, R.A., C.R. Vernon and H.I. Jager, 2021: Global biodiversity implications of alternative electrification strategies under the shared socioeconomic pathways. *Biol. Conserv.*, **260**, 109234, doi:10.1016/j.biocon.2021.109234.

McNamara, K.E., et al., 2020: An assessment of community-based adaptation initiatives in the Pacific Islands. *Nat. Clim. Change*, **10**(7), 628–639, doi:10.1038/s41558-020-0813-1.

McPhearson, T. and K. Wijsman, 2017: Transitioning complex urban systems: the importance of Urban ecology for sustainability in new York City. In: *Urban Sustainability Transitions* [Frantzeskaki, N., Broto, V.C., Coenen, L. and Loorbach, D. (eds.)]. Routledge, London. ISBN 978-1315228389.

McPhetres, J. and M. Zuckerman, 2018: Religiosity predicts negative attitudes towards science and lower levels of science literacy. *PLoS ONE*, **13**(11), doi:10.1371/journal.pone.0207125.

Meadows, D., 1999: *Leverage Points: Places to Intervene in a System*. The Sustainability Institute. Available at: https://donellameadows.org/archives/leverage-points-places-to-intervene-in-a-system/ (accessed 31.01.22)

Melica, G., et al., 2018: Multilevel governance of sustainable energy policies: The role of regions and provinces to support the participation of small local authorities in the Covenant of Mayors. *Sustain. Cities Soc.*, **39**, 729–739. Doi: 10.1016/j.scs.2018.01.013.

Meriluoto, T., 2018: 'The will to not be empowered (according to your rules)': Resistance in Finnish participatory social policy. *Crit. Soc. Policy*, doi:10.1177/0261018318764322.

Mersha, A.A. and F. van Laerhoven, 2019: Gender and climate policy: a discursive institutional analysis of Ethiopia's climate resilient strategy. *Reg. Environ. Change*, **19**(2), 429–440.

Metcalf, G.E., 2016: A conceptual framework for measuring the effectiveness of green fiscal reforms. *Int. J. Green Growth Dev.*, **2**(2), 87–126.

Metcalf, G.E., 2019: *On the Economics of a Carbon Tax for the United States*. Brookings Papers on Economic Activity. Available at: https://www.brookings.edu/wp-content/uploads/2019/03/On-the-Economics-of-a-Carbon-Tax-for-the-United-States.pdf (accedded 31.01.22).

Mganga, K.Z., N.K.R. Musimba and D.M. Nyariki, 2015: Combining sustainable land management technologies to combat land degradation and improve rural livelihoods in semi-arid lands in Kenya. *Environ Manage*, **56**(6), 1538–1548.

Michalena, E. and J.M. Hills, 2018: Paths of renewable energy development in small island developing states of the South Pacific. *Renew. Sustain. Energy Rev.*, **82**, 343–352, doi:10.1016/j.rser.2017.09.017.

Mikulewicz, M., 2018: Politicizing vulnerability and adaptation: on the need to democratize local responses to climate impacts in developing countries. *Clim. Dev.*, **10**(1), 18–34, doi:10.1080/17565529.2017.1304887.

Mikulewicz, M., 2019: Thwarting adaptation's potential? A critique of resilience and climate resilient development. *Geoforum*, **104**, 267–282, doi:10.1016/j.geoforum.2019.05.010.

Mikulewicz, M. and M. Taylor, 2020: Getting the resilience right: climate change and development policy in the 'African Age'. *New Polit. Econ.*, **25**(4), 626–641, doi:10.1080/13563467.2019.1625317.

Millennium Ecosystem Assessment, 2005: *Ecosystems and Human Well-Being: Synthesis*. Island Press, Washington, D.C.

Miller, C.A., 2017: Incorporating sustainability into climate change adaptation. In: *Encyclopedia of Sustainable Technologies* [Abraham, M. A.(ed.)]. Elsevier, Oxford, pp. 175–182. ISBN 978-0128047927.

Milman, A. and Y. Arsano, 2014: Climate adaptation and development: contradictions for human security in Gambella, Ethiopia. *Glob. Environ. Chang.*, **29**, 349–359, doi:10.1016/j.gloenvcha.2013.11.017.

Mimura, N., R.S. Pulwarty, D.M. Duc, I. Elshinnawy, M.H. Redsteer, H.Q. Huang, J.N. Nkem, and R.A. Sanchez Rodriguez, 2014: Adaptation Planning and Implementation. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C. B., V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea and L. L. White (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 869-898. ISBN 9781107058071.

Minx, J.C., et al., 2017: Learning about climate change solutions in the IPCC and beyond. *Environ. Sci. Policy*, **77**, 252–259, doi:10.1016/j.envsci.2017.05.014.

Mirumachi, N., A. Sawas and M. Workman, 2020: Unveiling the security concerns of low carbon development: climate security analysis of the undesirable and unintended effects of mitigation and adaptation. *Clim. Dev.*, **12**(2), 97–109, doi:10.1080/17565529.2019.1604310.

Mirzabaev, A., et al., 2015: Bioenergy, food security and poverty reduction: trade-offs and synergies along the water–energy–food security nexus. *Water Int.*, **40**(5-6), 772–790, doi:10.1080/02508060.2015.1048924.

Mistry, J., B.A. Bilbao and A. Berardi, 2016: Community owned solutions for fire management in tropical ecosystems: casestudies from Indigenous communities of South. *Philos. Trans.*, **371**, 1–10.

Mitchell, D., S. Enemark and P. van der Molen, 2015: Climate resilient urban development: why responsible land governance is important. *Land Use Policy*, **48**, 190–198, doi:10.1016/j.landusepol.2015.05.026.

Mitchell, T. and S. Maxwell, 2010: *Defining Climate Compatible Development*. CDKR. Available at: https://www.gov.uk/research-for-development-outputs/defining-climate-compatible-development#:~:text='Climate%20compatible%20development'%20is%20development,emissions%2C%20more%20resilient%2C%20future. (accessed 31.01.22).

Mitter, H., et al., 2020: Shared socio-economic pathways for European agriculture and food systems: the Eur-Agri-SSPs. *Glob. Environ. Chang.*, **65**, 102159, doi:10.1016/j.gloenvcha.2020.102159.

Mocca, E. and S. Osborne, 2019: "Solidarity is our weapon": social Mobilisation in Scotland in the contest of the post-political condition. *Antipode*, **51**(2), 620–641, doi:10.1111/anti.12466.

Mogelgaard, K., et al., 2018: *From Planning to Action: Mainstreaming Climate Change Adaptation Into Development*. World Resources Institute. Available at: https://www.wri.org/research/planning-action-mainstreaming-climate-change-adaptation-development (accessed 31.01.22).

Mohammed, R. and M. Scholz, 2017: Adaptation strategy to mitigate the impact of climate change on water resources in arid and semi-arid regions: a

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

case study. *Water Resour. Manag.*, **31**(11), 3557–3573, doi:10.1007/s11269-017-1685-7.

Montoute, A., D. Mohammed and J. Francis, 2019: Prospects and challenges for civil society and climate change engagement in the caribbean: the case of trinidad and Tobago. *Caribb. Stud.*, **47**(2), 81–109, doi:10.1353/crb.2019.0015.

Moore, M.-L., D. Riddell and D. Vocisano, 2015: Scaling out, scaling up, scaling deep: strategies of non-profits in advancing systemic social innovation. *J. Corp. Citizsh.*, **58**, 67–84.

Mora, C., et al., 2017: Global risk of deadly heat. *Nat. Clim. Change*, **7**(7), 501–506, doi:10.1038/nclimate3322.

Mora, O., et al., 2020: Exploring the future of land use and food security: A new set of global scenarios. *PLoS ONE*, **15**(7), e235597.

Moran, et al., 2018: *The Intersection of Global Fragility and Climate Risks*. United States Agency for International Development, Washington, D.C.

Mormina, M., 2019: Science, technology and innovation as social goods for development: rethinking research capacity building from Sen's capabilities approach. *SCI ENG ETHICS*, **25**(3), 671–692.

Morote, Á.-F., J. Olcina and M. Hernández, 2019: The use of non-conventional water resources as a means of adaptation to drought and climate change in semi-arid regions: south-eastern Spain. *Water*, **11**(1), 93, doi:10.3390/w11010093.

Morton, T., 2013: *Hyperobjects: Philosophy and Ecology after the End of the World*, 1st edn., Univ Of Minnesota Press, Minneapolis, ISBN 978-0816689231. 240 pp.

Morton, T., 2021: Contesting coal, contesting climate: materializing the social drama of climate change in Australia and Germany. *Environ. Commun.*, **15**(4), 465–481, doi:10.1080/17524032.2020.1865428.

Mosberg, M., E. Nyukuri and L.O. Naess, 2017: The power of 'know-who': adaptation to climate change in a changing humanitarian landscape in Isiolo, Kenya. *IDS Bull.*, **48**(4), doi:10.19088/1968-2017.154.

Moser, S.C. and J.A. Ekstrom, 2011: Taking ownership of climate change: participatory adaptation planning in two local case studies from California. *J Environ Stud Sci*, **1**(1), 63–74, doi:10.1007/s13412-011-0012-5.

Moser, S., S. Meerow, J. Arnott and E. Jack-Scott, 2019: The turbulent world of resilience: interpretations and themes for transdisciplinary dialogue. *Clim. Change*, **153**(1), 21–40, doi:10.1007/s10584-018-2358-0.

Mosley, J. and E.E. Watson, 2016: Frontier transformations: development visions, spaces and processes in Northern Kenya and Southern Ethiopia. *J. East. African Stud.*, **10**(3), 452–475.

Mouratiadou, I., et al., 2016: The impact of climate change mitigation on water demand for energy and food: an integrated analysis based on the shared socioeconomic pathways. *Environ. Sci. Policy*, **64**, 48–58, doi:10.1016/j.envsci.2016.06.007.

Moyer, J.D. and D.K. Bohl, 2019: Alternative pathways to human development: assessing trade-offs and synergies in achieving the sustainable development goals. *Futures*, **105**, 199–210, doi:10.1016/j.futures.2018.10.007.

Republic of Mozambique and IUCN, 2014: *Climate Change and Gender Action Plan for the Republic of Mozambique*. The Global Gender Office of the International Union for Conservation of Nature (IUCN GGO). Available at: https://genderandenvironment.org/climate-change-gender-action-plan-phase-ii-for-the-republic-of-mozambique/ Accessed 2019-09-24.

Mpandeli, S., et al., 2018: Climate change adaptation through the water-energy-food nexus in southern Africa. *IJERPH*, **15**(10), 2306, doi:10.3390/ijerph15102306.

https://www.mrfcj.org/wp-content/uploads/2015/11/MRFCJ-Rights-for-Action-edition-2.pdf (accessed 31.01.22). (28 pp).

Mullins, J.T. and C. White, 2020: Can access to health care mitigate the effects of temperature on mortality? *J Public Econ*, **191**, 104259, doi:10.1016/j.jpubeco.2020.104259.

Mulugetta, Y., E.B. Hagan and D. Kammen, 2019: Energy access for sustainable development. *Environ. Res. Lett.*, **14**(2), 20201, doi:10.1088/1748-9326/aaf449.

Muok, B., M. Mosberg, S. Eriksen and D. Ochieng, 2021: The politics of forest governance in a changing climate: Political reforms, conflict and socio-environmental changes in Laikipia, Kenya. *For. Policy Econ.* In press. Doi: 10.1016/j.forpol.2021.102590

Muratori, M., et al., 2020: EMF-33 insights on bioenergy with carbon capture and storage (BECCS). *Clim Change*, doi:10.1007/s10584-020-02784-5.

Muricho, D.N., D.J. Otieno, W. Oluoch-Kosura and M. Jirström, 2019: Building pastoralists' resilience to shocks for sustainable disaster risk mitigation: Lessons from West Pokot County, Kenya. *Int. J. Disaster Risk Reduct.*, **34**, 429–435.

Murphy, B.L., 2011: From interdisciplinary to inter-epistemological approaches: confronting the challenges of integrated climate change research. *Can. Geogr.*, **55**(4), 490–509, doi:10.1111/j.1541-0064.2011.00388.x.

Murtinho, F., 2016: What facilitates adaptation? An analysis of community-based adaptation to environmental change in the Andes. *Int. J. Commons*, **10**(1), 119–141, doi:10.18352/ijc.585.

Mustafa, S., A. Estim and R. Shapawi, 2019: *Future-Proofing Oceans for Food Security and Poverty Alleviation*, 1–11. ISBN 978-3319696270. Doi: 10.1007/978-3-319-71058-7_57-1

Mustonen, T., 2013: Oral histories as a baseline of landscape restoration – co-management and watershed knowledge in Jukajoki river. *Fennia*, **191**, 76–91. Doi: 10.11143/7637

Mustonen, T., 2014: Endemic time-spaces of Finland: Aquatic regimes. *Fennia*, **192**(2), 120–139.

Mustonen, T., 2018: Meaningful engagement and oral histories of the indigenous peoples of the north. *Nord. Geogr. Publ.*, **47**(2), 1–38.

Mustonen, T. and P. Feodoroff, 2020: What is a river? A cross-disciplinary and indigenous assessment. In: *Indigenous Wellbeing and Enterprise Self-Determination and Sustainable Economic Development* [Colborne, R.(ed.)]. Routledge, London.

Mustonen, T. and V. Shadrin, 2020: *The River Alazeya: Shifting socio-ecological systems connected to a Northeastern Siberian Rive*. Arctic Institute of North America, Calgary.

Mycoo, M. A., 2018: Beyond 1.5°C: vulnerabilities and adaptation strategies for Caribbean Small Island Developing States. *Reg Environ Change*. Doi: 10.1007/s10113-017-1248-8

Mythen, G. and S. Walklate, 2016: Not knowing, emancipatory catastrophism and metamorphosis: embracing the spirit of Ulrich beck. *Secur. Dialogue*, **47**(5), 403–419, doi:10.1177/0967010616651027.

Nabuurs, G.-J., et al., 2017: By 2050 the mitigation effects of EU forests could nearly double through climate smart forestry. *Forests*, **8**, 484, doi:10.3390/f8120484.

Nabuurs, G.-J., et al., 2019: Next-generation information to support a sustainable course for European forests. *Nat. Sustain.*, **2**(9), 815–818, doi:10.1038/s41893-019-0374-3.

Nachmany, M., S. Fankhauser, J. Setzer and A. Averchenkova, 2017: *Global trends in climate change legislation and litigation: 2017 update*. Available at: https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2017/05/Global_trends_in_climate_change_legislation_and_litigation_summary_flyer.pdf (accessed 31.01.22).

Nachmany, M. and J. Setzer, 2018: *Policy brief Global trends in climate change legislation and litigation: 2018 snapshot*. Grantham Research Center on Climate Change and the Environment and Center for Climate Change Economics and Policy, London.

Naess, L.O., 2013: The role of local knowledge in adaptation to climate change. *WIREs Clim. Chang.*, **4**(2), 99–106, doi:10.1002/wcc.204.

Naess, L.O., et al., 2015: Climate policy meets national development contexts: insights from Kenya and Mozambique. *Glob. Environ. Chang.*, **35**, 534–544, doi:10.1016/j.gloenvcha.2015.08.015.

Nagoda, S., 2015: New discourses but same old development approaches? Climate change adaptation policies, chronic food insecurity and development interventions in northwestern Nepal. *Glob. Environ. Chang.*, **35**, 570–579, doi:10.1016/j.gloenvcha.2015.08.014.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Nagoda, S. and A.J. Nightingale, 2017: Participation and power in climate change adaptation policies: vulnerability in food security programs in Nepal. *World Dev*, **100**, 85–93, doi:10.1016/j.worlddev.2017.07.022.

Naidoo, R. and B. Fisher, 2020: Reset sustainable development goals for a pandemic world. *Nature*, **583**(7815), 198–201, doi:10.1038/d41586-020-01999-x.

Nakashima, D.J., et al., 2012: *Weathering Uncertainty: Traditional Knowledge for Climate Change Assessment and Adaptation*. UNESCO, and Darwin, UNU, Paris.

Nalau, J., et al., 2018: The role of indigenous and traditional knowledge in ecosystem-based adaptation: a review of the literature and case studies from the Pacific Islands. *Wea. Clim. Soc.*, **10**(4), 851–865, doi:10.1175/WCAS-D-18-0032.1.

Nalau, J., B.L. Preston and M.C. Maloney, 2015: Is adaptation a local responsibility? *Environ. Sci. Policy*, **48**, 89–98.

Naspolini, G.F., B.S. Ciasca, E.L. La Rovere and A.O. Pereira Jr, 2020: Brazilian environmental-economic accounting for water: a structural decomposition analysis. *J. Environ. Manag.*, **265**, 110508.

Naude, P., 2019: Decolonising knowledge: can Ubuntu ethics save us from coloniality? *J. Bus. Ethics.*, **159**(1), 23–37, doi:10.1007/s10551-017-3763-4.

Naylor, A., J. Ford, T. Pearce and J. Van Alstine, 2020: Conceptualizing climate vulnerability in complex adaptive systems. *One Earth*, **2**(5), 444–454.

NDRC, 2015: *China Belt and Road Initiative*. Available at: https://www.cfr.org/backgrounder/chinas-massive-belt-and-road-initiative (accessed 31.01.22).

NEF, 2016: *Happy Planet Index*. Available at: https://happyplanetindex.org/wp-content/themes/hpi/public/downloads/happy-planet-index-briefing-paper.pdf (accessed 31.01.22).

Newell, P., 2019: Trasformismo or transformation? The global political economy of energy transitions. *Rev. Int. Polit. Econ.*, **26**(1), 25–48, doi:10.1080/09692290.2018.1511448.

Newell, P., 2020: Towards a global political economy of transitions: a comment on the transitions research agenda. *Environ. Innov. Soc. Transit.*, **34**, 344–345, doi:10.1016/j.eist.2019.10.007.

Newell, P. and R. Lane, 2020: A climate for change? The impacts of climate change on energy politics. *Camb. Rev. Int. Aff.*, **33**(3), 347–364, doi:10.1080/09557571.2018.1508203.

Newman, T.P., E.C. Nisbet and M.C. Nisbet, 2018: Climate change, cultural cognition, and media effects: Worldviews drive news selectivity, biased processing, and polarized attitudes. *Public Underst. Sci.*, doi:10.1177/0963662518801170.

Nhamo, G. and S. Nhamo, 2018: Gender and Geographical Balance: With a Focus on the UN Secretariat and the Intergovernmental Panel on Climate Change. *Gend. Quest.*, **5**(1). Doi: 10.25159/2412-8457/2520

Nhamo, L., B. Ndlela, S. Mpandeli and T. Mabhaudhi, 2020: The water-energy-food nexus as an adaptation strategy for achieving sustainable livelihoods at a local level. *Sustainability*, **12**(20), 8582, doi:10.3390/su12208582.

Nielsen, S. and I.R. Skov, 2019: Investment screening model for spatial deployment of power-to-gas plants on a national scale – a Danish case. *Int J Hydrogen Energy*, **44**(19), 9544–9557, doi:10.1016/j.ijhydene.2018.09.129.

Nightingale, A.J., 2016: Adaptive scholarship and situated knowledges? Hybrid methodologies and plural epistemologies in climate change adaptation research. *Area*, **48**(1), 41–47, doi:10.1111/area.12195.

Nightingale, A.J., 2017: Power and politics in climate change adaptation efforts: Struggles over authority and recognition in the context of political instability. *Geoforum*, **84**, 11–20.

Nightingale, A.J., et al., 2020: Beyond Technical Fixes: climate solutions and the great derangement. *Clim. Dev.*, **12**(4), 343–352.

Nightingale, A.J., T. Böhler, B. Campbell and L. Karlsson, 2019: Background and history of sustainability. In: *Environment and Sustainability in a Globalizing World* [Nightingale, A.J., T. Böhler, B. Campbell and L. Karlsson (eds).]. Routledge, London. pp. 13–34. ISBN 978-0765646446.

Nikulina, V., D. Simon, H. Ny and H. Baumann, 2019: Context-adapted urban planning for rapid transitioning of personal mobility towards sustainability: A systematic literature review. *Sustainability*, **11**(4), 1007.

Nilsson, M. and N. Weitz, 2019: Governing trade-offs and building coherence in policy-making for the 2030 agenda. *Polit. Gov.*, **7**(4), 254–263, doi:10.17645/pag.v7i4.2229.

Nilsson, M., et al., 2012: Understanding policy coherence: analytical framework and examples of sector–environment policy interactions in the EU. *Environ. Policy Gov.*, **22**(6), 395–423, doi:10.1002/eet.1589.

Nkemelang, T., M. New and M. Zaroug, 2018: Temperature and precipitation extremes under current, 1.5°C and 2.0°C global warming above pre-industrial levels over Botswana, and implications for climate change vulnerability. *Environ. Res. Lett.*, **13**(6), 65016.

Nordhaus, W.D. and J. Tobin, 1973: Is growth obsolete? In: *The measurement of economic and social performance* [Moss, M. (eds.)..National Bureau of Economic Research, Cambridge, MA. , pp. 509–564.

Novák, A., 2021: Every city needs a Klinika: The struggle for autonomy in the post-political city. *Soc. Mov Stud.*, **20**(3), 276–291, doi:10.1080/14742837.2020.1770070.

Nunn, P. and N. Reid, 2016: Aboriginal memories of inundation of the Australian coast dating from more than 7000 years ago. *Aust. Geogr.*, **47**(1), 11–47, doi:10.1080/00049182.2015.1077539.

Nyariki, D.M. and D.A. Amwata, 2019: The value of pastoralism in Kenya: Application of total economic value approach. *Pastoralism*, **9**(1), 9.

Nyasimi, M., et al., 2018: *Inclusion of gender in africa's climate change policies and strategies*, 171–185. Springer, Berlin. ISBN 978-3319698373.

Nyberg, G., et al., 2015: Enclosures in West Pokot, Kenya: transforming land, livestock and livelihoods in drylands. *Pastoralism*, **5**(1), 25.

O'Brien, K., S. Eriksen, T.H. Inderberg and L. Sygna, 2015: *Climate change adaptation and development: transforming through paradigms and practics*. Routledge, New York.

O'Brien, K. and E. Selboe, 2015: *Social Transformation: The Real Adaptive Challenge*, 311–324. Cambridge University Press, Cambridge. ISBN 978-1139149389.

O'Brien, K.L., 2016: Climate change and social transformations: is it time for a quantum leap? *WIREs Clim. Chang.*, **7**(5), 618–626, doi:10.1002/wcc.413.

O'Brien, K., 2018: Is the 1.5°C target possible? Exploring the three spheres of transformation. *Curr. Opin. Environ. Sustain.*, **31**, 153–160, doi:10.1016/j.cosust.2018.04.010.

O'Brien, K., 2021: Reflecting on the anthropocene: the call for deeper transformations. *Ambio*, **50**(10), 1793–1797, doi:10.1007/s13280-020-01468-9.

O'Neil, T., A. Fleury and M. Foresti, 2017: *Gender equality, migration and the 2030 Agenda for Sustainable Development*. Louise Arbour, UN Special Representative for International Migration, 45.

O'Neill, B.C., et al., 2017: The roads ahead: narratives for shared socioeconomic pathways describing world futures in the 21st century. *Glob. Environ. Chang.*, **42**, 169–180, doi:10.1016/j.gloenvcha.2015.01.004.

O'Neil, T., A. Fleury and M. Foresti, 2017: *Women on the move: Gender equality, migration and the 2030 Agenda for Sustainable Development*. Oversees Development Institute. Available at: https://odi.org/en/publications/women-on-the-move-migration-gender-equality-and-the-2030-agenda-for-sustainable-development/ (accessed 31.01.22).

O'Neill, B.C., et al., 2017: The roads ahead: narratives for shared socioeconomic pathways describing world futures in the 21st century. *Glob. Environ. Chang.*, **42**, 169–180, doi:10.1016/j.gloenvcha.2015.01.004.

O'Neill, D.W., A.L. Fanning, W.F. Lamb and J.K. Steinberger, 2018: A good life for all within planetary boundaries. *Nat. Sustain.*, **1**(2), 88–95, doi:10.1038/s41893-018-0021-4.

Ochieng, J., L. Kirimi and J. Makau, 2017: Adapting to climate variability and change in rural Kenya: farmer perceptions, strategies and climate trends. *Nat Resour Forum*, **41**(4), 195–208.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

OECD, 2017: *Mobilising Investment in Clean Energy Infrastructure*. Available at: https://www.oecd.org/investment/investment-policy/clean-energy-infrastructure.htm (accessed 31.01.22).
OECD, 2019a: *Better Life Index*. Available at: https://www.oecdbetterlifeindex.org/ (accessed 31.01.22).
OECD, 2019b: *Society at a Glance 2019*. Available at: https://www.oecd-ilibrary.org/social-issues-migration-health/society-at-a-glance-2019_soc_glance-2019-en (accessed 31.01.22).
OECD, 2021: *Climate change and long term fiscal sustainability*. Available at: https://www.oecd.org/gov/budgeting/scoping-paper-on-fiscal-sustainability-and-climate-change.pdf (accessed 31.01.22).
Ofir, Z., 2021: *The DAC Criteria Guidance 2021 - Evaluation for transformation*. Available at: https://www.oecd.org/dac/evaluation/daccriteriaforevaluatingdevelopmentassistance.htm (accessed 31.01.22).
Ogar, E., G. Pecl and T. Mustonen, 2020: Science must embrace traditional and indigenous knowledge to solve our Biodiversity crisis. *One Earth*, 162–164, doi:10.1016/j.oneear.2020.07.006.
Ojwang, L., et al., 2017: Assessment of coastal governance for climate change adaptation in Kenya. *Earth's Future*, **5**(11), 1119–1132, doi:10.1002/2017EF000595.
Oke, C., et al., 2021: Cities should respond to the biodiversity extinction crisis. *Npj Urban Sustain.*, **1**(1), 1–4, doi:10.1038/s42949-020-00010-w.
Oleribe, O.O. and S.D. Taylor-Robinson, 2016: Before sustainable development goals (SDG): why Nigeria failed to achieve the millennium development goals (MDGs). *Pan. Afr. Med. J.*, **24**, 156–156, doi:10.11604/pamj.2016.24.156.8447.
Olmstead, S.M., 2014: Climate change adaptation and water resource management: a review of the literature. *Energy Econ.*, **46**, 500–509, doi:10.1016/j.eneco.2013.09.005.
Olsson, L., M. Opondo, P. Tschakert, A. Agrawal, S.H. Eriksen, S. Ma, L.N. Perch, and S.A. Zakieldeen, 2014: Livelihoods and Poverty. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C. B., V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea and L. L. White (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 793-832. ISBN 9781107058071.
Omukuti, J., 2020: Country ownership of adaptation: Stakeholder influence or government control? *Geoforum*, **113**, 26–38, doi:10.1016/j.geoforum.2020.04.019.
Onarheim, K.H., J.H. Iversen and D.E. Bloom, 2016: Economic benefits of investing in women's health: a systematic review. *PLoS ONE*, **11**(3), e150120, doi:10.1371/journal.pone.0150120.
Opiyo, F., et al., 2016: Determinants of perceptions of climate change and adaptation among Turkana pastoralists in northwestern Kenya. *Clim. Dev.*, **8**(2), 179–189.
Opiyo, F.E., O.V. Wasonga and M.M. Nyangito, 2014: Measuring household vulnerability to climate-induced stresses in pastoral rangelands of Kenya: Implications for resilience programming. *Pastoralism*, **4**(1), 10.
Oppenheimer, M., B.C. Glavovic , J. Hinkel, R. van de Wal, A.K. Magnan, A. Abd-Elgawad, R. Cai, M. Cifuentes-Jara, R.M. DeConto, T. Ghosh, J. Hay, F. Isla, B. Marzeion, B. Meyssignac, and Z. Sebesvari, 2019: Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [Pörtner, H.-O., D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama and N. M. Weyer (eds.)]. In press.
Orlove, B., R. Shwom, E. Markowitz and S.-M. Cheong, 2020: Climate decision-making. *Annu. Rev. Environ. Resour.*, **45**(1), 271–303, doi:10.1146/annurev-environ-012320-085130.
Ota, T., 2017: Economic growth, income inequality and environment: assessing the applicability of the Kuznets hypotheses to Asia. *Palgrave Commun*, **3**(1), 1–23, doi:10.1057/palcomms.2017.69.
Ott, C. and B. Kiteme, 2016: Concepts and practices for the democratisation of knowledge generation in research partnerships for sustainable development. *Evid. Policy: A J. Res. Debate Pract.*, **12**(3), 405–430, doi:10.1332/174426416X14700793045951.
Ott, K.K., 2018: On the political economy of solar radiation management. *Front. Environ. Sci.*, **6**, doi:10.3389/fenvs.2018.00043.
Owen, G., 2020: What makes climate change adaptation effective? A systematic review of the literature. *Glob. Environ. Change*, **62**, 102071, doi:10.1016/j.gloenvcha.2020.102071.
Paik, S., D.T.P. Le, L.T. Nhu and B.F. Mills, 2020: Salt-tolerant rice variety adoption in the mekong river delta: farmer adaptation to sea-level rise. *PLoS ONE*, **15**(3), e229464, doi:10.1371/journal.pone.0229464.
Palazzo, A., et al., 2017: Linking regional stakeholder scenarios and shared socioeconomic pathways: Quantified West African food and climate futures in a global context. *Glob. Environ. Chang.*, **45**, 227–242, doi:10.1016/j.gloenvcha.2016.12.002.
Palermo, V. and Y. Hernandez, 2020: Group discussions on how to implement a participatory process in climate adaptation planning: a case study in Malaysia. *Ecol. Econ.*, **177**, 106791, doi:10.1016/j.ecolecon.2020.106791.
Pant, L.P., B. Adhikari and K.K. Bhattarai, 2015: Adaptive transition for transformations to sustainability in developing countries. *Curr. Opin. Environ. Sustain.*, **14**, 206–212, doi:10.1016/j.cosust.2015.07.006.
Papoutsi, M., M. Piaszzesi and M. Schneider, 2021: *How Unconventional is Green Monetary Policy?* Available at: https://web.stanford.edu/~piazzesi/How_unconventional_is_green_monetary_policy.pdf (accessed 31.01.22).
Paprocki, K., 2018: Threatening dystopias: development and adaptation regimes in Bangladesh. *Ann. Am. Assoc. Geogr.*, **108**(4), 955–973, doi:10.1080/24694452.2017.1406330.
Parikh, K.S., J.K. Parikh and P.P. Ghosh, 2018: Can India grow and live within a 1.5 degree CO2 emissions budget? *Energy Policy*, **120**, 24–37.
Parraguez-Vergara, E., et al., 2018: Does indigenous and campesino traditional agriculture have anything to contribute to food sovereignty in Latin America? Evidence from Chile, Peru, Ecuador, Colombia, Guatemala and Mexico. *Int. J. Agric. Sustain.*, 326–341, doi:10.1080/14735903.2018.1489361.
Parry, I., 2021: *Implementing the United States' Domestic and International Climate Mitigation Goals: A Supportive Fiscal Policy Approach*. IMF Working Paper. Doi: 10.5089/9781513571003.001.
Parry, J.-E., 2017: *Building a Climate-Resilient City: Transformational adaptation*. IISD, http://prairieclimatecentre.ca/wp-content/uploads/2017/04/pcc-brief-climate-resilient-city-transformational-adaptation.pdf. (accessed 31.01.22).
Parsons, M., C. Brown, J. Nalau and K. Fisher, 2018: Assessing adaptive capacity and adaptation: insights from Samoan tourism operators. *Clim. Dev.*, **10**(7), 644–663, doi:10.1080/17565529.2017.1410082.
Parsons, M., K. Fisher and J. Nalau, 2016: Alternative approaches to co-design: insights from indigenous/academic research collaborations. *Curr. Opin. Environ. Sustain.*, **20**, 99-105.
Partzsch, L., 2017: 'Power with' and 'power to' in environmental politics and the transition to sustainability. *Env Polit*, **26**(2), 193–211, doi:10.1080/09644016.2016.1256961.
Pascual, U., et al., 2017: Valuing nature's contributions to people: the IPBES approach. *Curr. Opin. Environ. Sustain.*, **26-27**, 7–16, doi:10.1016/j.cosust.2016.12.006.
Pasquini, L., 2020: The urban governance of climate change adaptation in least-developed African countries and in small cities: the engagement of local decision-makers in Dar es Salaam, Tanzania, and Karonga, Malawi. *Clim. Dev.*, **12**(5), 408–419, doi:10.1080/17565529.2019.1632166.
Paton, F.L., H.R. Maier and G.C. Dandy, 2014: Including adaptation and mitigation responses to climate change in a multiobjective evolutionary algorithm framework for urban water supply systems incorporating GHG emissions. *Water Resour. Res.*, **50**(8), 6285–6304, doi:10.1002/2013WR015195.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Patorniti, N.P., N.J. Stevens and P.M. Salmon, 2017: A systems approach to city design: exploring the compatibility of sociotechnical systems. *Habitat Int.*, **66**, 42–48, doi:10.1016/j.habitatint.2017.05.008.

Patorniti, N.P., N.J. Stevens and P.M. Salmon, 2018: A sociotechnical systems approach to understand complex urban systems: A global transdisciplinary perspective. *Hum. Factors Ergonomics Manuf. Serv. Ind.*, **28**(6), 281–296, doi:10.1002/hfm.20742.

Patterson, J., et al., 2017: Exploring the governance and politics of transformations towards sustainability. *Environ. Innov. Soc. Transit.*, **24**, 1–16, doi:10.1016/j.eist.2016.09.001.

Patterson, J.J., et al., 2018: Political feasibility of 1.5° C societal transformations: the role of social justice. *Curr. Opin. Environ. Sustain.*, **31**, 1–9.

Patton, M.Q., 2021: Evaluation criteria for evaluating transformation: implications for the coronavirus pandemic and the global climate emergency. *Am. J. Eval.*, **42**(1), 53–89, doi:10.1177/1098214020933689.

Pauliuk, S., T. Wang and D.B. Müller, 2013: Steel all over the world: estimating in-use stocks of iron for 200 countries. *Resour. Conserv. Recycl.*, **71**, 22–30, doi:10.1016/j.resconrec.2012.11.008.

Pauw, W.P., et al., 2018: Beyond headline mitigation numbers: we need more transparent and comparable NDCs to achieve the Paris Agreement on climate change. *Clim Change*, **147**(1), 23–29, doi:10.1007/s10584-017-2122-x.

PBCSF, 2019: *Support for BRI low carbon development: a green finance roadmap*. Available at: https://www.climateworks.org/wp-content/uploads/2019/08/BRI_Exec_Summary_v10-screen_pages_lo-1.pdf (accessed 31.01.22).

Pearce, T.D., E.H. Rodríguez, D. Fawcett and J.D. Ford, 2018a: How is Australia adapting to climate change based on a systematic review? *Sustainability*, **10**(9), 3280, doi:10.3390/su10093280.

Pearce, W., M. Mahony and S. Raman, 2018b: Science advice for global challenges: learning from trade-offs in the IPCC. *Environ. Sci. Policy*, **80**, 125–131, doi:10.1016/j.envsci.2017.11.017.

Pearse, R., 2017: Gender and climate change. *WIREs Clim. Chang.*, **8**(2), e451, doi:10.1002/wcc.451.

Pecl, G.T., et al., 2017: Biodiversity redistribution under climate change: impacts on ecosystems and human well-being. *Science*, **355**(6332), doi:10.1126/science.aai9214.

Pelling, M., 2010: *Adaptation to Climate Change: From Resilience to Transformation*, 1st edn., Routledge, London, UK, ISBN 978-0203889046.

Pelling, M., T. Abeling and M. Garschagen, 2016: Emergence and transition in London's climate change adaptation pathways. *J. Extrem. Events*, **03**(03), 1650012.

Pelling, M. and M. Garschagen, 2019: Put equity first in climate adaptation. *Nature*, **569**(7756), 327–329, doi:10.1038/d41586-019-01497-9.

Pelling, M., et al., 2018: Africa's urban adaptation transition under a 1.5° climate. *Curr. Opin. Environ. Sustain.*, **31**, 10–15, doi:10.1016/j.cosust.2017.11.005.

Pelling, M., K. O'Brien and D. Matyas, 2015: Adaptation and transformation. *Clim Change*, **133**(1), 113–127, doi:10.1007/s10584-014-1303-0.

Pereira, J.J., 2018: Science and technology to enhance disaster resilience in a changing climate. In: *Science and Technology in Disaster Risk Reduction in Asia* [Shaw, R., K. Shiwaku and T. Izumi(eds.)] Vol.3, Academic Press, Cambridge, MA, pp. 31–38. ISBN 978-0128127117.

Perera, A.T.D., et al., 2020: Quantifying the impacts of climate change and extreme climate events on energy systems. *Nat. Energy*, **5**(2), 150–159, doi:10.1038/s41560-020-0558-0.

Perkins, P.E., 2019: Climate justice, commons, and degrowth. *Ecol. Econ.*, **160**, 183–190, doi:10.1016/j.ecolecon.2019.02.005.

Persson, Å., 2019: Global adaptation governance: an emerging but contested domain. *WIREs Clim. Chang.*, **10**(6), e618, doi:10.1002/wcc.618.

Pervin, M., et al., 2013: *A framework for mainstreaming climate resilience into development planning*. https://pubs.iied.org/pdfs/10050IIED.pdf, (accessed 31.01.22)..

Peters, H.P., 2013: Gap between science and media revisited: Scientists as public communicators. *Proc. Natl. Acad. Sci.*, **110**(Supplement_3), 14102–14109.

Peterson, G.D., et al., 2018: Welcoming different perspectives in IPBES: "Nature's contributions to people" and "Ecosystem services". *Ecol. Soc.*, **23**(1), doi:10.5751/es-10134-230139.

Petrides, D., A. Papacharalampopoulos, P. Stavropoulos and G. Chryssolouris, 2018: Dematerialisation of products and manufacturing-generated knowledge content: relationship through paradigms. *Int. J. Prod. Res.*, **56**(1), 86–96, doi:10.1080/00207543.2017.1401246.

Phillips, C.A., et al., 2020: Compound climate risks in the COVID-19 pandemic. *Nat. Clim. Chang.*, **10**(7), 586–588, doi:10.1038/s41558-020-0804-2.

Piggot, G., 2018: The influence of social movements on policies that constrain fossil fuel supply. *Clim. Policy*, **18**(7), 942–954, doi:10.1080/14693062.2017.1394255.

Pineda-López, M.R., et al., 2015: The role of women in the forest conservation in a Mexican national park: pruning firs for the manufacture of christmas wreaths. *Hum Ecol*, **43**(3), 493–501, doi:10.1007/s10745-015-9756-y.

Pinnegar, J.K., et al., 2021: Future Socio-political scenarios for aquatic resources in europe: a common framework based on shared-socioeconomic-pathways (SSPs). *Front. Mar. Sci.*, **7**(1096), doi:10.3389/fmars.2020.568219.

Pirmana, V., A.S. Alisjahbana, R. Hoekstra and A. Tukker, 2019: Implementation barriers for a system of environmental-economic accounting in developing countries and its implications for monitoring sustainable development goals. *Sustainability*, **11**(22), 6417, doi:10.3390/su11226417.

Plank, C., et al., 2021: Climate policy integration viewed through the stakeholders' eyes: a co-production of knowledge in social-ecological transformation research. *Environ. Policy Gov.*, **31**(4), 387–399, doi:10.1002/eet.1938.

Plesa, P., 2019: A theoretical foundation for ecopsychology: looking at ecofeminist epistemology. *New Ideas Psychol*, **52**, 18–25, doi:10.1016/j.newideapsych.2018.10.002.

Popescu, G.H., et al., 2017: Stabilizing valences of an optimum monetary zone in a resilient economy—approaches and limitations. *Sustainability*, **9**(6), 1051, doi:10.3390/su9061051.

Popp, A., et al., 2014: Land-use transition for bioenergy and climate stabilization: model comparison of drivers, impacts and interactions with other land use based mitigation options. *Clim Change*, **123**(3), 495–509, doi:10.1007/s10584-013-0926-x.

Porta, D., 2020: Protests as critical junctures: some reflections towards a momentous approach to social movements. *Soc. Mov Stud.*, **19**(5-6), 556–575, doi:10.1080/14742837.2018.1555458.

Power, M., et al., 2016: The political economy of energy transitions in Mozambique and South Africa: the role of the rising powers. *Energy Res. Soc. Sci.*, **17**, 10–19, doi:10.1016/j.erss.2016.03.007.

Preston, B.L., L. Rickards, H. Fünfgeld and R.J. Keenan, 2015: Toward reflexive climate adaptation research. *Curr. Opin. Environ. Sustain.*, **14**, 127–135.

Price, R., 2021: *Overview of Political Economy Analysis Frameworks in the Area of Climate Governance and Key Issues to Consider*. Institute of Development Studies. Available at: https://opendocs.ids.ac.uk/opendocs/bitstream/handle/20.500.12413/16655/1014_PEA_climate_change_frameworks.pdf?sequence=1&isAllowed=y (Accessed 31.01.22).

Pringle, P. and T. Leiter, 2018: *Pitfalls and potential of measuring climate change adaptation through adaptation metrics*. In: Adaptation metrics: Perspectives on measuring, aggregating and comparing adaptation results [Christiansen, L. (eds.)]. UNEP DTU Partnership, Copenhagen, Denmark. ISBN 978-8793458277.

Psaltoglou, A. and E. Calle, 2018: Enhanced connectivity index - A new measure for identifying critical points in urban public transportation networks. *Int. J. Crit. Infrastruct. Prot.*, **21**, 22–32, doi:10.1016/j.ijcip.2018.02.003.

Purdon, M., 2014: *The Comparative Turn in Climate Change Adaptation and Food Security Governance Research*. CCAFS Working Paper no. 92. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Quader, M. A., S. Ahmed and R.A.R. Ghazillaa, 2016: Recent progress and future trends of CO2 breakthrough iron and steelmaking technologies for

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

CO2 mitigation. In: *Ironmaking and Steelmaking Processes: Greenhouse Emissions, Control, and Reduction* [Cavaliere, P.(ed.)]. Springer International Publishing, Cham, pp. 373–388. ISBN 978-3319395296.

Rabaey, K., T. Vandekerckhove, A.V. de Walle and D.L. Sedlak, 2020: The third route: Using extreme decentralization to create resilient urban water systems. *Water Res.*, **185**, 116276, doi:10.1016/j.watres.2020.116276.

Radcliffe, S.A., 2014: Gendered frontiers of land control: indigenous territory, women and contests over land in Ecuador. *Gend. Place Cult.*, **21**(7), 854–871, doi:10.1080/0966369X.2013.802675.

Ramalho, J., 2019: Worlding aspirations and resilient futures: Framings of risk and contemporary city-making in Metro Cebu, the Philippines. *Asia Pac Viewp*, **60**(1), 24–36, doi:10.1111/apv.12208.

Ramkissoon, H. and L. Smith, 2014: *The Relationship between Environmental Worldviews, Emotions and Personal Efficacy in Climate Change*. International Journal of Arts & Sciences, CD-ROM. ISSN: 1944-6934, 7(1):93–109.

Randers, J., et al., 2019: Achieving the 17 sustainable development goals within 9 planetary boundaries. *Glob. Sustain.*, **2**, e24.

Rao, N., 2019: From abandonment to autonomy: Gendered strategies for coping with climate change, Isiolo County, Kenya. *Geoforum*, **102**, 27–37, Doi: 10.1016/j.geoforum.2019.03.017.

Rao, N., et al., 2019a: A qualitative comparative analysis of women's agency and adaptive capacity in climate change hotspots in Asia and Africa. *Nat. Clim. Chang.*, **9**(12), 964–971, doi:10.1038/s41558-019-0638-y.

Rao, N.D., P. Sauer, M. Gidden and K. Riahi, 2019b: Income inequality projections for the shared socioeconomic pathways (SSPs). *Futures*, **105**, 27–39, doi:10.1016/j.futures.2018.07.001.

Rasul, G. and B. Sharma, 2016: The nexus approach to water–energy–food security: an option for adaptation to climate change. *Clim. Policy*, **16**(6), 682–702, doi:10.1080/14693062.2015.1029865.

Raworth, K., 2017: *Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist*. Chelsea Green Publishing, White River Junction, Vermont, 320. ISBN 978-1603586740.

Reckien, D., et al., 2018: Equity, environmental justice, and urban climate change. In: *Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network* [Rosenzweig, C., et al.(ed.)]. Cambridge University Press, Cambridge, pp. 173–224. ISBN 978-1316603338.

Reed, M.G., A. Scott, D. Natcher and M. Johnston, 2014: Linking gender, climate change, adaptive capacity, and forest-based communities in Canada. *Can. J. For. Res.*, **44**(9), 995–1004, doi:10.1139/cjfr-2014-0174.

Reid, R.S., M. E. Fernández-Giménez and K. A. Galvin, 2014: Dynamics and resilience of rangelands and pastoral peoples around the globe. *Annu. Rev. Environ. Resour.*, **39**(1), 217–242.

Remling, E., 2021: *Climate-related Security Risks in the 2020 Updated Nationally Determined Contributions*. SIPRI, January, 2021. , Accessed 2021-08-30. https://www.sipri.org/publications/2021/sipri-insights-peace-and-security/climate-related-security-risks-2020-updated-nationally-determined-contributions

Remling, E. and J. Veitayaki, 2016: Community-based action in Fiji's Gau Island: a model for the Pacific? *Int. J. Clim. Chang. Strateg. Manag.*, **8**(3), 375–398, doi:10.1108/IJCCSM-07-2015-0101.

Repo, P. and K. Matschoss, 2020: Social innovation for sustainability challenges. *Sustainability*, **12**(1), 319.

Riahi, K., et al., 2017: The shared socioeconomic pathways and their energy, land use, and greenhouse gas emissions implications: an overview. *Glob. Environ. Chang.*, **42**, 153–168, doi:10.1016/j.gloenvcha.2016.05.009.

Ribeiro, H.V., D. Rybski and J.P. Kropp, 2019: Effects of changing population or density on urban carbon dioxide emissions. *Nat Commun*, **10**(1), 3204, doi:10.1038/s41467-019-11184-y.

Ribot, J., 2011: Vulnerability before adaptation: toward Transformative climate action. *Glob. Environ. Chang.*, **21**, 1160–1162, doi:10.1016/j.gloenvcha.2011.07.008.

Richardson, K.J., et al., 2018: Food security outcomes under a changing climate: impacts of mitigation and adaptation on vulnerability to food insecurity. *Clim Change*, **147**(1), 327–341, doi:10.1007/s10584-018-2137-y.

Riechers, M., Á. Balázsi, M. García-Llorente and J. Loos, 2021: Human-nature connectedness as leverage point. *Ecosyst. People*, **17**(1), 215–221, doi:10.1080/26395916.2021.1912830.

Roberts, D., J. Douwes, C. Sutherland and V. Sim, 2020: Durban's 100 resilient cities journey: governing resilience from within. *environ urban*, **32**(2), 547–568, doi:10.1177/0956247820946555.

Robinson, S., et al., 2021: Climate compatible development in practice. *Dev. Pract.*, **0**(0), 1–11, doi:10.1080/09614524.2021.1907534.

Rochette, A., 2016: Climate change is a social justice issue: The need for a gender-based analysis of mitigation and adaptation policies in Canada and Quebec. *J. Environ. Law Pract.*, **29**, 383–410.

Rockström, J., et al., 2009a: A safe operating space for humanity. *Nature*, **461**(7263), 472–475, doi:10.1038/461472a.

Rockström, J., et al., 2009b: Planetary boundaries: exploring the safe operating space for humanity. *Ecol. Soc.*, **14**(2), doi:10.5751/ES-03180-140232.

Roelich, K. and J. Giesekam, 2019: Decision making under uncertainty in climate change mitigation: introducing multiple actor motivations, agency and influence. *Clim. Policy*, **19**(2), 175–188.

Rogelj, J., et al., 2010: Copenhagen accord pledges are paltry. *Nature*, **464**(7292), 1126–1128, doi:10.1038/4641126a.

Rogelj, J., D. Shindell, K. Jiang, S. Fifita, P. Forster, V. Ginzburg, C. Handa, H. Kheshgi, S. Kobayashi, E. Kriegler, L. Mundaca, R. Séférian, and M.V. Vilariño, 2018: Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor and T. Waterfield (eds.)]. In press. ISBN 9789291691517.

Rogers, P., J.J. Bohland and J. Lawrence, 2020: Resilience and values: Global perspectives on the values and worldviews underpinning the resilience concept. *Polit Geogr*, **83**, 102280, doi:10.1016/j.polgeo.2020.102280.

Roggema, R., T. Vermeend and A.V. Dobbelsteen, 2012: Incremental change, transition or transformation? Optimising change pathways for climate adaptation in spatial planning. *Sustainability*, **4**(10), doi:10.3390/su4102525.

Rohat, G., et al., 2019: Influence of changes in socioeconomic and climatic conditions on future heat-related health challenges in Europe. *Glob. Planet. Change.*, **172**, 45–59, doi:10.1016/j.gloplacha.2018.09.013.

Romero-Lankao, P., et al., 2018: Urban transformative potential in a changing climate. *Nature Clim Change*, **8**(9), 754–756, doi:10.1038/s41558-018-0264-0.

Romero Mosquera, M., 2019: Banning plastic straws: the beginning of the war against plastics. *Environ. Earth Law J. (eelj)*, **9**(1).

Rose, S.K., 2017: *Managing Climate Damages: Exploring Trade-offs*. Electric Power Research Institute, http://web.stanford.edu/group/emf-research/docs/sm/2019/wk2/Rose.pdf, (accessed 31.01.22).

Rose, S.K., et al., 2014: Bioenergy in energy transformation and climate management. *Clim Change*, **123**(3), 477–493, doi:10.1007/s10584-013-0965-3.

Rose, S.K. and M. Scott, 2018: *Grounding Decisions: A Scientific Foundation for Companies Considering Global Climate Scenarios and Greenhouse Gases*. Electric Power Research Institute, https://www.epri.com/research/products/000000003002014510, (accessed 31.01.22).

Rose, S.K. and M. Scott, 2020: *Review of 1.5°C and Other Newer Global Emissions Scenarios: Insights for Company and Financial Climate Low-Carbon Transition Risk Assessment and Greenhouse Gas Goal Setting*. Electric Power Research

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Institute, https://www.epri.com/research/products/000000003002018053, (accessed 31.01.22).
Rosenberg, M.N., 2021: What matters? The role of values in transformations toward sustainability: a case study of coffee production in Burundi. *Sustain Sci*, doi:10.1007/s11625-021-00974-3.
Rosenzweig, C. and W. Solecki, 2018: Action pathways for transforming cities. *Nature Clim Change*, **8**(9), 756–759, doi:10.1038/s41558-018-0267-x.
Rougoor, W. and C. van Marrewijk, 2015: Demography, growth, and global income inequality. *World Dev.*, **74**(C), 220–232.
Rowell, L. and A. Feldman, 2019: Knowledge democracy and action research. *Educ. Action Res.*, **27**(1), 1–6, doi:10.1080/09650792.2019.1557456.
Roy, J., P. Tschakert, H. Waisman, S. Abdul Halim, P. Antwi-Agyei, P. Dasgupta, B. Hayward, M. Kanninen, D. Liverman, C. Okereke, P.F. Pinho, K. Riahi, and A.G. Suarez Rodriguez, 2018: Sustainable Development, Poverty Eradication and Reducing Inequalities. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor and T. Waterfield (eds.)]. In press. ISBN 9789291691517.
Rudebusch, G., 2019: *Climate change and the Federal Reserve*. FRBS Economic Letter Available at: https://www.frbsf.org/economic-research/publications/economic-letter/2019/march/climate-change-and-federal-reserve/ (accessed 31.01.22).Ruggeri Laderchi, C., R. Saith and F. Stewart, 2003: Does it matter that we do not agree on the definition of poverty? A comparison of four approaches. *Oxf. Dev. Stud.*, **31**, 243–274, doi:10.1080/1360081032000111698.
Ruggiero, S., H. Busch, T. Hansen and A. Isakovic, 2021: Context and agency in urban community energy initiatives: an analysis of six case studies from the Baltic Sea region. *Energy Policy*, **148**, 111956, doi:10.1016/j.enpol.2020.111956.
Runhaar, H., 2018: Mainstreaming climate adaptation : taking stock about B what works ^ from empirical research worldwide. *Reg Environ Change*, **18**, 1201–1210.
Ryan, D. and E. Bustos, 2019: Knowledge gaps and climate adaptation policy: a comparative analysis of six Latin American countries. *Clim. Policy*, **19**(10), 1297–1309, doi:10.1080/14693062.2019.1661819.
Ryan, L., S. Moarif, E. Levina and R. Baron, 2011: *Energy efficiency policy and carbon pricing*. IEA Information Paper. Available at: https://www.iea.org/reports/energy-efficiency-policy-and-carbon-pricing (accessed 31.01.22).
Ryota, N., 2019: *A Possible Approach to Fiscal Rules in Small Islands — Incorporating Natural Disasters and Climate ChangeRyot*. IMF Working paper. WP/19/186.
Sachdeva, S., 2016: *Religious Identity, Beliefs, and Views about Climate Change*. Oxford University Press USA, 2016.
Sadoff, C.W., E. Borgomeo and S. Uhlenbrook, 2020: Rethinking water for SDG 6. *Nat. Sustain.*, **3**(5), 346–347, doi:10.1038/s41893-020-0530-9.
Sage, C., C. Kropp and I. Antoni-Komar, 2021: *Grassroots initiatives in food system transformation: the role of food movements in the second 'Great Transformation'*, 1–19. Routledge, ISBN 978-1003131304.
Saj, S., et al., 2017: The way forward: an agroecological perspective for climate-smart agriculture. *Agric. Ecosyst. Environ.*, **250**, 20–24, doi:10.1016/j.agee.2017.09.003.
Saja, A.M. A., A. Goonetilleke, M. Teo and A.M. Ziyath, 2019: A critical review of social resilience assessment frameworks in disaster management. *Int. J. Disaster Risk Reduct.*, **35**, 101096. 10.1016/j.ijdrr.2019.101096
Sakaguchi, K., A. Varughese and G. Auld, 2017: Climate wars? A systematic review of empirical analyses on the links between climate change and violent conflict. *Int. Stud. Rev.*, **19**(4), 622–645, doi:10.1093/isr/vix022.
Salamon, M.K., 2019: Leading the public into emergency mode. *Clim. Mobilization*.
Sánchez, A. and M. Izzo, 2017: Micro hydropower: an alternative for climate change mitigation, adaptation, and development of marginalized local communities in Hispaniola Island. *Clim. Change*, **140**(1), 79–87, doi:10.1007/s10584-016-1865-0.
Sanchez Rodriguez, R., D. Ürge-Vorsatz and A.S. Barau, 2018: Sustainable development goals and climate change adaptation in cities. *Nature Clim Change*, **8**(3), 181–183, doi:10.1038/s41558-018-0098-9.
Sanganyado, E., C. Teta and B. Masiri, 2018: Impact of African traditional worldviews on climate change adaptation. *Integr Environ Assess Manag*, **14**(2), 189–193, doi:10.1002/ieam.2010.
Sarker, S., et al., 2018: From science to action: Exploring the potentials of Blue Economy for enhancing economic sustainability in Bangladesh. *Ocean. Coast. Manag.*, **157**, 180–192, doi:10.1016/j.ocecoaman.2018.03.001.
Satyal, P., M.F. Byskov and K. Hyams, 2020: Addressing multi-dimensional injustice in indigenous adaptation: the case of Uganda's Batwa community. *Clim. Dev.*, **0**(0), 1–14, doi:10.1080/17565529.2020.1824888.
Savaget, P., M. Geissdoerfer, A. Kharrazi and S. Evans, 2019: The theoretical foundations of sociotechnical systems change for sustainability: A systematic literature review. *J Clean Prod*, **206**, 878–892, doi:10.1016/j.jclepro.2018.09.208.
Scarano, F.R., 2017: Ecosystem-based adaptation to climate change: concept, scalability and a role for conservation science. *Perspect. Ecol. Conserv.*, **15**(2), 65–73, doi:10.1016/j.pecon.2017.05.003.
Schaeffer, M., et al., 2015: Mid- and long-term climate projections for fragmented and delayed-action scenarios. *Technol Forecast Soc Change*, **90**, 257–268, doi:10.1016/j.techfore.2013.09.013.
Scheffran, J., 2020: Climate extremes and conflict dynamics. In: *Climate Extremes and Their Implications for Impact and Risk Assessment* [Sillmann, J., S. Sippel and S. Russo(eds.)]. Elsevier, Amsterdam, pp. 293–315. ISBN 978-0128148952 Chapter 16). https://doi.org/10.1016/C2017-0-01794-9.
Scherer, L., et al., 2018: Trade-offs between social and environmental sustainable development goals. *Environ. Sci. Policy*, **90**, 65–72, doi:10.1016/j.envsci.2018.10.002.
Schipper, E.L.F., 2020: Maladaptation: when adaptation to climate change goes very wrong. *One Earth*, **3**(4), 409–414, doi:10.1016/j.oneear.2020.09.014.
Schipper, E.L.F., et al., 2014: *Community-based adaptation to climate change : scaling it up*. Routledge, Oxfordshire, UK, ISBN 978-0203105061.
Schipper, E.L.F., et al., 2020a: Turbulent transformation: abrupt societal disruption and climate resilient development. *Clim. Dev.*, **0**(0), 1–8, doi:10.1080/17565529.2020.1799738.
Schipper, E.L.F., et al., 2020b: Turbulent transformation: abrupt societal disruption and climate resilient development. *Clim. Dev.* https://doi.org/10.1080/17565529.2020.1799738
Schipper, E.L.F., et al., 2020c: The debate: Is global development adapting to climate change? *World Dev. Perspect.*, **18**, 100205, doi:10.1016/j.wdp.2020.100205.
Schleussner, C.-F., et al., 2021: Pathways of climate resilience over the 21st century. *Environ. Res. Lett.*, **16**(5), 54058, doi:10.1088/1748-9326/abed79.
Schlosberg, D., L.B. Collins and S. Niemeyer, 2017: Adaptation policy and community discourse: risk, vulnerability, and just transformation. *Env Polit*, **26**(3), 413–437, doi:10.1080/09644016.2017.1287628.
Schmitz, H., 2017: Who drives climate-relevant policies in the rising powers? *New Polit. Econ.*, **22**(5), 521–540, doi:10.1080/13563467.2017.1257597.
Schoenmaker, D., 2019: *Greening monetary policy*. https://www.bruegel.org/2019/02/greening-monetary-policy/. Accessed 29 Apr 2019 . Schoenmaker, D. and W. Schramade, 2020: *Asset Pricing and Sustainability: A Teaching Note*. Social Science Research Network, Rochester, NY. Available at: https://papers.ssrn.com/abstract=3539080.
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3539080. Accessed 2020.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Schot, J. and W.E. Steinmueller, 2018: Three frames for innovation policy: R&D, systems of innovation and transformative change. *Res Policy*, **47**(9), 1554–1567.

Schwarz, M., C. Nakhle and C. Knoeri, 2020: Innovative designs of building energy codes for building decarbonization and their implementation challenges. *J Clean Prod*, **248**, 119260, doi:10.1016/j.jclepro.2019.119260.

Scobie, M., 2013: Climate regulation: implications for trade competitiveness in caribbean states. In: *Climate-Smart Technologies Integrating Renewable Energy and Energy Efficiency in Mitigation and Adaptation Responses*. Springer, Berlin Heidelberg, pp. 33–49.

Scobie, M., 2017: Fossil fuel reform in developing states: the case of Trinidad and Tobago, a petroleum producing small island developing state. *Energy Policy*, **104**, 265–273, doi:10.1016/j.enpol.2017.02.008.

Scobie, M., J. Skovgaard and H. Asselt, 2018: *Actors, frames and contexts in fossil fuel subsidy reform: the case of Trinidad and Tobago*, 283–302. Cambridge University Press, 2018, UK. ISBN 978-1108416795.

Scott, S. and C. Ku, 2018: The UN Security Council and global action on climate change. *Fac. Scholarsh.*, 1–24, doi:10.4337/9781785364648.00008.

Scoville-Simonds, M., H. Jamali and M. Hufty, 2020: The hazards of mainstreaming: climate change adaptation politics in three dimensions. *World Dev.*, **125**, 104683, doi:10.1016/j.worlddev.2019.104683.

Segger, M.-C., 2016: Advancing the Paris Agreement on climate change for sustainable development. *Camb. Int. Law J.*, **5**, 202–237, doi:10.4337/cilj.2016.02.03.

Sellers, S. and K.L. Ebi, 2018: Climate change and health under the shared socioeconomic pathway framework. *IJERPH*, **15**(1), doi:10.3390/ijerph15010003.

Sen, A., 2000: *Development as Freedom*. Anchor, New York, ISBN 978-0385720274. Reprint edition, 384 pp.

Sengers, F., A.J. Wieczorek and R. Raven, 2019: Experimenting for sustainability transitions: A systematic literature review. *Technol Forecast Soc Change*, **145**, 153–164, doi:10.1016/j.techfore.2016.08.031.

Serfilippi, E. and G. Ramnath, 2018: Resilience measurement and conceptual frameworks: a review of the literature. *Ann. Public Coop. Econ.*, **89**(4), 645–664.

Settele, J., R. Scholes, R. Betts, S. Bunn, P. Leadley, D. Nepstad, J.T. Overpeck, and M. A. Taboada, 2014:Terrestrial and inland water systems. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability.Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 271–359. ISBN 978-1107058071.

Setzer, J. and R. Byrnes, 2019: Global trends in climate change litigation: 2019 snapshot. Grantham Research Institute on Climate Change and the Environment and the Centre for Climate Change Economics and Policy, www.lse.ac.uk/GranthamInstitute, Accessed 2022-03-16.

Seyfang, G. and A. Smith, 2007: Grassroots innovations for sustainable development: Towards a new research and policy agenda. *Env Polit*, **16**(4), 584–603, doi:10.1080/09644010701419121.

Shaneyfelt, K.M., A.R. Anderson, P. Kumar and W.F. Hunt, 2017: Air quality considerations for stormwater green street design. *Environ. Pollut.*, **231**, 768–778, doi:10.1016/j.envpol.2017.08.081.

Sharifi, A., 2020: Trade-offs and conflicts between urban climate change mitigation and adaptation measures: A literature review. *J Clean Prod*, **276**, 122813, doi:10.1016/j.jclepro.2020.122813.

Sharpe, B., et al., 2016: Three horizons: a pathways practice for transformation. *Ecol. Soc.*, **21**(2), doi:10.5751/ES-08388-210247.

Shaw, J., 2016: Archaeology, climate change and environmental ethics: diachronic perspectives on human:non-human:environment worldviews, activism and care. *World. Archaeol.*, **48**(4), 449–465, doi:10.1080/00438243.2016.1326754.

Sheller, M., 2021: Reconstructing tourism in the Caribbean: connecting pandemic recovery, climate resilience and sustainable tourism through mobility justice. *J. Sustain. Tour.*, **29**(9), 1436–1449, doi:10.1080/09669582.2020.1791141.

Shi, J., V.H.M. Visschers and M. Siegrist, 2015: Public perception of climate change: the importance of knowledge and cultural worldviews. *Risk Analysis*, **35**(12), 2183–2201, doi:10.1111/risa.12406.

Shi, L., 2020a: Beyond flood risk reduction: How can green infrastructure advance both social justice and regional impact? *Socio-ecological Pract. Res.*, **2**(4), 311–320, doi:10.1007/s42532-020-00065-0.

Shi, L., 2020b: From progressive cities to resilient cities: lessons from history for new debates in equitable adaptation to climate change. *Urban Aff. Rev.*, doi:10.1177/1078087419910827. 1078087419910827.

Shi, L. and S. Moser, 2021: Transformative climate adaptation in the United States: trends and prospects. *Science*, **372**(6549), doi:10.1126/science.abc8054.

Shiller, R., 2012: *Finance and the Good Society*. Princeton University Press, Princeton, New Jersey.

Shim, Y.-H., 2015: A research methodological debate on emancipatory catastrophism: The case of transnational marriage. *Curr. Sociol.*, **63**(1), 105–109, doi:10.1177/0011392114559850.

Shindell, D., et al., 2017: A climate policy pathway for near- and long-term benefits. *Science*, **356**(6337), 493–494, doi:10.1126/science.aak9521.

Shiva, V., 2017: Swaraj. Hart, J. ed., 2017 In: *The Wiley Blackwell Companion to Religion and Ecology*. John Wiley & Sons, Ltd, UK, In, pp. 12–19. ISBN 978-1118465523.

Shukla, P. R., J. Skea, R. Slade, R. van Diemen, E. Haughey, J. Malley, M. Pathak, J. Portugal Pereira (eds.), 2019: Technical Summary, 2019. In: *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.

Sillitoe, P., 2016: *Indigenous studies and engaged anthropology: The collaborative moment*. Routledge, Oxfordshire, UK.

Silva Rodríguez de San Miguel, J.A., 2018: Gender and water management in Mexico. *Manag. Environ. Qual. Int. J.*, **29**(5), 842–858, doi:10.1108/MEQ-10-2017-0112.

Silver, J.J. and L.M. Campbell, 2018: Conservation, development and the blue frontier: the Republic of Seychelles' debt restructuring for marine conservation and climate adaptation program. *Int. Soc. Sci. J.*, **68**(229-230), 241–256, doi:10.1111/issj.12156.

Silvola, H. and T. Landau, 2021: *Sustainable Investing: Beating the Market with ESG*, 1st edn., Palgrave Macmillan, Cham, Switzerland, ISBN 978-3030714888. 266 pp.

Siméant-Germanos, J., 2019: Conceptualizing contexts or contextualizing concepts? On some issues of the modeling of relational spaces in the study of collective action. *Soc. Mov Stud.*, **0**(0), 1–16, doi:10.1080/14742837.2019.1629899.

Simonee, N. et al., 2021: Sila qanuippa? (how's the weather?): Integrating Inuit Qaujimajatuqangit and environmental forecasting products to support travel safety around Pond Inlet, Nunavut in a changing climate. *Weather, Climate, and Society*. doi:10.1175/WCAS-D-20-0174.1.

Simonet, C. and G. Jobbins, 2016: *Understanding patterns of climate resilient development – the case of Senegal*. Overseas Development Institute, London. Available at: http://prise.odi.org/wp-content/uploads/2016/04/Understanding-patterns-of-climate-resilient-development-%E2%80%93-the-case-of-Senegal_Low-Res.pdf.

Singh, C., 2019: Migration as a driver of changing household structures: implications for local livelihoods and adaptation. *Migr. Dev.*, **8**(3), 301–319, doi:10.1080/21632324.2019.1589073.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Singh, C. et al., 2018: The utility of weather and climate information for adaptation decision-making: current uses and future prospects in Africa and India. *Clim. Dev.*, **10**(5), 389–405, doi:10.1080/17565529.2017.1318744.

Singh, C., et al., 2021a: Interrogating 'effectiveness' in climate change adaptation: 11 guiding principles for adaptation research and practice. *Clim. Dev.*, 1–15, doi:10.1080/17565529.2021.1964937.

Singh, C., D. Solomon and N. Rao, 2021b: How does climate change adaptation policy in India consider gender? An analysis of 28 state action plans. *Clim. Policy*, **21**(7), 958–975, doi:10.1080/14693062.2021.1953434.

Sitas, N., et al., 2019: Exploring the usefulness of scenario archetypes in science-policy processes: experience across IPBES assessments. *Ecol. Soc.*, **24**(3), doi:10.5751/ES-11039-240335.

Sitas, N., O. Selomane, M. Hamann and S.P.S. Gajjar, 2021: Towards equitable urban resilience in the global south within a context of planning and management. In: *Urban Ecology in the Global South* [Shackleton, C.M., S.S. Cilliers, E. Davoren and M.J. du Toit(eds.)]. Springer International Publishing, Cham, pp. 325–345. ISBN 978-3030676506.

Slaven, M. and J. Heydon, 2020: Crisis, deliberation, and extinction rebellion. *Crit. Stud. Secur.*, **8**(1), 59–62.

Slee, B., 2015: Is there a case for community-based equity participation in Scottish on-shore wind energy production? Gaps in evidence and research needs. *Renew. Sustain. Energy Rev.*, **41**, 540–549.

Sloat, L.L., et al., 2020: Climate adaptation by crop migration. *Nat Commun*, **11**(1), 1243, doi:10.1038/s41467-020-15076-4.

Smit, B., et al., 2001: Adaptation to climate change in the context of sustainable development and equity. In: *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White(eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 877–912. ISBN 978-0521807685.

Smith, A. and A. Stirling, 2018: Innovation, sustainability and democracy: an analysis of grassroots contributions. *J. Self-gov. Manag. Econ.*, **6**(1), 64, doi:10.22381/JSME6120183.

Smith, L.T., 2013: *Decolonizing methodologies: Research and indigenous peoples*. Zed Books Ltd.London.

Smith, P., et al., 2013: How much land-based greenhouse gas mitigation can be achieved without compromising food security and environmental goals? *Glob Change Biol*, **19**(8), 2285–2302, doi:10.1111/gcb.12160.

Smith, R. and K. McNamara, 2015: Future migrations from Tuvalu and Kiribati: exploring government, civil society and donor perceptions. *Clim. Dev.*, **7**, doi :10.1080/17565529.2014.900603.

Smucker, T.A., et al., 2015: Differentiated livelihoods, local institutions, and the adaptation imperative: Assessing climate change adaptation policy in Tanzania. *Geoforum*, **59**, 39–50.

Söderholm, P. and J.E. Tilton, 2012: Material efficiency: An economic perspective. *Resour. Conserv. Recycl.*, **61**, 75–82, doi:10.1016/j.resconrec.2012.01.003.

Soga, M. and K.J. Gaston, 2016: Extinction of experience: the loss of human–nature interactions. *Front. Ecol. Environ.*, **14**(2), 94–101, doi:10.1002/fee.1225.

Solecki, W., M. Pelling and M. Garschagen, 2017: Transitions between risk management regimes in cities. *Ecol. Soc.*, **22**, 38, doi:10.5751/ES-09102-220238.

Solecki, W., et al., 2018: City transformations in a 1.5°C warmer world. *Nature Clim Change*, **8**(3), 177–181, doi:10.1038/s41558-018-0101-5.

Soma, K., et al., 2018: Social innovation – A future pathway for Blue growth? *Mar. Policy.*, **87**, 363–370, doi:10.1016/j.marpol.2017.10.008.

Song, L., et al., 2020a: Contested energy futures, conflicted rewards? Examining low-carbon transition risks and governance dynamics in China's built environment. *Energy Res. Soc. Sci.*, **59**, 101306, doi:10.1016/j.erss.2019.101306.

Song, S., Z. Liu, C. He and W. Lu, 2020b: Evaluating the effects of urban expansion on natural habitat quality by coupling localized shared socioeconomic pathways and the land use scenario dynamics-urban model. *Ecol Indic*, **112**, 106071, doi:10.1016/j.ecolind.2020.106071.

Sørensen, E. and J. Torfing, 2019: Designing institutional platforms and arenas for interactive political leadership. *Public Manag. Rev.*, **21**(10), 1443–1463, doi:10.1080/14719037.2018.1559342.

Sovacool, B.K., 2018: Bamboo beating bandits: conflict, inequality, and vulnerability in the political ecology of climate change adaptation in Bangladesh. *World Dev.*, **102**, 183–194, doi:10.1016/j.worlddev.2017.10.014.

Sovacool, B.K., et al., 2015: The political economy of climate adaptation. *Nature Clim Change*, **5**(7), 616–618.

Sovacool, B.K., M. Tan-Mullins, D. Ockwell and P. Newell, 2017: Political economy, poverty, and polycentrism in the global environment facility's least developed countries fund (LDCF) for climate change adaptation. *Third World Q*, **38**(6), 1249–1271, doi:10.1080/01436597.2017.1282816.

Srivastava, A., Sharma, R.K. and Suresh, A., 2020. Impact of Covid-19 on sustainable development goals. *Int. J. Adv. Sci. Technol*, *29*, pp.253-258. Stafford-Smith, M., et al., 2017: Integration: the key to implementing the sustainable development goals. *Sustain Sci*, **12**(6), 911–919, doi:10.1007/s11625-016-0383-3.

Stańczuk-Gałwiaczek, M., K. Sobolewska-Mikulska, H. Ritzema and J.M. van Loon-Steensma, 2018: Integration of water management and land consolidation in rural areas to adapt to climate change: Experiences from Poland and the Netherlands. *Land Use Policy*, **77**, 498–511, doi:10.1016/j.landusepol.2018.06.005.

Starbird, E., M. Norton and R. Marcus, 2016: Investing in family planning: key to achieving the sustainable development goals. *Glob Health Sci Pract*, **4**(2), 191–210, doi:10.9745/GHSP-D-15-00374.

Steelman, T.A., et al., 2019: Identifying transformational space for transdisciplinarity: using art to access the hidden third. *Sustain Sci*, **14**(3), 771–790, doi:10.1007/s11625-018-0644-4.

Steffen, B., 2018: The importance of project finance for renewable energy projects. *Energy Econ.*, **69**, 280–294, doi:10.1016/j.eneco.2017.11.006.

Stein, S. and M. Kalina, 2019: Becoming an agricultural growth corridor. *Environ. Soc.*, **10**(1), 83–100.

Sterk, M., I. A. van de Leemput and E.T. Peeters, 2017: How to conceptualize and operationalize resilience in socio-ecological systems? *Curr. Opin. Environ. Sustain.*, **28**, 108–113, doi:10.1016/j.cosust.2017.09.003.

Stern, N., 2007: *The Economics of Climate Change: The Stern Review*. Cambridge University Press, Cambridge, ISBN 978-0511817434.

Stevenson, K.T., et al., 2014: Overcoming skepticism with education: interacting influences of worldview and climate change knowledge on perceived climate change risk among adolescents. *Clim Change*, **126**(3), 293–304, doi:10.1007/s10584-014-1228-7.

Stiglitz, J.E., Sen, A. and Fitoussi, J.P., 2009. Report by the commission on the measurement of economic performance and social progress.Stjepanović, S., D. Tomic and M. Skare, 2017: A new approach to measuring green GDP: a cross-country analysis. *Entrepreneurship Sustain. Issues*, **4**, 574–590, doi:10.9770/jesi.2017.4.4(13).

Stjepanović, S., D. Tomic and M. Skare, 2019: Green GDP: an analysis for developing and developed countries. *E+m Ekon. A Manag.*, **22**, 4–17, doi:10.15240/tul/001/2019-4-001.

Stoddard, I., et al., 2021: Three decades of climate mitigation: why haven't we bent the global emissions curve? *Annu. Rev. Environ. Resour.*, doi:10.1146/annurev-environ-012220-011104.

Strazds, L., 2019: Radical hope: Transforming sustainability. *J. Sustain. Educ. Journal of Sustainability Education,* **21**, 1–18.

Stuart, D., R. Gunderson and B. Petersen, 2020: The climate crisis as a catalyst for emancipatory transformation: An examination of the possible. *Int. Sociol.*, **35**(4), 433–456.

Sugden, F., et al., 2014: Agrarian stress and climate change in the eastern Gangetic plains: gendered vulnerability in a stratified social formation. *Glob. Environ. Chang.*, **29**, 258–269, doi:10.1016/j.gloenvcha.2014.10.008.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Sultana, F., 2010: Living in hazardous waterscapes: Gendered vulnerabilities and experiences of floods and disasters. *Environ. Hazards*, **9**(1), 43–53, doi:10.3763/ehaz.2010.SI02.

Sultana, F., 2021: Climate change, COVID-19, and the co-production of injustices: a feminist reading of overlapping crises. *Soc. Cult. Geogr.*, **22**(4), 447–460, doi:10.1080/14649365.2021.1910994.

Sultana, P., et al., 2019: Transforming local natural resource conflicts to cooperation in a changing climate: Bangladesh and Nepal lessons. *Clim. Policy*, **19**(sup1), 94–106, doi:10.1080/14693062.2018.1527678.

Solomon, S., C. Singh and F. Islam, 2021: Examining the outcomes of urban adaptation interventions on gender equality using SDG 5. *Clim. Dev.*, **0**(0), 1–12, doi:10.1080/17565529.2021.1939643.

Susskind, L., et al., 2020: Breaking out of carbon lock-in: Malaysia's path to decarbonization. *Front. Built Environ.*, **6**, 21, doi:10.3389/fbuil.2020.00021.

Swaffield, J., 2017: Freebies, freedom and fundamental change: resistance to neoliberal environmentalism in large "green" corporations. *Local Environ*, **22**(5), 553–567, doi:10.1080/13549839.2016.1233952.

Swatuk, L.A., et al., 2021: The 'boomerang effect': insights for improved climate action. *Clim. Dev.*, **13**(1), 61–67, doi:10.1080/17565529.2020.1723470.

Swyngedouw, E., 2018: *Promises of the Political: Insurgent Cities in a Post-Political Environment*. The MIT Press, Cambridge, Massachusetts, ISBN 978-0262535656. 232 pp.

Swyngedouw, E., 2019: The perverse lure of autocratic postdemocracy. *South Atl. Q.*, **118**(2), 267–286, doi:10.1215/00382876-7381134.

Tan, R.R. and D.C.Y. Foo, 2018: Integrated multi-scale water management as a climate change adaptation strategy. *Clean Technol. Environ. Policy*, **20**(6), 1123–1125, doi:10.1007/s10098-018-1551-1.

Tanaka, K., 2011: Review of policies and measures for energy efficiency in industry sector. *Energy Policy*, **39**(10), 6532–6550, doi:10.1016/j.enpol.2011.07.058.

Tanner, T. and J. Allouche, 2011: Towards a new political economy of climate change and development. *IDS Bull.*, **42**(3), 1–14, doi:10.1111/j.1759-5436.2011.00217.x.

Tanner, T., et al., 2019: Influencing resilience: the role of policy entrepreneurs in mainstreaming climate adaptation. *Disasters*, **43**(S3), 388–S411, doi:10.1111/disa.12338.

Tari, D. and J. Pattison, 2014: *Evolving Customary Institutions in the Drylands An Opportunity for Devolved Natural Resource Governance in Kenya*? Issue Paper. IIED, London ISBN 978-1784310424.

Tauginienė, L., et al., 2020: Citizen science in the social sciences and humanities: the power of interdisciplinarity. *Palgrave Commun*, **6**(1), 1–11, doi:10.1057/s41599-020-0471-y.

Taylor, M., 2008: Beyond technology-push and demand-pull: Lessons from California's solar policy. *Energy Econ.*, **30**(6), 2829–2854, doi:10.1016/j.eneco.2008.06.004.

Temmer, J., 2017a: *Building a Climate-Resilient City: Agriculture and food security*. IISD, http://prairieclimatecentre.ca/wp-content/uploads/2017/04/pcc-brief-climate-resilient-city-agriculture-food.pdf. Accessed April 23, 2017

Temmer, J., 2017b: *Building a Climate-Resilient City: Disaster preparedness and emergency management*. IISD, http://prairieclimatecentre.ca/wp-content/uploads/2017/04/pcc-brief-disaster-mangement-emergency-preparedness.pdf.

Tengö, M., et al., 2017: Weaving knowledge systems in IPBES, CBD and beyond—lessons learned for sustainability. *Curr. Opin. Environ. Sustain.*, **26-27**, 17–25, doi:10.1016/j.cosust.2016.12.005.

Terry, G., 2009: No climate justice without gender justice: an overview of the issues. *Gend. Dev.*, **17**(1), 5–18, doi:10.1080/13552070802696839.

Terton, A., 2017: *Building a Climate-Resilient City: Urban ecosystems*. IISD, http://prairieclimatecentre.ca/wp-content/uploads/2017/04/pcc-brief-climate-resilient-city-urban-ecosystems.pdf. Accessed 13th May 2019.

Thackeray, S.J., et al., 2020: Civil disobedience movements such as school strike for the climate are raising public awareness of the climate change emergency. *Glob Change Biol*, **26**(3), 1042–1044.

The People's Republic of China, 2017: *Vision for Maritime Cooperation under the Belt and Road Initiative*.

Thew, H., L. Middlemiss and J. Paavola, 2020: "Youth is not a political position": Exploring justice claims-making in the UN Climate change negotiations. *Glob. Environ. Chang.*, **61**, 102036.

Thomas, B.K., 2008: Methodological debate in poverty studies: towards 'participatory qual–quant'? *Dev. Pract.*, **18**(2), 280–288, doi:10.1080/09614520801899218.

Thompson-Hall, M., E.R. Carr and U. Pascual, 2016: Enhancing and expanding intersectional research for climate change adaptation in agrarian settings. *Ambio*, **45**(3), 373–382, doi:10.1007/s13280-016-0827-0.

Tilleard, S. and J. Ford, 2016: Adaptation readiness and adaptive capacity of transboundary river basins. *Clim Change*, **137**(3-4), 575–591.

Tobias, J.K. and R.C.A., 2014: "that land means everything to us as Anishinaabe….": environmental dispossession and resilience on the north shore of Lake Superior. *Health Place*, **29**, 26–33, doi:10.1016/j.healthplace.2014.05.008.

Tolliver, C., A.R. Keeley and S. Managi, 2019: Green bonds for the Paris Agreement and sustainable development goals. *Environ. Res. Lett.*, **14**(6), 64009, doi:10.1088/1748-9326/ab1118.

Törnberg, A., 2018: Combining transition studies and social movement theory: towards a new research agenda. *Theor Soc*, **47**(3), 381–408, doi:10.1007/s11186-018-9318-6.

Tramel, S., 2018: Convergence as political strategy: social justice movements, natural resources and climate change. *Third World Q*, **39**(7), 1290–1307, doi :10.1080/01436597.2018.1460196.

Tramutola, M.J., 2019: *Adpatación al Cambio Climático ¿Con Perspectiva de Género?* LatinoAdapta, http://www.cambioclimaticoydecisiones.org/wp-content/uploads/2019/08/PolicyBrief-Genero_5_09_2019.pdf.

Trewin, D. and J. Hall, 2004: Measures of Australia's progress: key economic, social and environment indicators. *Oecd Obs.*, **246-247**, 35–37.

Tschakert, P., et al., 2016: Tchange: the role of values and visioning in transformation science. *Curr. Opin. Environ. Sustain.*, **20**, 21–25, doi:10.1016/j.cosust.2016.04.003.

Tufa, F., A. Amsalu and E.B. Zoomers, 2018: Failed promises: governance regimes and conflict transformation related to Jatropha cultivation in Ethiopia. *Ecol. Soc.*, **23**(4), doi:10.5751/ES-10486-230426.

Turnhout, E., et al., 2021: Enabling transformative economic change in the post-2020 biodiversity agenda. *CONSERVATION LETTERS*, **14**(4), e12805, doi:10.1111/conl.12805.

TWI, 2019: *TWI2050 Report: The Digital Revolution and Sustainable Development: Opportunities and Challenges*. https://iiasa.ac.at/web/home/research/twi/Report2019.html.

Ullah, I., H. Fang and K. Jebran, 2019: Do gender diversity and CEO gender enhance firm's value? Evidence from an emerging economy. *Corporate Governance*, **20**(1), 44–66, doi:10.1108/CG-03-2019-0085.

UNDRR, 2015: *Sendai Framework for Disaster Risk Reduction*. United Nations International Strategy for Disaster Reduction, Geneva, Switzerland, 2015–2030.

Undrr, 2019: *Global Assessment Report on Disaster Risk Reduction*. Geneva, Switzerland. United Nations Office for Disaster Risk Reduction.

UNEP, 2014: *Adaptation Gap Report 2014*.

UNEP, 2018a: *Adaptation Gap Report 2018*.

UNEP, 2018b: *Single-Use Plastics: A Roadmap for Sustainability*. https://www.unenvironment.org/resources/report/single-use-plastics-roadmap-sustainability.

UNEP, 2021: *Adaptation Gap Report 2020*.

UNESCO, 2019: *Resilience in a Time of Uncertainty: Indigenous peoples and climate change*. https://en.unesco.org/events/resilience-time-uncertainty-indigenous-peoples-and-climate-change.

UNESCO, 2018: *What is Local and Indigenous Knowledge*. United Nations Educational, Scientific and Cultural Organization.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

UNFCCC, 1992: *United Nations Framework Convention on Climate Change*. https://unfccc.int/resource/docs/convkp/conveng.pdf.
UNFCCC, 2010: *Cancún Climate Change Conference*.
UNFCCC, 2011: *Launching the Green Climate Fund*. https://unfccc.int/resource/docs/2011/cop17/eng/09a01.pdf#page=55.
UNFCCC, 2015: *Paris Agreement*. United Nations. United Nations Framework Convention on Climate Change.
UNFCCC, 2017: *The China Clean Development Mechanism Fund (CCDMF)*.
United Nations, 1994: *United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa*. United Nations, New York, NY.
United Nations, 2007: *United Nations Declaration on the Rights of Indigenous Peoples*. New York, https://www.un.org/development/desa/indigenouspeoples/wp-content/uploads/sites/19/2018/11/UNDRIP_E_web.pdf.
United Nations, 2015: *Transforming our world: the 2030 Agenda for Sustainable Development*. https://sustainabledevelopment.un.org/post2015/transformingourworld.
United Nations, 2020: *Human Development Report 2020. The Next Frontier: Human Development and the Anthropocene*. United Nations Development Programme.
United Nations, 2021: *The Sustainable Development Goals Report*. Department of Economic and Social Affairs, United Nations, New York, N.Y.
United Nations, 2021: *Adaptation Gap Report 2020*. https://www.unep.org/adaptation-gap-report-2020 . (United Nations Environment Programme, Programme, U. N. E., Nairobi, Kenya, 99 pp.).
Ura, K. and K. Galay, 2004: *Gross National Happiness and Development*.
USAID, 2014: *Climate resilient development a framework for understanding and addressing climate change*. https://pdf.usaid.gov/pdf_docs/PBAAA245.pdf.
USAID, 2018: *Climate Risk Profile: Kenya*.
USEPA, 2019: *Global Greenhouse Gas Emissions Data*.
Wuebbles, D.J., et al. (ed.), 2017: *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. Washington, DC, USA. U.S. Global Change Research Program, 470 pp.
Vaghefi, N., C. Siwar and S. Aziz, 2015: Green GDP and Sustainable Development in Malaysia. *Curr. World Environ.*, **10**(1), 1–8.
Valta, J., 2020: Innovation ecosystem perspective accelerating sustainable business models. In: *Affordable and Clean Energy* [Leal Filho, W., A.M. Azul, L. Brandli, P.G. Özuyar and T. Wall(eds.)]. Springer International Publishing, Cham, pp. 1–11. ISBN 978-3319710570.
van Baalen, S. and M. Mobjörk, 2018: Climate change and violent conflict in east Africa: integrating qualitative and quantitative research to probe the mechanisms. *Int. Stud. Rev.*, **20**(4), 547–575, doi:10.1093/isr/vix043.
Van den Bergh, J.C., 2007: *Abolishing GDP*.
van Dooren, C., et al., 2018: Unsustainable dietary habits of specific subgroups require dedicated transition strategies: Evidence from the Netherlands. *Food Policy*, **79**, 44–57, doi:10.1016/j.foodpol.2018.05.002.
van Egmond, N.D. and H.J.M. de Vries, 2011: Sustainability: The search for the integral worldview. *Futures*, **43**(8), 853–867, doi:10.1016/j.futures.2011.05.027.
Van Opstal, M. and J. Hugé, 2013: Knowledge for sustainable development: a worldviews perspective. *Environ Dev Sustain*, **15**(3), 687–709, doi:10.1007/s10668-012-9401-5.
van Puijenbroek, P.J.T.M., A. F. Bouwman, A.H.W. Beusen and P.L. Lucas, 2014: Global implementation of two shared socioeconomic pathways for future sanitation and wastewater flows. *Water Sci. Technol.*, **71**(2), 227–233, doi:10.2166/wst.2014.498.
van Ruijven, B.J., et al., 2014: Enhancing the relevance of shared socioeconomic pathways for climate change impacts, adaptation and vulnerability research. *Clim Change*, **122**(3), 481–494, doi:10.1007/s10584-013-0931-0.
Van Vuuren, D.P., et al., 2019: Integrated scenarios to support analysis of the food–energy–water nexus. *Nat. Sustain.*, **2**(12), 1132–1141, doi:10.1038/s41893-019-0418-8.
Vander Stichele, M., 2020: *The Financialised Firm*.
Veland, S., I. Gram-Hanssen, D. Maggs and A.H. Lynch, 2021: Can the sustainable development goals harness the means and the manner of transformation? *Sustain Sci*, doi:10.1007/s11625-021-01032-8.
Venema, H. and J. Temmer, 2017a: *Building a Climate-Resilient City: Electricity and information and communication technology infrastructure*. IISD, http://prairieclimatecentre.ca/wp-content/uploads/2017/04/pcc-brief-climate-resilient-city-electricity-ict.pdf.
Venema, H. and J. Temmer, 2017b: *Building a Climate-Resilient City: Water supply and sanitation systems*. e International Institute for Sustainable Development and the University of Winnipeg, , http://prairieclimatecentre.ca/wp-content/uploads/2017/04/pcc-brief-climate-resilient-city-water-supply-sanitation.pdf, Accessed 2022-03-16.
Verkerk, P.J., et al., 2020: Climate-smart forestry: the missing link. *For. Policy Econ.*, **115**, 102164, doi:10.1016/j.forpol.2020.102164.
Vermeulen, S.J., et al., 2018: Transformation in practice: a review of empirical cases of transformational adaptation in agriculture under climate change. *Front. Sustain. Food Syst.*, **2**, doi:10.3389/fsufs.2018.00065.
Vihemäki, H., A. Toppinen and R. Toivonen, 2020: Intermediaries to accelerate the diffusion of wooden multi-storey construction in Finland. *Environ. Innov. Soc. Transit.*, **36**, 433–448, doi:10.1016/j.eist.2020.04.002.
Villamayor-Tomas, S. and G. García-López, 2018: Social movements as key actors in governing the commons: Evidence from community-based resource management cases across the world. *Glob. Environ. Chang.*, **53**, 114–126, doi:10.1016/j.gloenvcha.2018.09.005.
Vincent, K. and W. Colenbrander, 2018: Developing and applying a five step process for mainstreaming climate change into local development plans: A case study from Zambia. *Clim. Risk Manag.*, **21**, 26–38, doi:10.1016/j.crm.2018.04.005.
Vinyeta, K., K. Whyte and K. Lynn, 2016: *Climate Change Through an Intersectional Lens: Gendered Vulnerability and Resilience in Indigenous Communities in the United States*. Social Science Research Network, Rochester, NY. Available at: https://papers.ssrn.com/abstract=2770089.
Visseren-Hamakers, I.J., et al., 2021: Transformative governance of biodiversity: insights for sustainable development. *Curr. Opin. Environ. Sustain.*, **53**, 20–28, doi:10.1016/j.cosust.2021.06.002.
Visvizi, A., M.D. Lytras, E. Damiani and H. Mathkour, 2018: Policy making for smart cities: innovation and social inclusive economic growth for sustainability. *J. Sci. Technol. Policy Manag.*, **9**(2), 126–133, doi:10.1108/JSTPM-07-2018-079.
Vogel, C. and K. O'Brien, 2021: Getting to the heart of transformation. *Sustain Sci*, doi:10.1007/s11625-021-01016-8.
Vogl, V., M. Åhman and L.J. Nilsson, 2018: Assessment of hydrogen direct reduction for fossil-free steelmaking. *J Clean Prod*, **203**, 736–745, doi:10.1016/j.jclepro.2018.08.279.
von Stechow, C., et al., 2016: 2°C and SDGs: united they stand, divided they fall? *Environ. Res. Lett.*, **11**(3), e34022.
von Uexkull, N. and H. Buhaug, 2021: Security implications of climate change: a decade of scientific progress. *J. Peace Res.*, **58**(1), 3–17, doi:10.1177/0022343320984210.
Wada, Y., et al., 2016: Modeling global water use for the 21st century: the Water Futures and Solutions (WFaS) initiative and its approaches. *Geosci. Model Dev.*, **9**(1), 175–222, doi:10.5194/gmd-9-175-2016.
Waddock, S., 2019: Shaping the shift: shamanic leadership, memes, and transformation. *J. Bus. Ethics.*, **155**(4), 931–939, doi:10.1007/s10551-018-3900-8.
Walch, C., 2019: Adaptive governance in the developing world: disaster risk reduction in the state of Odisha, India. *Clim. Dev.*, **11**(3), 238–252, doi:10.1080/17565529.2018.1442794.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Waldherr, A., 2012: The mass media as actors in innovation systems. In: *Innovation Policy and Governance in High-Tech Industries* [Bauer, J., A. Lang and V. Schneider(eds.)]. Springer, Berlin Heidelberg, pp. 77–100. ISBN 978-3642125621 978-3-642-12563-8).

Walsh, C., 2018: 9. Development as Buen Vivir: institutional arrangements and (de)colonial entanglements. In: B. Reiter (ed.), *Constructing the Pluriverse: The Geopolitics of Knowledge*. Duke University Press, pp. 184–194. ISBN 978-1478002017.

Walsh, J.H. and J. Dillard-Wright, 2020: The case for "structural missingness:" A critical discourse of missed care. *Nurs Philos*, **21**(1), e12279, doi:10.1111/nup.12279.

Walshe, R. and A.G. Argumedo, 2016: Ayni, Ayllu, Yanantin and Chanincha: the cultural values enabling adaptation to climate change in communities of the Potato Park, in the Peruvian Andes. *Gaia - Ecol. Perspect. Sci. Soc.*, **25**(3), 166–173, doi:10.14512/gaia.25.3.7.

Walton, A. A., 2018: Fossil Fuel Divestment: The Power of Positively Deviant Leadership for Catalyzing Climate Action and Financing Clean Energy. In: Evolving Leadership for Collective Wellbeing (Building Leadership Bridges). Emerald Publishing Limited, Bingley, pp. 101–120.

Walton, A. A., 2018: Positive deviance and behavior change: A research methods approach for understanding fossil fuel divestment. *Energy Research & Social Science*, **45**, 235–249, doi:https://doi.org/10.1016/j.erss.2018.07.003.

Wamsler, C., 2019: Contemplative sustainable futures: the role of individual inner dimensions and transformation in sustainability research and education. In: *Sustainability and the Humanities* [Leal Filho, W. and A. Consorte McCrea(eds.)]. Springer International Publishing, Cham, pp. 359–373. ISBN 978-3319953366.

Wamsler, C. and E. Brink, 2018: Mindsets for sustainability: exploring the link between mindfulness and sustainable climate adaptation. *Ecol. Econ.*, **151**, 55–61, doi:10.1016/j.ecolecon.2018.04.029.

Wang, F., R. Wang and J. Wang, 2020: Measurement of China's green GDP and its dynamic variation based on industrial perspective. *Environ. Sci. Pollut. Res.* **27**, 43813–43828.

Wang, Y., et al., 2019: Tens of thousands additional deaths annually in cities of China between 1.5°C and 2.0°C warming. *Nat Commun*, **10**(1), 3376, doi:10.1038/s41467-019-11283-w.

Washington-Ottombre, C. and B.C. Pijanowski, 2013: Rural organizations and adaptation to climate change and variability in rural Kenya. *Reg Environ Change*, **13**(3), 537–550.

Washington, H. and P. Twomey (eds.), 2016: *A Future Beyond Growth: Towards a Steady State Economy*, 1st edn., Routledge, Oxfordshire, 282 pp.

Watson, E.E., H.H. Kochore and B.H. Dabasso, 2016: Camels and climate resilience: adaptation in northern Kenya. *Hum Ecol*, **44**(6), 701–713.

Watts, N., et al., 2019: The 2019 report of The Lancet Countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate. *Lancet*, **394**, doi:10.1016/S0140-6736(19)32596-6.

Webb, R., et al., 2018: Sustainable urban systems: Co-design and framing for transformation. *Ambio*, **47**(1), 57–77, doi:10.1007/s13280-017-0934-6.

Webber, S., 2016: Climate change adaptation as a growing development priority: towards critical adaptation scholarship. *Geogr. Compass*, **10**(10), 401–413, doi:10.1111/gec3.12278.

Webber, S. and S.D. Donner, 2017: Climate service warnings: cautions about commercializing climate science for adaptation in the developing world. *Wires Clim. Chang.*, **8**(1), e424, doi:10.1002/wcc.424.

Weir, T., 2018: Renewable energy in the Pacific Islands: Its role and status. *Renew. Sustain. Energy Rev.*, **94**, 762–771, doi:10.1016/j.rser.2018.05.069.

Weir, T. and M. Kumar, 2020: Renewable energy can enhance resilience of small islands. *Nat Hazards*, **104**(3), 2719–2725, doi:10.1007/s11069-020-04266-4.

Welch, D. and L. Yates, 2018: The practices of collective action: Practice theory, sustainability transitions and social change. *J Theory Soc Behav*, **48**(3), 288–305, doi:10.1111/jtsb.12168.

Wells, P., W. Abouarghoub, S. Pettit and A. Beresford, 2020: A socio-technical transitions perspective for assessing future sustainability following the COVID-19 pandemic. *Sustain. Sci. Pract. Policy*, **16**(1), 29–36, doi:10.1080/15487733.2020.1763002.

Werners, S.E., et al., 2018: *Towards Climate Resilient Development Pathways for the People in the Hindu Kush Himalayan Region*. HI-AWARE, Kathmandu.

Werners, S.E., et al., 2021: Adaptation pathways: A review of approaches and a learning framework. *Environ. Sci. Policy*, **116**, 266–275, doi:10.1016/j.envsci.2020.11.003.

Westholm, L. and S. Arora-Jonsson, 2015: Defining solutions, finding problems: deforestation, gender, and REDD+ in Burkina Faso. *Conserv. Soc.*, **13**(2), 189–199.

Westholm, L. and S. Arora-Jonsson, 2018: What room for politics and change in global climate governance? Addressing gender in co-benefits and safeguards. *Env Polit*, **27**(5), 917–938, doi:10.1080/09644016.2018.1479115.

Westley, F., et al., 2011: Tipping toward sustainability: emerging pathways of transformation. *Ambio*, **40**(7), 762, doi:10.1007/s13280-011-0186-9.

Westwell, E. and J. Bunting, 2020: The regenerative culture of extinction rebellion: self-care, people care, planet care. *Env Polit*, **29**(3), 546–551.

Weyant, J. and E. Kriegler, 2014: Preface and introduction to EMF 27. *Clim Change*, **123**(3), 345–352, doi:10.1007/s10584-014-1102-7.

White, D., 2020: Just transitions/design for transitions: preliminary notes on a design politics for a green new deal. *Capitalism Nat. Social.*, **31**(2), 20–39, doi:10.1080/10455752.2019.1583762.

WHO, 2016: *Climate And Health Country Profile – 2015: Kenya*. World Health Organisation, Geneva, Switzerland.

Wiebe, K., et al., 2015: Climate change impacts on agriculture in 2050 under a range of plausible socioeconomic and emissions scenarios. *Environ. Res. Lett.*, **10**(8), 85010, doi:10.1088/1748-9326/10/8/085010.

Wieczorek, A.J., 2018: Sustainability transitions in developing countries: Major insights and their implications for research and policy. *Environ. Sci. Policy*, **84**, 204–216, doi:10.1016/j.envsci.2017.08.008.

Wijsman, K. and M. Feagan, 2019: Rethinking knowledge systems for urban resilience: Feminist and decolonial contributions to just transformations. *Environ. Sci. Policy*, **98**, 70–76, doi:10.1016/j.envsci.2019.04.017.

Wilhelmi, O.V., P.D. Howe, M.H. Hayden and C.R. O'Lenick, 2021: Compounding hazards and intersecting vulnerabilities: experiences and responses to extreme heat during COVID-19. *Environ. Res. Lett.*, **16**(8), 84060, doi:10.1088/1748-9326/ac1760.

Williams, A., J. Dickman and R. Smurthwaite, 2021: Advancing evaluation and learning on transformational change: lessons from the climate investment funds' transformational change learning partnership. *Am. J. Eval.*, **42**(1), 90–109, doi:10.1177/1098214020970283.

Wilson, N.J., et al., 2019: Water is medicine: Reimagining water security through Tr'ondëk Hwëch'in relationships to treated and traditional water sources in Yukon. *Canada. water*, **11**(3), 624, doi:10.3390/w11030624.

Wilson, N.J. and J. Inkster, 2018: Respecting water: Indigenous water governance, ontologies, and the politics of kinship on the ground. *Environ. Plan. E: Nat. Space*, doi:10.1177/2514848618789378.

Winkler, H., A. Boyd, M. Torres Gunfaus and S. Raubenheimer, 2015: Reconsidering development by reflecting on climate change. *Int. Environ. Agreements: Polit. Law Econ.*, **15**(4), 369–385, doi:10.1007/s10784-015-9304-7.

Winkler, H. and N.K. Dubash, 2016: Who determines transformational change in development and climate finance? *Clim. Policy*, **16**(6), 783–791, doi:10.1080/14693062.2015.1033674.

v. Winterfeldt, D., 2013: Bridging the gap between science and decision making. *Proc. Natl. Acad. Sci.*, **110**(Supplement 3), 14055–14061, doi:10.1073/pnas.1213532110.

Wise, R.M., et al., 2016: How climate compatible are livelihood adaptation strategies and development programs in rural Indonesia? *Clim. Risk Manag.*, **12**, 100–114, doi:10.1016/j.crm.2015.11.001.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Woiwode, C., 2020: Inner transformation for 21st-century futures: the missing dimension in higher education. *Environ. Sci. Policy Sustain. Dev.*, **62**(4), 30–38, doi:10.1080/00139157.2020.1764299.

Wood, B.T., 2017: *Socially just Triple-Wins? An Evaluation of Projects that Pursue Climate Compatible Development Goals in Malawi*. University of Leeds, Leeds, UK.

Wood, B.T., C.H. Quinn, L.C. Stringer and A.J. Dougill, 2017: Investigating climate compatible development outcomes and their implications for distributive justice: evidence from Malawi. *Environ Manage*, **60**(3), 436–453.

World Bank, 2000: *World Development Report 2000/2001: Attacking Poverty*. https://openknowledge.worldbank.org/handle/10986/11856 . World Bank, Washington, DC, USA..

World Bank, 2017: *Climate Vulnerability Assessment: Making Fiji Climate Resistant*. World Bank, Washington, DC, USA.

World Bank, 2021: GINI Index. In: *The World Development Indicators (WDI)*. World Bank, Washington, DC.

World Bank G., 2019: *Using Carbon Revenues*. https://openknowledge.worldbank.org/handle/10986/32247, Accessed 2022-03-16.

World Commission on Environment and Development, 1987: *Our Common Future*. Oxford University Press, Oxford, UK.

World Economic Forum, 2019: *Innovate Europe: Competing for Global Innovation Leadership, Geneva, Switzerland*.

Woroniecki, S., 2019: Enabling environments? Examining social co-benefits of ecosystem-based adaptation to climate change in Sri Lanka. *Sustainability*, **11**(3), 772, doi:10.3390/su11030772.

Worrell, E., J. Allwood and T. Gutowski, 2016: The role of material efficiency in environmental stewardship. *Annu. Rev. Environ. Resour.*, **41**(1), 575–598, doi:10.1146/annurev-environ-110615-085737.

Xu, T., 2018: Investigating environmental Kuznets curve in China–aggregation bias and policy implications. *Energy Policy*, **114**, 315–322, doi:10.1016/j.enpol.2017.12.027.

Xu, Y. and V. Ramanathan, 2017: Well below 2°C: Mitigation strategies for avoiding dangerous to catastrophic climate changes. *Proc. Natl. Acad. Sci.*, **114**(39), 10315–10323, doi:10.1073/pnas.1618481114.

Xue, W., et al., 2016: Cultural worldviews and climate change: A view from China. *Asian J Soc Psychol*, **19**(2), 134–144, doi:10.1111/ajsp.12116.

Yadav, S.S. and R. Lal, 2018: Vulnerability of women to climate change in arid and semi-arid regions: The case of India and South Asia. *J. Arid Environ.*, **149**, 4–17, doi:10.1016/j.jaridenv.2017.08.001.

Yalew, A.W., 2020: Climate Resilient Development. In: *Economic Development under Climate Change : Economy-Wide and Regional Analysis for Ethiopia* [Yalew, A.W.(ed.)]. Springer Fachmedien, Wiesbaden, pp. 99–108. ISBN 978-3658294137.

Yao, M., et al., 2017: Building regional water-use scenarios consistent with global shared socioeconomic pathways. *Environ. Process.*, **4**(1), 15–31.

Yohe, G.W., R.D. Lasco, Q.K. Ahmad, N.W. Arnell, S.J. Cohen, C. Hope, A.C. Janetos and R.T. Perez, 2007: Perspectives on climate change and sustainability. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson(eds.)]. Cambridge University Press, Cambridge, UK, pp. 811–841. ISBN 978-0521880107.

Young, I.M., 2003: *Political Responsibility and Structural Injustice*. University of Kansas, Department of Philosophy, Lawrence, Kansas.

Yu, Y., et al., 2019: National green GDP assessment and prediction for China based on a CA-Markov land use simulation model. *Sustainability*, **11**(3), 576.

Yunkaporta, T., 2019: *Sand Talk: How Indigenous thinking can save the world*. Text Publishing, Melbourne.

Yurdakul, M. and H. Kazan, 2020: Effects of eco-innovation on economic and environmental performance: evidence from Turkey's manufacturing companies. *Sustainability*, **12**(8), 3167, doi:10.3390/su12083167.

Zaman, F., 2021: The role of popular discourse about climate change in disaster preparedness: A critical discourse analysis. *Int. J. Disaster Risk Reduct.*, **60**, 102270, doi:10.1016/j.ijdrr.2021.102270.

Zambia, R. o. and IUCN, 2017: *Climate Change Gender Action Plan of The Republic of Zambia*. (International Union for Conservation of Nature Global Gender Office (IUCN GGO)).https://portals.iucn.org/union/sites/union/files/doc/ccgap-zambia-final-web.pdf, Accessed 2019-09-24.

Zavaleta, C., et al., 2018: Multiple non-climatic drivers of food insecurity reinforce climate change maladaptation trajectories among Peruvian Indigenous Shawi in the Amazon. *PLoS ONE*, **13**(10), e205714, doi:10.1371/journal.pone.0205714.

Ziervogel, G., 2019: Building transformative capacity for adaptation planning and implementation that works for the urban poor: Insights from South Africa. *Ambio*, **48**(5), 494–506, doi:10.1007/s13280-018-1141-9.

Ziervogel, G., E. Archer van Garderen and P. Price, 2016a: Strengthening the knowledge–policy interface through co-production of a climate adaptation plan: leveraging opportunities in Bergrivier Municipality, South Africa. *environ urban*, **28**(2), 455–474.

Ziervogel, G., A. Cowen and J. Ziniades, 2016b: Moving from adaptive to transformative capacity: building foundations for inclusive, thriving, and regenerative urban settlements. *Sustainability*, **8**(9), 955, doi:10.3390/su8090955.

Ziervogel, G., J. Enqvist, L. Metelerkamp and J. van Breda, 2021: Supporting transformative climate adaptation: community-level capacity building and knowledge co-creation in South Africa. *Clim. Policy*, **0**(0), 1–16, doi:10.1080/14693062.2020.1863180.

Zinsstag, J., et al., 2018: Climate change and one health. *FEMS Microbiol. Lett.*, **365**(11), doi:10.1093/femsle/fny085.

Zivkovic, S., 2018: Systemic innovation labs: a lab for wicked problems. *Social Enterprise Journal,* **14** (3), 348–366.

Zummo, L., B. Donovan and K.C. Busch, 2020: Complex influences of mechanistic knowledge, worldview, and quantitative reasoning on climate change discourse: Evidence for ideologically motivated reasoning among youth. *J Res Sci Teach*, doi:10.1002/tea.21648.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB | Feasibility Assessment of Adaptation Options: An Update of the SR1.5

Authors: Debora Ley (Guatemala/Mexico), Helen Adams (UK), Malcolm Araos (Canada/USA), Ritwika Basu (India/UK), Amir Bazaz (India), Luigi Conte (Italy), Katy Davis (UK), Constantino Dockendorff (Chile/Germany), James Ford (UK/Canada), Sabine Fuss (Germany), Elisabeth A Gilmore (USA/Canada), Tania Guillén Bolaños (Nicaragua/Germany), Ove Hoegh-Guldberg (Australia), Mark Howden (Australia), Bavisha Kalyan (South Africa/USA), Laura Moro (Italy), Anuszka Mosurska (UK/Poland), Reinhard Mechler (Germany), Joana Portugal-Pereira (Brazil), Aromar Revi (India), Swarnika Sharma (India), Anne J. Sietsma (the Netherlands/UK), Chandni Singh (India), Alessandro Triacca (Italy), Bianca van Bavel (Canada/Ireland/UK), Ivan Villaverde Canosa (Spain/UK), Mustafa Babiker (Sudan/Saudi Arabia), Paolo Bertoldi (Italy), Brett Cohen (South Africa), Annette Cowie (Australia), Kiane de Kleijne (the Netherlands), Jeremy Emmet-Booth (Ireland), Amit Garg (India), Gert-Jan Nabuurs (the Netherlands), André Frossard Pereira de Lucena (Brazil), Adrian Leip (Italy/Germany), Lars J. Nilsson (Sweden), Pete Smith (UK), Linda Steg (the Netherlands), Masahiro Sugiyama (Japan)

Key Messages

The feasibility assessment (FA) presents a systematic framework to assess adaptation and mitigation options organised by system transitions. This Cross-Chapter Box assessed the feasibility of 23 adaptation options across six dimensions: economic, technological, institutional, socio-cultural, environmental-ecological, and geophysical to identify factors within each dimension that present barriers to the achievement of the option. The results are presented below.

For energy systems transitions, the adaptation options of infrastructure resilience, efficient water use and water management, and reliable power systems enable energy systems to work during disasters with reduced costs, demonstrating the synergistic relationships between mitigation and adaptation (*high confidence*). There is high confidence in the high feasibility of infrastructure resilience and reliable power systems as they enable power systems to provide emergency services during disasters, as well as continue these services during recovery periods. New evidence has focused on both options for peri-urban and rural areas through distributed generation and isolated renewable energy systems, which also provide multiple social co-benefits (*medium confidence*). For efficient water use and management, the synergistic potential with mitigation can make processes more efficient and cost effective (*high confidence*). With regards to adaptation feasibility, efficient water use is especially useful in drought-stricken areas and provides better water management for multiple uses (*high confidence*).

There are multiple adaptation options for land and ocean ecosystems. Forest- and biodiversity-based adaptation options are generally promoted on the basis of their positive impacts on adaptive and ecological capacities, increased provision of ecosystem services and goods, with a particularly strong contribution to carbon sequestration (*high confidence*). However, large afforestation projects and the introduction of non-native and fast-growing vegetation reduce water availability, impoverish habitats for wildlife and reduce overall ecological resilience, threatening the achievement of some Sustainable Development Goals (SDGs), and potentially leading to maladaptation (*high confidence*).Over-reliance on forest-based solutions may increase the susceptibility to wildfires, with detrimental consequences both for mitigation and adaptation (*medium confidence*). Over the last decade, forest- and biodiversity-based solutions have gained considerable political traction and social acceptability (*high confidence*), but in countries with economies highly dependent on the export of agricultural commodities, opportunity costs continue to hinder the expansion of these alternatives, particularly against more profitable land uses (*high confidence*). In such cases, government support and innovative financial schemes, including payments for ecosystem services, are fundamental for broader adherence to forest- and biodiversity-based options.

Agro-forestry solutions have strong ecological and adaptive co-benefits (*high confidence*), including improved provision of ecosystem services, synergies with the water–energy–land–food nexus, and positive outcomes in agricultural intensification, job diversification and household income. While broad inclusion of agro-forestry schemes in countries' Nationally Determined Contributions (NDCs) reflect growing international interest in these strategies, insufficient financial support to smallholder farmers continues to limit the expansion of agro-forestry initiatives in developing and tropical countries.

Implementing environmentally and biodiversity sensitive coastal defence options—often as part of Integrated Coastal Zone Management—is limited by economic, environmental, institutional and social barriers. Successful implementation requires a strong socioeconomic framework and can offer diverse social, ecological and economic benefits, as well as sequestering carbon (*high confidence*). There is extensive experience with hard coastal defence structures (e.g., sea walls), which can be cost-effective in economic terms, depending on the location (*medium confidence*); however, they are considered maladaptive and unsustainable in some contexts (*medium confidence*) due to their lack of flexibility or robustness in response to a changing climate, as well as their carbon-intensiveness and potential ecological impacts (*medium confidence*).

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

There is *medium confidence* on the feasibility of sustainable aquaculture and fisheries as adaptation options. There are financial barriers to implementing sustainable aquaculture and fisheries, even though they can improve employment opportunities, especially for local communities (*medium confidence*). Technical resource availability is still lacking and could represent a barrier to implementing sustainable aquaculture and fisheries (*medium confidence*). Robust institutional and legal frameworks are needed to guarantee effective adaptation (*high confidence*). Sustainable aquaculture and fisheries are highly dependent on healthy and resilient ecosystems (*high confidence*). They can provide diverse ecosystem services and support coastal ecosystems restoration (*medium confidence*).

There are a range of strategies to improve livestock system efficiency including improved livestock diets, enhanced animal health, breeding and manure management, and grassland management. This suite of strategies has strong feasibility to build resilience while improving incomes (*medium confidence*) and providing mitigation co-benefits (*high confidence*). While technological and ecological feasibility is high, institutional, market and socio-political acceptability remain significant barriers (*medium confidence*).

Improving water use efficiency and water resource management under land and ecosystem transitions has high technological feasibility (*high confidence*) with positive resilience-building and socioeconomic co-benefits. However, economic and institutional barriers remain and are based on type, scale and location of interventions (*medium confidence*). Notably, inadequate institutional capacities to prepare for changing water availability, especially in the long term, unsustainable and unequal water use and sharing practices, and fragmented water resource management approaches remain critical barriers to feasibility (*high confidence*).

Improved cropland management includes agricultural adaptation strategies such as integrated soil management, no/reduced tillage, conservation agriculture, planting of stress-resistant or early maturing crop varieties, and mulching. These strategies have high economic and environmental feasibility (*high confidence*) and substantial mitigation co-benefits (*medium confidence*). However, high costs, inadequate information and technical know-how, delays between actions and tangible benefits, lack of comprehensive policies, fragmentation across different sectors, inadequate access to credit, and unequal access to resources constrain technological, institutional and socio-cultural feasibility (*medium confidence*).

For urban and infrastructure system transitions, sustainable urban planning can support both adaptation and decarbonisation by mainstreaming climate concerns, including effective land use into urban policies, by promoting resilient and low-carbon infrastructure, and by protecting and integrating carbon-reducing biodiversity and ecosystem services into city planning (*medium confidence*). Urban green infrastructure and ecosystem services have high feasibility to support climate adaptation and mitigation efforts in cities, for example to reduce flood exposure and attenuate the urban heat island (*high confidence*). While green infrastructure options are cost-effective and provide co-benefits in terms of ecosystem services such as improved air quality or other health benefits (*high confidence*), there remains a need for systematically assessing co-benefits, particularly for flood risk management and sustainable material flow analysis. Governments across scales can support urban sustainable water management by undertaking projects to recycle wastewater and runoff through green infrastructure; enabling greater coherence between urban water and riverine basin management; decentralising water systems; supporting networks for sharing best practices in water supply and storm runoff treatment to scale sustainable management; and foregrounding equity and justice concerns, especially through participation involving informal settlement residents (*medium confidence*).

Strong and equitable health systems can protect the health of populations in the face of known and unexpected stressors (*medium confidence*). Health and health systems adaptation is feasible where capacity is well developed, and where options align with national priorities and engage local and international communities (*medium confidence*). Socio-cultural acceptability of health and health systems adaptation is high and there is significant potential for risk-mitigation and social co-benefits where adaptation addresses the needs of vulnerable regions and populations (*medium confidence*). Microeconomic feasibility and socioeconomic vulnerability reduction potentials are also high (*high confidence*), although economic feasibility may pose a significant challenge in low-income settings (*medium confidence*). However, inadequate institutional capacity and resource availability represent major barriers, particularly for health systems struggling to manage current health risks (*high confidence*).

There is strong evidence that disaster risk management (DRM) is highly feasible when supported by strong institutions, good governance, local engagement and trust across actors (*medium confidence*). DRM is constrained by lack of capacity, inadequate institutions, limited coordination across levels of government (*high confidence*), lack of transparency and accountability, and poor communication (*medium confidence).* There is a preference for top-down DRM processes, which can undermine local institutions and perpetuate uneven power relationships (*medium confidence*). However, local integration of worldviews, belief systems and local and

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Indigenous Knowledge into DRM activities can facilitate successful, disability-inclusive and gender-focused DRM (*medium confidence*). Moves towards community-based and ecosystem-based DRM are promising but uneven and may increase vulnerability if they fail to address underlying and structural determinants of vulnerability (*high confidence*).

Climate services that are demand-driven and context-specific (e.g., to a particular crop or agricultural system) build adaptation capacity and enable short- and longer-term risk management decisions (*high confidence*). Metrics to assess the economic outcomes of climate services remain insufficient to capture longer-term benefits of interventions (*medium confidence*). While technological capacity and political acceptance is high (*medium confidence*), institutional barriers, poor fit with user requirements and inadequate regional coverage constrain the option's overall feasibility.

Risk insurance can be a feasible tool to adapt to climate risks and support sustainable development (*high confidence*). They can reduce both vulnerability and exposure, support post-disaster recovery and reduce financial burden on governments, households and business. Insurance mechanisms enjoy wide legal and regulatory acceptability among policymakers and are institutionally feasible (*high confidence*). However, socio-cultural and financial barriers make insurance spatially and temporally challenging to implement (*high confidence*), even though it can improve the health and well-being of populations (*medium confidence*). The risk of generating maladaptive outcomes can further limit the uptake of insurance, as it can provide disincentives for reducing risk over the long term (*medium confidence*). Expanding the knowledge base on insurance is fundamental to successfully implement insurance among all relevant stakeholders. Ensuring equitable access to and benefits from innovative financial products (e.g., loans) is needed to guarantee successful uptake of insurance across all the population (*high confidence*).

Migration has been used by millions around the world to maintain and improve their well-being in the face of changed circumstances, often as part of labour or livelihood diversification (*very high confidence*). Properly supported and, where levels of agency and assets are high, migration as a climate response can reduce exposure and socioeconomic vulnerability (*medium confidence*). Households and communities in climate-exposed regions experience a range of intersecting stressors. These households can undertake distress migration, which results in negative adaptive and resilience outcomes (*high confidence*). Outcomes can be improved through a systematic examination of the political economy of local and regional sectors that employ precarious communities and by addressing vulnerabilities that pose barriers to *in situ* adaptation and livelihood strategies (*medium confidence*). Migrants and their sending and receiving communities can be supported through temporary labour-migration schemes, improving discourses on migration, and matching existing migration agreements with development objectives (*medium confidence*).

Planned relocation and resettlement have low feasibility as climate responses (*medium confidence*). Previous disaster- and development-related relocation has been expensive, contentious, posed multiple challenges for governments and amplified existing, and generated new, vulnerabilities for the people involved (*high confidence*). Planned relocation will be increasingly required as climate change undermines habitability, especially for coastal areas (*medium confidence*). Full participation of those affected, ensuring human rights-based approaches, preserving cultural, emotional and spiritual bonds to place, and dedicated governance structures and associated funding are associated with improved outcomes (*high confidence*). Improving the feasibility of planned relocation and resettlement is a high priority for managing climate risks (*high confidence*).

CCB FEASIB.1 Scope

The Paris Climate Agreement marked a significant shift for the IPCC AR6 assessment towards a systematic exploration of climate solutions and a suite of linked adaptation and mitigation options (IPCC, 2018b; IPCC, 2019b). This shift was first evidenced in SR1.5, whose plenary-approved outline sought to define feasibility as 'referring to the potential for a mitigation or adaptation option to be implemented. Factors influencing feasibility are context-dependent, temporally dynamic, and may vary between different groups and actors. Feasibility depends on geophysical, environmental-ecological, technological, economic, socio-cultural and institutional factors that enable or constrain the implementation of an option. The feasibility of options may change when different options are combined and increase when enabling conditions are strengthened'. Based on this, SR1.5 identified (with *high confidence*) rapid and far-reaching transitions in four systems: energy, land and other ecosystems, urban and infrastructure (including transport and buildings), and industrial systems, are necessary to enable pathways to limit average global warming to 1.5°C compared with pre-industrial temperatures (Bazaz et al., 2018; IPCC, 2018b). This was deepened for terrestrial systems in SRCCL, while SROCC added additional evidence from ocean and cryosphere systems. The assessment also included the interactions between carbon dioxide removal (CDR) and adaptation outcomes: compared with previous Assessment Reports, it is clear that the ambitious temperature targets agreed upon in Paris in 2015 will require at least some CDR, that is all 1.5°C pathways will eventually feature annual removals at gigaton level (Rogelj et al., 2018a). This necessitates assessing the interactions of CDR with adaptation.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

This feasibility assessment (FA) of adaptation options is situated within four system transitions identified in SR1.5 (de Coninck et al., 2018b). In this report, feasibility refers to the potential for an adaptation option to be implemented. Twenty-three key adaptation options have been identified in AR6, across these system transitions, and mapped against representative key risks at global scale (Chapter 16) (Figure 1).

This cross-chapter box first presents the methodology for the (FA) of adaptation options (Section 2); findings of the FA (Section 3); presents synergies and trade-offs (S&Ts) of adaptation for mitigation options and mitigation for adaptations (Section 4); and knowledge gaps (Section 5).

Feasibility assessment options mapped against Representative Key Risks (RKR)

Systems transitions RKRs	Energy systems transitions	Land and ecosystems transitions	Urban and infrastructure systems transitions	Overarching adaptation options
Risk to costal socio-ecological systems		• Coastal defense and hardening • Sustainable aquaculture		• Social safety nets • Risk spreading and sharing • Climate services (including EWS) • Disaster risk management • Population health and health systems • Human migration and displacement • Planned relocation and resettlement
Risk to terrestrial and ocean ecosystems		• Integrated coastal zone management including wetland, mangrove conservation • Sustainable forest management and conservation, forestations and afforestation • Biodiversity management and ecosystem connectivity		
Risk associated with critical physical infrastructure, networks, and services	• Resilient power infrastructure • Improved power reliability		• Green infrastructure and ecosystem services • Sustainable land-use land urban planning	
Risk to living standards and equity		• Livelihood diversification		
Risk to human health				
Risk to food security		• Improved cropland management (including integrated soil management, conservation agriculture) • Efficient livestock systems (including improved grazing land management) • Agroforestry		
Risk to water security	• Improve water use efficiency	• Water use efficiency and water resource management	• Sustainable urban water management	
Risk to peace and migration				

Figure Cross-Chapter Box FEASIB.1 | Feasibility assessment option mapped against representative key risks (RKRs)

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

There has been growing research emphasis on synthesising adaptation literature through meta-reviews of adaptation research (Sietsma et al., 2021; Berrang-Ford et al. 2021), adaptation readiness (Ford et al., 2015a; Ford et al., 2017), adaptation progress (Araos et al., 2016a), adaptation barriers and enablers (Biesbroek et al., 2013; Eisenack et al., 2014; Barnett et al., 2015), and adaptation outcomes (Owen, 2020) (Cross-Chapter Box ADAPT in Chapter 1). In particular, understanding which adaptation options are effective, to what risks, and under what conditions, is particularly challenging given the lack of a clearly defined and globally- agreed- adaptation goals, as well as disagreement on the metrics to assess adaptation effectiveness (Berrang-Ford et al., 2019; Singh et al., 2021c) (17.5.2 on Successful Adaptation). Effectiveness studies often use metrics such as reduced risk exposure, damage costs averted, which lend themselves well to infrastructural options (e.g., effectiveness of seawalls in reducing sea level rise [SLR] exposure in coastal cities), but do not translate well to 'soft' adaptation options such as climate services or changing building codes.

CCB FEASIB.2 Methodology: feasibility assessment of adaptation options across key system transitions

The multi-dimensional feasibility of 23 adaptation options is assessed across six dimensions. This multi-dimensional framework goes beyond technical or economic feasibility alone to capture how adaptation is mediated by the political environment, sociocultural norms (Evans et al., 2016), cognitive and motivational factors (van Valkengoed and Steg, 2019), economic incentives and benefits (Masud et al., 2017), and ecological conditions (Biesbroek et al., 2013).

The six feasibility dimensions are underpinned by a set of 20 indicators. Each adaptation option is scored as having *robust*, *medium* or *limited evidence* on barriers based on a review of literature published from 2018 onwards (pre-2018 literature is expected to be covered by SR1.5 but in some cases pre-2018 literature was added) that reports studies that are 1.5°C-relevant. Further details and motivations for this methodology can be found in Singh et al., 2020c.

The scoring process is undertaken by one author and reviewed by at least two more authors to ensure robustness and geographical coverage. While the literature does not support an assessment at different temperature levels or an assessment of how feasibility can change over time, some examples of these spatial and temporal aspects are detailed below.

CCB FEASIB.3 Findings: feasibility assessment of adaptation options across key system transitions

The following sections outline the findings of a 1.5°C-relevant feasibility assessment of adaptation options by the four system transitions. A synoptic summary of the findings of the multi-dimensional feasibility is shown at the end of this section in Figure Cross-Chapter Box FEASIB.2. The full line of sight can be found in the Supplementary Material (SM).

CCB FEASIB.3.1 Energy systems transitions

The adaptation options assessed for energy system transitions are resilient power infrastructure; water management, focused on water efficiency and cooling, for all types of generation sources; and reliable power systems. Since SR1.5, there has not been significant change in the feasibility of the first two options as they continue to be implemented successfully, allowing for power generation to maintain or increase its reliability during extreme weather events (*high confidence*) (Zhang et al., 2018; Ali and Kumar, 2016; DeNooyer et al., 2016). As in the case of SR1.5, these options are not sufficient for the far-reaching transformations required in the energy sector, which tend to focus on technological transitions from a fossil-based to a renewable energy regime (Erlinghagen and Markard, 2012; Muench et al., 2014; Brand and von Gleich, 2015; Monstadt and Wolff, 2015; Child and Breyer, 2017; Hermwille et al., 2017). The main difference from SR1.5 is that resilient power infrastructure now includes distributed generation utilities, such as microgrids, as there is increasing evidence of its role in reducing vulnerability, especially within underserved populations (*high confidence*).

The option for resilient power infrastructure considers all types generation sources, and transmission and distribution systems. There is *robust evidence* and *high agreement* for the high feasibility of the economic and technological dimensions as the technologies have been used and their cost effectiveness is high, although the latter is dependent upon the generation source and location of each specific generation plant. There is medium institutional feasibility (*medium evidence*, *medium agreement*) as there are insufficient policies for resilient infrastructure, although there is high acceptability for these options.

The option of efficient water use and management also has high feasibility for the economic, technological and environmental dimensions (*robust evidence*, *high agreement*), as this option also has proven that technology and efficient water use can make power generation operations more efficient and cost effective as well as have positive effects on the environment, especially in drought-stricken regions. There is high political acceptability, existence of water use policies, regulations and supporting institutional frameworks to ensure compliance (Ali and Kumar, 2016; DeNooyer et al., 2016; Zhang et al., 2018). There is *medium evidence* and *high agreement* for the medium feasibility of the socio-cultural dimension, especially given the evidence of resilience in distributed generation systems and independent microgrids.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Since AR5, the reliability of power systems has gained interest because of the numerous service disruptions during extreme weather events. As with resilient power systems, there is increasing evidence of the feasibility of increased reliability for both existing power plants, independently of the generation source, and for rural landscapes. The option has *high confidence* (*robust evidence*, *high agreement*) for the high feasibility of the technological and social dimensions. As with previous options, the technological means exist to create redundancy in power generation, transmission and distribution systems and their implementation ensures the continuous functionality of emergency services, such as communications, health and water pumping, amongst others, in urban, peri-urban and rural landscapes (*high confidence*). There is high feasibility for the economic, technical and socio-cultural dimensions (the latter more prominently for decentralised systems), and medium feasibility for institutional and geophysical dimensions.

For the three options, some of the indicators within the institutional, social and geophysical dimensions have *limited evidence* as they have not been the focus of dedicated research. For example, when discussing the social co-benefits of energy reliable systems of efficient water use, the literature does not focus on intergenerational or gender issues separately from the broad range of social co-benefits the options provide, but, for example, highlight the need for electricity for communications and health centres.

CCB FEASIB.3.2 Land and ecosystems

CCB FEASIB.3.2.1 Coastal defence and hardening

There is *robust evidence* and *medium agreement* regarding the feasibility of coastal defence and hardening as adaptation options in some circumstances, which here includes grey coastal infrastructure. Economic and social factors may limit the feasibility of these options as they require large investments (both construction, maintenance and monitoring) (Hamin et al., 2018; Magnan and Duvat, 2018; Morris et al., 2018; Morris et al., 2019; Nicholls et al., 2019; Hanley et al., 2020b) (Section CCP2.3). While these costs present challenges for rural areas, coastal defence structures may still be cost-effective in other areas, such as those with larger economies (Aerts, 2018; Lincke and Hinkel, 2018; Tiggeloven et al., 2020; Vousdoukas et al., 2020; Lima and Coelho, 2021). Strong, transparent and inclusive governance is key, suggesting that these measures can occasionally fail to adequately balance competing stakeholder interests. Consequently, they may disproportionately benefit wealthier people and exacerbate existing vulnerability of the poor (Kind et al., 2017; O'Donnell, 2019; Ratter et al., 2019; Siders and Keenan, 2020; Siriwardane-de Zoysa, 2020). They are also potentially maladaptive if they are not flexible or robust in response to a changing climate (Antunes do Carmo, 2018; Hamin et al., 2018; Morris et al., 2019; Bailles et al., 2020; Foti et al., 2020; Hanley et al., 2020b) and can have negative impacts on the local environment, habitats, ecosystem services, and communities (Mills et al., 2016; Morris et al., 2018; Morris et al., 2019; Foti et al., 2020; Hanley et al., 2020b).

Recent projects have focused on improving adaptability and increasing ecological and social sustainability by combining both hard engineering and 'softer' nature-based solutions (Morris et al., 2019; Scheres and Schüttrumpf, 2019; Schoonees et al., 2019; Van Loon-Steensma and Vellinga, 2019; Du et al., 2020; Foti et al., 2020; Winters et al., 2020; Ghiasian et al., 2021; Joy and Gopinath, 2021; Tanaya et al., 2021; Waryszak et al., 2021). For example, coastal defence might involve a combination of 'stabilising' ecosystems (e.g., seagrasses, mangroves, salt marshes) and hard human-made structures. Such coastal defence 'mixed' structures can be part of an Integrated Coastal Zone Management (ICZM) strategy, which is covered as a separate option below.

CCB FEASIB.3.2.2 Sustainable aquaculture

There is *medium evidence* with *medium agreement* on the feasibility of sustainable aquaculture as an adaptation measure. Sustainable aquaculture (e.g., integrated multi-trophic aquaculture, polyculture, aquaponics, mangrove-integrated culture) can have socioeconomic benefits for vulnerable communities and small-scale fisheries (Ahmed, 2018; Blasiak et al., 2019; Mustafa et al., 2021; Thomas et al., 2021; Xuan et al., 2021). However, caution is important to guarantee that access to fish supply of local and vulnerable communities is not affected (Chan et al., 2019; Galappaththi et al., 2020). Access to financial resources is often a barrier to implementation, although sustainable aquaculture can increase employment opportunities that are increasingly gender equitable (Alleway et al., 2018; Leakhena et al., 2018; Valenti et al., 2018; Gopal et al., 2020), as well as increasing the resilience of coastal livelihoods to climate change (Shaffril et al., 2017; Blasiak and Wabnitz, 2018). Technological, institutional and socio-cultural factors can form barriers to the feasibility of sustainable aquaculture (e.g., Ahmed et al., 2018; Blasiak et al., 2019; Galappaththi et al., 2019; Boyd et al., 2020; Osmundsen et al., 2020; Stentiford et al., 2020; Mustapha et al., 2021; Xuan et al., 2021).

Sustainable aquaculture depends on healthy ecosystems (Sampantamit et al., 2020; Stentiford et al., 2020; Qurani et al., 2021). At the same time, its implementation can increase or regenerate ecosystem services, enhance ecosystems' adaptive capacity (Shaffril et al., 2017; Freduah et al., 2018; Custódio et al., 2020; Bricknell et al., 2021; Mustafa et al., 2021) and protect nursery grounds and habitats for fish and other important organisms (i.e., many commercial species are associated with mangroves). It may also prevent ecosystem

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

degradation such as deforestation, enhancing land use potential (Ahmed et al., 2018; Stentiford et al., 2020; Turolla et al., 2020; Mustafa et al., 2021).

Environmental and economic aspects are key when assessing the sustainability of aquaculture practices (Ahmed et al., 2018; Aubin et al., 2019; Bohnes et al., 2019; Galappaththi et al., 2019; Boyd et al., 2020; Galappaththi et al., 2020; Osmundsen et al., 2020; Stentiford et al., 2020; Thomas et al., 2021). A global picture of where sustainable aquaculture is possible is needed and desirable (FAO, 2018; Galappaththi et al., 2019; Bricknell et al., 2021), yet there are few new references to its physical feasibility. Adaptation options for existing sustainable aquaculture need to be developed, along with institutional arrangements such as education and technology transfer, focused on developing sustainable industries (Section 8.6.2.3). Sustainable agriculture is likely to receive strong support from many countries but may also experience resistance for several reasons (e.g., competition with existing industries, debates over tolerance to aesthetic changes to coastlines). Literature on this area is growing. Potential barriers at the government and political levels are significant (e.g., Jayanthi et al., 2018; Blasiak et al., 2019; Hargan et al., 2020; Osmundsen et al., 2020; Stentiford et al., 2020; Mustafa et al., 2021; Qurani et al., 2021).

CCB FEASIB.3.2.3 Integrated coastal zone management (ICZM)

ICZM measures such as salt marsh management, re-vegetation of shorelines, community-based coastal adaptation and ecosystem-based adaptation were considered in this assessment. There is *robust evidence* and *high agreement* that ICZM increases ecological and adaptive capacity to climate change (Villamizar et al., 2017; Antunes do Carmo, 2018; Hamin et al., 2018; Le Cornu et al., 2018; Propato et al., 2018; Romañach et al., 2018; Rosendo et al., 2018; Warnken and Mosadeghi, 2018; Morecroft et al., 2019; Morris et al., 2019; Alves et al., 2020; Donatti et al., 2020; Erftemeijer et al., 2020; Foti et al., 2020; Gómez Martín et al., 2020; Hanley et al., 2020b; Jones et al., 2020b; Krauss and Osland, 2020; O'Mahony et al., 2020; Perera-Valderrama et al., 2020; Cantasano et al., 2021).

Diverse socioeconomic co-benefits have been identified, including integration of tourism activities, increased educational opportunities for the reduction in storm damage, maintenance of ecosystems and their services, increasing adaptive capacities of institutions (Romañach et al., 2018; Mestanza-Ramón et al., 2019; Morris et al., 2019; Donatti et al., 2020; Ellison et al., 2020; Erftemeijer et al., 2020; Gómez Martín et al., 2020; Hanley et al., 2020a; Jones et al., 2020b; Martuti et al., 2020; Perera-Valderrama et al., 2020; Telave and Chandankar, 2021); as well as environmental and geophysical co-benefits aspects, including mitigation potential and hazard risk reduction (Propato et al., 2018; Romañach et al., 2018; Ellison et al., 2020; Erftemeijer et al., 2020; Hanley et al., 2020a; Jones et al., 2020b; Martuti et al., 2020; Cantasano et al., 2021).

ICZM measures are generally more cost-effective than 'hard engineering' measures (Antunes do Carmo, 2018; Morecroft et al., 2019; Morris et al., 2019; Donatti et al., 2020; Erftemeijer et al., 2020; Hanley et al., 2020a; Jones et al., 2020b), but implementation pose barriers, especially in low-income countries (Lamari et al., 2016; Villamizar et al., 2017; Rosendo et al., 2018; Mestanza-Ramón et al., 2019; Barragán Muñoz, 2020; Botero and Zielinski, 2020; Caviedes et al., 2020; Martuti et al., 2020; Lin et al., 2021). ICZM implementation requires strong institutional frameworks, where all relevant stakeholders (especially representatives of local communities) are part of decision-making processes (Pérez-Cayeiro and Chica-Ruiz, 2015; Lamari et al., 2016; Hassanali, 2017; Antunes do Carmo, 2018; Hamin et al., 2018; Phillips et al., 2018; Romañach et al., 2018; Rosendo et al., 2018; Warnken and Mosadeghi, 2018; Mestanza-Ramón et al., 2019; Morecroft et al., 2019; Morris et al., 2019; Walsh, 2019; Barragán Muñoz, 2020; Caviedes et al., 2020; Donatti et al., 2020; Ellison et al., 2020; Martuti et al., 2020; O'Mahony et al., 2020; Perera-Valderrama et al., 2020). This aspect is mentioned as a key challenge in developing countries (Pérez-Cayeiro and Chica-Ruiz, 2015; Villamizar et al., 2017; Rosendo et al., 2018; Alves et al., 2020). Similarly, explicitly incorporating gender considerations into ICZM is generally recommended, mainly because women are key knowledge holders in coastal communities; however, this is rarely done in practice, which may lead to sub-optimal or unequal outcomes (Nguyen Mai and Dang Hoang, 2018; Hoegh-Guldberg et al., 2019; Pearson et al., 2019; Barreto et al., 2020). The perception that building 'hard' infrastructure (i.e., coastal defence and hardening) is a more efficient way of reducing coastal risk than the implementation of 'soft' or nature-based solutions (NbS) measures has been challenged in recent studies (Magnan and Duvat, 2018).

CCB FEASIB.3.2.4 Agro-forestry

There is *robust evidence* and *high agreement* that agro-forestry systems can increase ecological and adaptive capacity (Schoeneberger et al., 2012; Smith et al., 2013a; Minang et al., 2014; Apuri et al., 2018; Kmoch et al., 2018; IPCC, 2019b; Jordon et al., 2020). Benefits include preservation of ecosystems services, such as water provision and soil conservation, more efficient use of limited land, alleviation of land degradation, prevention of desertification and improved agricultural output. Agro-forestry solutions also result in co-benefits in the water–energy–land–food nexus, with observed positive outcomes in soil management, crop diversification, water efficiency and alternative sources of energy (De Beenhouwer et al., 2013; Elagib and Al-Saidi, 2020). Further, they can have social and economic benefits

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

and positive synergies between adaptation and mitigation (Section 8.6.2.2) (Coulibaly et al., 2017; Hernández-Morcillo et al., 2018; Tschora and Cherubini, 2020; Duffy et al., 2021).

When locally adapted to fine-scale ecological and social variation, agro-forestry initiatives can improve household income, and provide regular employment and sustainable livelihood to local communities, thereby strengthening peoples' resilience to cope with adverse impacts of changing climate conditions (Coe et al., 2014; Ogada et al., 2020; Sharma et al., 2020; Sollen-Norrlin et al., 2020; Awazi et al., 2021). However, Cechin et al. (2021) questions the financial viability of agro-forestry systems, especially in the case of smallholders in agrarian reform settlements, struggling with high upfront costs. Similarly, insufficient financial support was found to be a major constraint for the implementation of broader agro-forestry initiatives in Southeast Asia and Africa (Sections 8.5.2 and 8.6.2.1) (Dhyani et al., 2021; Williams et al., 2021b).

Over the last decade, agro-forestry schemes have grown in acceptability and political support, most notably observed in their broad inclusion in countries' NDCs and National Adaptation Plans (NAPs). Governance and institutional arrangements, however, have not been conducive to broader implementation of agro-forestry initiatives at the landscape level (Dhyani et al., 2021; Williams et al., 2021b). *Medium evidence* with *medium agreement* suggests that economic and cultural barriers may explain difficulties with the implementation of agro-forestry systems (Coe et al., 2014; Quandt et al., 2017; Cedamon et al., 2018; Hernández-Morcillo et al., 2018; Ghosh-Jerath et al., 2021). Also, unclear land tenure and ownership issues, together with inappropriate mapping and incomplete databases for monitoring vegetation, continue to hinder the adoption of broader agro-forestry strategies, particularly in remote areas and tropical forests (Martin et al., 2020).

Notably, agro-forestry practices are often part of Indigenous and local Knowledge (Santoro et al., 2020), and so far, most literature refers to the evaluation of existing agro-forestry practices or autonomous adaptation, with few studies evaluating the effects of targeted interventions, especially in low- and middle-income countries (Miller, 2020; Castle et al., 2021).

CCB FEASIB.3.2.5 Forest-based adaptation, including sustainable forest management, forest conservation and restoration, avoided deforestation, reforestation and afforestation

There is *robust evidence* and *medium agreement* supporting the overall feasibility of forest-based adaptation options. Regarding its economic feasibility, some studies (Nabuurs et al., 2017b; Chow et al., 2019; Seddon et al., 2020a) highlight that the net benefits of measures such as reforestation, sustainable forest management and ecosystem restoration outweigh the costs of implementation and maintenance. Yet, another strand of literature observes that limited access to financial resources is a major constraint to forest-based initiatives, especially in the face of upfront investment costs and alternative, more profitable land uses, such as agriculture (Bustamante et al., 2019; Ota et al., 2020; Seddon et al., 2020b). In countries with extensive rural areas where forests provide for local communities, government support together with private investments and long-term assurances of maintenance, are considered fundamental for the long-term viability of forest conservation strategies (Bustamante et al., 2019; Seddon et al., 2020b). In rural areas, smallholders can diversify their livelihood and increase household income as a result of improved local forest governance (Bustamante et al., 2019; Fleischman et al., 2020; Ota et al., 2020) Similarly, forest and ecosystem restoration has been found to reduce poverty and improve social inclusion and participation, given that ecosystems can be managed jointly and in traditional ways (Woroniecki et al., 2019). *Robust evidence* (*high agreement*) links forest-based adaptation to job creation, improved health and recreational benefits, most notably for indigenous, rural and remote communities (Muricho et al., 2019b; Rahman et al., 2019; Ambrosino et al., 2020; Bhattarai, 2020; Ota et al., 2020; von Holle et al., 2020; Tagliari et al., 2021). However, Chausson et al. (2020) note that frameworks for assessing the cost-effectiveness of adaptation strategies continue to be tailored to conventional, engineered interventions, which fail to capture the broader array of material and non-material benefits that forest-based interventions might bring.

Forest-based solutions enjoy wide local, regional and international support (Lange et al., 2019; Chausson et al., 2020; Seddon et al., 2020b), and most countries have a basic regulatory framework for environmental protection. However, lack of institutional capacity, deficient inter-agency coordination, and insufficient staff and budget continue to limit broader implementation of forest-based adaptation measures. Limited technical capacity, insufficient production and supply of seeds and seedlings, long transport distances and immature supply chains have also been identified as significant barriers that hinder the expansion of forest-based initiatives (Bustamante et al., 2019; Nunes et al., 2020).

There is *robust evidence* and *medium agreement* that forest-based solutions support ecosystems' capacity to adapt to climate change, including better regulation of microclimate, increased groundwater recharge, improved quality of air and water, reduced soil erosion, improved and climate-adapted biodiversity habitats and expansion of biomass, as well as continuous provision of renewable wood

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

products (Nabuurs et al., 2017b; Chow et al., 2019; Lochhead et al., 2019; Shannon et al., 2019; Weng et al., 2019; von Holle et al., 2020; Dooley et al., 2021; Forster et al., 2021; Tagliari et al., 2021). In well-designed systems, adaptation and mitigation can then go hand in hand, as in climate-smart forestry. What is more, adaptive forest management is already being tested in climate-smart forestry pilots in several temperate regions (Nabuurs et al., 2017b). However, large afforestation and non-native monoculture plantations may negatively impact non-forest ecosystems, such as grasslands, shrublands and peatlands, their water resources and biodiversity (Seddon et al., 2019; Seddon et al., 2020a; Seddon et al., 2020b). Similarly, the International Resource Panel (2019) warns that restoration may also imply trade-offs with other ecological and societal goals.

Regarding risk reduction potential, forest-based strategies are found to protect in-land infrastructure from landslides and coastal infrastructure from storm surges (Seddon et al., 2020a; Seddon et al., 2020b), together with offering a cheaper solution than engineered grey solutions (Chausson et al., 2020). Land availability is a limiting factor for expanding forest-based solutions (Morecroft et al., 2019; Ontl et al., 2020). However, there is *high agreement* and *robust evidence* that reforestation, environmental conservation and NbS result in increased carbon sinks (Griscom et al., 2017b; Nabuurs et al., 2017b; de Coninck et al., 2018b; Fuss et al., 2018; Favretto et al., 2020; Forster et al., 2021). Some authors argue that primary ecosystems and native forests contain larger stocks of carbon than tree plantations (Seddon et al., 2019; Fleischman et al., 2020; Seddon et al., 2020a), while another strain of literature finds that net sequestration rate is lower in mature primary forests than in younger managed forests with their associated wood value chains (Cowie et al., 2021; Forster et al., 2021; Gundersen et al., 2021). There is *robust evidence* and *high agreement* that forest- and ecosystem-based strategies result in hazard risk reduction potential. Environmental restoration can be an effective climate change adaptation alternative, reducing susceptibility to extreme events, improving ecological capacities and increasing overall ecosystems' resilience (Chapter 8, Box 9.7) (Nunes et al., 2020). However, too much reliance on forests and green alternatives might increase water shortages and wildfires (Seddon et al., 2019; Fleischman et al., 2020).

CCB FEASIB.3.2.6 Biodiversity management and ecosystem connectivity

There is *robust evidence* and *medium agreement* supporting the overall feasibility of biodiversity management and ecosystem connectivity as adaptation options. With respect to its economic feasibility, financial constraints continue to hinder broader implementation of biodiversity-based solutions (Lausche et al., 2013; Chausson et al., 2020; Jones et al., 2020a). Seddon et al. (2020a) highlights that only 5% of climate finance goes towards adaptation strategies, and only 1% is destined to disaster risk management including NbS and biodiversity management. Government support via subsidies and fiscal transfers is critical for broader biodiversity management interventions. In addition, REDD+ (Reduced Emissions from Deforestation and Land Degradation) initiatives have been promoted as a profitable mechanism to advance biodiversity conservation strategies while reducing carbon emissions. As far as ecosystem connectivity is concerned, its feasibility will strongly depend on the existence of a regulatory framework that appropriately balances property rights, environmental regulations and monetary incentives to ensure landowners' willingness to participate and maintain ecosystem corridors (Jones et al., 2020b). The demands of commodity-based economies, favouring extractive land uses, present serious barriers to upscaling biodiversity-based adaptation interventions (Seddon et al., 2020a). In addition, integrated assessments have shown how biodiversity-based solutions can deliver jobs from landscape restoration or income from wildlife tourism and how those benefits are fairly distributed (Chausson et al., 2020).

Legal and regulatory instruments are not perceived as major barriers to biodiversity management and ecosystem connectivity projects (Lausche et al., 2013; D'Aloia et al., 2019). A challenge that biodiversity-based measures still face is less acceptance among decision makers because their efficiency and cost-benefit ratio are difficult to determine and most of the measures are only effective in the long term (Lange et al., 2019). Methodologies to determine cost-effectiveness vary substantially between studies, in part because these analyses must be tailored to the socio–ecological context to be meaningful for local governance. This makes it challenging to capture and synthesise the full economic benefits of biodiversity-based solutions in comparison to alternatives (Chausson et al., 2020). In all, biodiversity and nature-based solutions have gained considerable political traction, with the greatest emphasis on the role of ecosystems as carbon sinks (Lange et al., 2019; Chausson et al., 2020; Seddon et al., 2020a).

Several social co-benefits are found to follow from biodiversity management strategies, including improved community health, recreational activities and eco-tourism, in addition to educational, spiritual and scientific benefits (Lausche et al., 2013; Worboys et al., 2016; Seddon et al., 2020a). Lavorel et al. (2020) show how the benefits of biodiversity management are co-produced by harnessing ecological and social capital to promote resilient ecosystems with high connectivity and functional diversity. Furthermore, Chausson et al. (2020) note how properly implemented NBS, including biodiversity management, can strengthen social networks and foster a sense of place, supporting virtuous cycles of community engagement to sustain interventions over time.

There is *high agreement* and *robust evidence* supporting the ecological capacity enhancement of biodiversity-based and ecosystem connectivity strategies (Thompson et al., 2017; Lavorel et al., 2020). Forest management that favours mixed-species rather than non-

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

native monocultures can promote the resilience of timber production and carbon storage while also benefiting biodiversity (Chausson et al., 2020). Similarly, monocultures have been found to impoverish biodiversity and hold less resilient carbon stocks than natural and semi-natural forests (Seddon et al., 2020a).

There is a *relatively high agreement* that ecosystem connectivity has the potential to improve the adaptive capacity of both ecological systems and humans. Krosby et al. (2010), for example, found that planting trees in short distances could increase the probability of range shifts in species that depend on the habitat those trees provide. Likewise, connectivity conservation has benefits for climate change mitigation (Lausche et al., 2013), but empirical evidence of the adaptation benefits for humans is scant. More recently, it has been found that biodiversity conservation reduces the risk of zoonotic diseases when it provides additional habitats for species and reduces the potential contact between wildlife, livestock and humans (Van Langevelde et al., 2020). Ecosystem-based approaches have been promoted to address the risk of increased zoonotic diseases, including the conservation of wildlife corridors (Gibb et al., 2020).

Despite abundant literature on the necessity to implement ecosystem connectivity strategies, many policy recommendations are mostly discursive and not supported by evidence. There is a lack of specificity when referring to the actors that should intervene in the design, implementation and evaluation of policies. What is more, most of the literature comes from the natural sciences and is concerned with co-benefits to wildlife and nature, with very little elaboration on the socioeconomic co-benefits for humans.

CCB FEASIB.3.2.7 Improved cropland management

Improved cropland management, which includes agricultural adaptation strategies such as integrated soil management, no/reduced tillage, conservation agriculture, planting of stress-resistant or early maturing crop varieties, and mulching, has high economic and environmental feasibility (*robust evidence, high agreement*) (AGEGNEHU and AMEDE, 2017; Lalani et al., 2017; Schulte et al., 2017; Thierfelder et al., 2017; Aryal et al., 2018a; Mayer et al., 2018; Prestele et al., 2018; Sova et al., 2018; Gonzalez-Sanchez et al., 2019; Lunduka et al., 2019; McFadden et al., 2019; Shah and Wu, 2019; TerAvest et al., 2019; Adams et al., 2020; Aryal et al., 2020a; Debie, 2020; Mutuku et al., 2020; Somasundaram et al., 2020; Du et al., 2021). Despite higher initial costs in some cases, the economic feasibility of improved cropland management is high through improved productivity, higher net returns and reduced input costs (Aryal, 2020; Mottaleb et al., 2017; Keil et al., 2019; Lunduka et al., 2019; McFadden et al., 2019; Parihar et al., 2020). Self-efficacy is shown to be the most important predictor in technical and non-technical adaptation behaviour (Zobeidi et al., 2021), while subsidies, extension services, training, commercial custom-hire services and strong social connections such as farmer networks are among the factors supporting adoption among farmers (Section 8.5.2.3) (Aryal et al., 2015a; Aryal et al., 2015b; Kannan and Ramappa, 2017; Bedeke et al., 2019; Acevedo et al., 2020). In some regions and for some practices, technological feasibility is constrained by costs and inadequate information and technical know-how on particular practices and their benefits and trade-offs, indicating medium feasibility (Khatri-Chhetri et al., 2016; Bhatta et al., 2017; Dougill et al., 2017; Kannan and Ramappa, 2017; Aryal et al., 2018a; Sova et al., 2018; Findlater et al., 2019). Delays between actions and tangible benefits can reduce public and private acceptability and uptake of improved cropland management practices (e.g., Dougill et al., 2017 in Malawi).

There remain institutional and financial barriers to improved cropland management such as lack of comprehensive policies, inadequate mainstreaming into national policy priorities (e.g., Amjath-Babu et al., 2019 and Reddy et al., 2020 in South Asia), fragmentation across different sectors (Dougill et al., 2017 in Malawi), and inadequate access to credit (Aryal et al., 2018c in India). Adoption of improved cropland management practices is often strongly mediated by gender: structural barriers such as unequal access to land, machinery, inputs, and extension and credit services, constrain adoption by female farmers (Aryal et al., 2018b; Aryal et al., 2018c) Mponela et al., 2016; Van Hulst and Posthumus, 2016; Ntshangase et al., 2018; Somasundaram et al., 2020). Improved cropland management practices have social and ecological co-benefits in terms of better health, education and food security (Agarwal, 2017; Farnworth et al., 2017; Hörner and Wollni, 2020) and better soil health and ecosystem functioning (AGEGNEHU and AMEDE, 2017; Mottaleb et al., 2017; Thierfelder et al., 2017; Zomer et al., 2017; Sarkar et al., 2018; Gonzalez-Sanchez et al., 2019; Shah and Wu, 2019; Du et al., 2020; Mutuku et al., 2020; Somasundaram et al., 2020).

There is *robust evidence* (*medium agreement*) that improved cropland management can have mitigation co-benefits but the exact quantity of emissions reductions and increased removals depend on agro-ecosystem type, climatic factors and cropping practices (VandenBygaart, 2016; Han et al., 2018; Mayer et al., 2018; Prestele et al., 2018; Singh et al., 2018a; Sommer et al., 2018; Gonzalez-Sanchez et al., 2019; Ogle et al., 2019; Shah and Wu, 2019; Adams et al., 2020; Aryal et al., 2020a; Li et al., 2020; Wang et al., 2020b; Shang et al., 2021).

CCB FEASIB.3.2.8 Efficient livestock systems

Enhancing the production efficiency of livestock systems through, for example, improved livestock diets, enhanced animal health, breeding and manure management, can contribute to adaptation and mitigation (Ericksen and Crane, 2018; Accatino et al., 2019; Paul

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

et al., 2020; IPCC WGIII AR6 Section 7.4.3). While the technological and ecological feasibility of improving livestock production systems is high (i.e., measures are technically well established, with different options applicable to a range of livestock production systems and ecological conditions), there are multiple context-specific barriers to adoption. These include the lack of coordinated policy support or governance, potentially high implementation costs and limited access to finance, inadequate advisory, knowledge exchange or infrastructural capacity (Escarcha et al., 2018; Paul et al., 2020), the potential land requirements and associated ecological impacts of adjusting livestock management, lack of context-specific research (Pardo and del Prado, 2020) and socio-cultural barriers limiting access by women or low-income groups to better breeds or feed varieties (Luqman et al., 2018; Salmon et al., 2018), as well as women losing influence in the household in some contexts when farms intensify (Tavenner and Crane, 2018). In dryland livestock systems in Ethiopia and Kenya, Ericksen and Crane (2018) find that low governance capacities to implement improved grazing regimes constrain improved grassland management.

CCB FEASIB.3.2.9 Water use efficiency and water resource management

There is high technological feasibility (*robust evidence*, *high agreement*) of improving water use efficiency as well as of managing water resources at basin and field scales. These approaches include rainwater harvesting, drip irrigation, laser land levelling, drainage management and stubble retention (Dasgupta and Roy, 2017; Khatri-Chhetri et al., 2017; Rahman et al., 2017; Adham et al., 2018; Darzi-Naftchali and Ritzema, 2018; Terêncio et al., 2018; Velasco-Muñoz et al., 2018; Sojka et al., 2019). There is *robust evidence* (*medium agreement*) that such measures have socioeconomic co-benefits and improve adaptive capacities through improved water supply (e.g., through rainwater harvesting, increased infiltration or integrated watershed management) and sustainable water demand management (e.g., reduction of evaporation loss). There is *medium evidence* (*high agreement*) of the option's economic feasibility due to water and energy cost savings enhanced by low-cost monitoring systems in some cases (Kodali and Sarjerao, 2017; Viani et al., 2017). Implementation costs vary widely, with land forming and irrigation infrastructure requiring substantial up-front investment, while mulches and cover crops are low-cost practices. Water management and use efficiency is currently constrained by governance and institutional factors such as inadequate institutional capacities to prepare for changing water availability, especially in the long term; unsustainable and unequal water use and sharing practices, particularly across boundaries; and fragmented and siloed resource management approaches (Lardizabal, 2015; Margerum and Robinson, 2015; Singh et al., 2020a).

CCB FEASIB.3.2.10 Livelihood diversification

Livelihood diversification is a key coping and adaptation strategy to climatic and non-climatic risks (Gautam and Andersen, 2016; Asfaw et al., 2018; Liu, 2015; Goulden et al., 2013; Makate et al., 2016; Orchard et al., 2016; Nyantakyi-Frimpong, 2017; Schuhbauer et al., 2017; Kihila, 2018; Radel et al., 2018; Tian and Lemos, 2018; Buechler and Lutz-Ley, 2019; Salam and Bauer, 2020). There is *robust evidence* (*medium agreement*) that diversifying livelihoods improves incomes and reduces socioeconomic vulnerability, but depending on livelihood type, opportunities and local context, feasibility changes (Section 8.5.1) (Barrett, 2013; Martin and Lorenzen, 2016; Sina et al., 2019). Livelihood diversification has positive and negative outcomes for adaptive capacity, especially in ecologically and resource-stressed regions (e.g. Anderson et al., 2017; Woodhouse and McCabe, 2018; Rosyida et al., 2019; Ojea et al., 2020), with diversification predominantly out of rural farm-based livelihoods on the rise (Rigg and Oven, 2015; Shackleton et al., 2015; Ober and Sakdapolrak, 2020). Key barriers to livelihood diversification include socio-cultural and institutional barriers (including social networks; Goulden et al., 2013) as well as inadequate resources and livelihood opportunities that hinder the full adaptive possibilities of existing livelihood diversification practices (Shackleton et al., 2015; Nightingale, 2017b; Bhowmik et al., 2021; Rahut et al., 2021). Autonomous diversification in the absence of more equitable and harmonised efforts at regional and national scales to facilitate sustainable diversification can further skew development indicators at the sub-national scale in favour of local elites, increased inequality and environmental degradation (Ford et al., 2014; Wilson, 2014; Alobo Loison, 2015; Tanner et al., 2015; Gautam and Andersen, 2016; Baird and Hartter, 2017; Torell et al., 2017; Asfaw et al., 2018; Woodhouse and McCabe, 2018; Brown et al., 2019; Rosyida et al., 2019; Sani Ibrahim et al., 2019; Ojea et al., 2020; Salam and Bauer, 2020).

CCB FEASIB.3.3 Urban and infrastructure system transitions

CCB FEASIB.3.3.1 Sustainable land use and urban planning

Urban planning is a medium feasibility option to support adaptation by prioritising it in city plans, such as land use planning, transportation (Liang et al., 2020), and health and social services (Carter et al., 2015; Araos et al., 2016b); by procuring the design and construction of resilient infrastructure; by promoting community-based adaptation through community-based design and implementation of adaptation activities (Archer, 2016); and by protecting and integrating biodiversity and ecosystem services into city planning. Research since SR1.5 documents the challenging high costs of infrastructure (Georgeson et al., 2016; Woodruff et al., 2018); potential loss of municipal revenue in the case of managed retreat (Shi and Varuzzo, 2020; Siders and Keenan, 2020); and the fraught causal connection between planning

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

and the reduction of socioeconomic vulnerability (Keenan et al., 2018; Anguelovski et al., 2019a; Elliott, 2019; Paganini, 2019; Shokry et al., 2020). However, adaptation benefits could potentially outweigh costs (Carey, 2020). There is financial viability of green infrastructure (Meerow, 2019; Zhang et al., 2019; Van Oijstaeijen et al., 2020; Ossola and Lin, 2021); and availability of technical expertise, although the inequitable planning processes and distribution of those resources remains a significant concern (Serre and Heinzlef, 2018; Szewrański et al., 2018; Fitzgibbons and Mitchell, 2019; Hasan et al., 2019; Heikkinen et al., 2019; Colven, 2020; Goetz et al., 2020; Goh, 2020).

Structural disincentives and institutional arrangements create challenges for planning even where political willingness may be high (Di Gregorio et al., 2019; DuPuis and Greenberg, 2019; Shi, 2019; Zen et al., 2019; Rasmussen et al., 2020). Social resistance may significantly delay or block progress entirely, as vulnerable communities have responded negatively in cases where adaptive urban and land use planning leads to perceived 'resilience gentrification' (Keenan et al., 2018; Anguelovski et al., 2019a), if residents do not perceive themselves as included in the crafting of plans (Araos, 2020; Rasmussen et al., 2020), if the options such as managed retreat are perceived as culturally unacceptable (Ajibade, 2019; Koslov, 2019; Siders, 2019), or if wealthier and advantaged residents benefit from planning at the expense of socially vulnerable groups (Chu and Michael, 2018; Chu et al., 2018; Fainstein, 2018; Rosenzweig et al., 2018; Pelling and Garschagen, 2019a; Ranganathan and Bratman, 2021). Nonetheless, potential social co-benefits related to health and education are high (Raymond et al., 2017; Spaans and Waterhout, 2017; Klinenberg, 2018; Keeler et al., 2019; Meerow, 2019). Finally, the option is highly feasible in relation to ecological and geophysical characteristics, as urban and land use planning's primary tool is to shape the built environment and natural spaces to protect and reduce the vulnerability of residents.

CCB FEASIB.3.3.2 Green infrastructure and ecosystem services

Urban green infrastructure and ecosystem services have high feasibility to support climate adaptation and mitigation efforts in cities, for example to reduce flood exposure and attenuate the urban heat island effect (Perrotti and Stremke, 2018; Belčáková et al., 2019; De la Sota et al., 2019; Stefanakis, 2019). While green infrastructure options are cost-effective and provide co-benefits in terms of ecosystem services such as improved air quality or other health benefits (Depietri and McPhearson, 2017; Morris et al., 2018; Reguero et al., 2018; Escobedo et al., 2019; Filazzola et al., 2019; Hewitt et al., 2020b; Venter et al., 2020; Nieuwenhuijsen, 2021) (*robust evidence, high agreement*), a need remains for systematically assessing co-benefits, particularly for flood risk management (Alves et al., 2019; Stefanakis, 2019) and sustainable material flow analysis (Perrotti and Stremke, 2018). Moreover, while once neglected, rapidly increasing attention has been paid to the equity and justice dimensions of planning and implementing green infrastructure initiatives, such as inclusion of citizens in decision making or the allocation of benefits and impacts of projects (Anguelovski et al., 2019b; Buijs et al., 2019; Langemeyer et al., 2020; Venter et al., 2020)

Institutional barriers constrain the feasibility of urban green infrastructure (*medium confidence*), such as policy resistance to shift priorities from grey to green infrastructure (e.g., Johns, 2019 in Canada) or siloed governance structures (Willems et al., 2021). Further, social and political acceptability of green infrastructure is constrained by lack of confidence in efficacy (Thorne et al., 2018) or issues of accessibility (Biernacka and Kronenberg, 2018).

For flood management, a mix of green, blue and grey infrastructures are found effective, with grey infrastructure reducing the risk of flooding and green infrastructure yielding multiple co-benefits (Alves et al., 2019; Gu et al., 2019; Webber et al., 2020) but catchment-wide solutions are advocated as the best performing strategy (Webber et al., 2020). Recognising and addressing a full range of ecosystem disturbances and disasters over a larger urban spatial scale (Vargas-Hernández and Zdunek-Wielgołaska, 2021) are crucial for planning green infrastructure-based solutions. In some cases, low impact development interventions yield effective flood management outcomes but are adequate only for small flood peaks (Pour et al., 2020), with the major challenge being identifying best practices. NbS hold significant potential to achieve mitigation and adaptation goals in comparison with traditional approaches, but more research is necessary to understand their effectiveness, distribution, implementation at scale, cost-benefit and integration with spatial dimensions of planning (Davies et al., 2019; Dorst et al., 2019; Zwierzchowska et al., 2019; Hobbie and Grimm, 2020).

CCB FEASIB.3.3.3 Sustainable urban water management (blue infrastructure interventions e.g., lake/river restoration; rainwater harvesting)

Governments across scales can support urban sustainable water management with high feasibility by undertaking projects to recycle wastewater and runoff from higher intensity storms, with implications for decarbonisation and adaptation. Green infrastructure, for example, has shown a high potential to reduce water-use footprints and to save potable water for consumption (Liu and Jensen, 2018), and contributing to a 'circular' water system in cities (Oral et al., 2020). Supportive governance can yield positive outcomes such as improved water security (Jensen and Nair, 2019) and there is *medium evidence* and *high agreement* that participation, such as involving

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

informal settlement residents in water management can improve social inclusion (Pelling et al., 2018; Williams et al., 2018; Leigh and Lee, 2019b; Sletto et al., 2019). Green infrastructure can support the planning of 'sponge cities', such as in China, wherein large areas of green space, permeable surfaces and sustainable water sourcing combine to purify urban runoff, attenuate peak runoff and conserve water for consumption (Chan et al., 2018; Nguyen et al., 2019). Similar approaches in Dutch cities focus on designing and planning for the capturing, storing and draining of storm water (Dai et al., 2018). However, some interventions suffer from uncertainties in design, planning and financing (Nguyen et al., 2019). As drought becomes more severe in some regions, physical barriers in the form of reduced availability of water may become pressing (Singh et al., 2021b).

Deployment of decentralised water management through effective local governance frameworks, is an important water management strategy (Herslund and Mguni, 2019; Leigh and Lee, 2019b), but in general, insufficient institutional learning and capacity remains a critical barrier for the uptake of sustainable urban water management practices (Krueger et al., 2019a; Adem Esmail and Suleiman, 2020). Transnational networks of cities for sharing best practices in water supply and storm runoff treatment also hold the potential to scale sustainable management (Feingold et al., 2018). In rapidly growing large urban areas, sustainable water management faces challenges of institutional heterogeneity (Chu et al., 2018), scalar mismatch, particularly between river basin and city scales (van den Brandeler et al., 2019), and equity and justice concerns (Chu et al., 2018; Pelling et al., 2018). Finally, assessing the vulnerability of urban water infrastructures at city scale remains an important knowledge gap (Dong et al., 2020).

CCB FEASIB.3.4 Cross-cutting adaptation options

CCB FEASIB.3.4.1 Social safety nets

Social safety nets contribute to meeting development goals (e.g., poverty alleviation, accessible education and health services) and are increasingly being reconfigured to build adaptive capacities of the most vulnerable (Coirolo et al., 2013; Aleksandrova, 2020; Bowen et al., 2020; Fischer, 2020; Mueller et al., 2020). They include a range of policy and market-based instruments such as public works programmes and conditional or unconditional cash transfers, in-kind transfers, and insurance schemes (Centre, 2019; Aleksandrova, 2020). While there is *robust evidence* (*medium agreement*) that social safety nets can build adaptive capacities, reduce socioeconomic vulnerability and reduce risk linked to hazards (Fischer, 2020; Mueller et al., 2020), macroeconomic, institutional and regulatory barriers such as limited state resources, underdeveloped credit and insurance markets, and economic leakages constrain their feasibility (Singh et al., 2018c; Hansen et al., 2019; Aleksandrova, 2020; Lykke Strøbech and Bordon Rosa, 2020). Social safety nets have strong co-benefits with development goals (Section 8.6) (Castells-Quintana et al., 2018b; Ulrichs et al., 2019; Mueller et al., 2020) but these positive outcomes are constrained by inadequate regional inclusiveness (e.g., limited access in certain remote, rural areas; Singh et al., 2018b; Aleksandrova, 2020; Lykke Strøbech and Bordon Rosa, 2020) or focus on rural areas overlooks urban vulnerable groups (Coirolo et al., 2013).

CCB FEASIB.3.4.2 Risk spreading and sharing

There is *high confidence* on risk spreading and sharing, most commonly arranged through insurance, as an adaptation option, but high to medium feasibility depending on context (e.g., developed versus developing countries). Technological, economic and institutional feasibility is high, as insurance can spread risk, provide a buffer against the impact of climate hazards, support recovery and reduce the financial burden on governments, households and businesses (Wolfrom and Yokoi-Arai, 2015; O'Hare et al., 2016; Glaas et al., 2017; Jenkins et al., 2017; Patel et al., 2017; Kousky et al., 2021). Insurance can shift the mobilisation of financial resources away from *ad hoc* post-event payments, where funding is often unpredictable and delayed, towards more strategic approaches that are set up in advance of disastrous events (Surminski et al., 2016). By pricing risk, insurance can provide incentives for investments and behaviour that reduce vulnerability and exposure (Linnerooth-Bayer and Hochrainer-Stigler, 2015; Shapiro, 2016; Jenkins et al., 2017). Socio-cultural barriers, such as social inclusiveness, socio-cultural acceptability and gender equity constrains feasibility (Bageant and Barrett, 2017; Budhathoki et al., 2019). Insurance can provide disincentives for reducing risk through the transfer of the risk spatially and temporally, distorting incentives for adaptation if the pricing is too low (moral hazard) and is often unaffordable, poorly understood, and not widely utilised in developing nations even when subsidised, possibly leading to maladaptation (García Romero and Molina, 2015; Joyette et al., 2015; Lashley and Warner, 2015; Jin et al., 2016; Müller et al., 2017; Tesselaar et al., 2020). Insurance can reinforce exposure and vulnerability through underwriting a return to the 'status-quo' rather than enabling adaptive behaviour (e.g., through 'no-betterment' principles) (Collier and Cox, 2021). For low-income nations and in the absence of global support, insurance shifts responsibility to those least responsible for climate change (Surminski et al., 2016).

CCB FEASIB.3.4.3 Disaster risk management

There is *robust evidence* (*high agreement*) that DRM aids adaptation decision making, particularly where it is demand-driven, context-specific and supported by strong institutions, good governance, strong local engagement and trust across actors (Hasan et al., 2019; Kim

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

and Marcouiller, 2020; Peng et al., 2020; Smucker et al., 2020; Uddin et al., 2020; Webb, 2020; Ali et al., 2021; Anderson and Renaud, 2021; Glantz and Pierce, 2021; Ji and Lee, 2021; Villeneuve, 2021). These conditions are rarely met, and therefore DRM is often constrained by institutional factors that may even increase vulnerability (Booth et al., 2020; Islam et al., 2020b; Islam et al., 2020c; Marchezini, 2020; Goryushina, 2021; Mena and Hilhorst, 2021). The feasibility of DRM continues to be constrained by limited coordination across levels of government, lack of transparency and accountability, poor communication and a preference for top-down DRM processes that can undermine local institutions and perpetuate uneven power relationships (Atanga, 2020; Booth et al., 2020; Bordner et al., 2020; Bronen et al., 2020; Goryushina, 2021; Mena and Hilhorst, 2021; Son et al., 2021; Yumagulova et al., 2021). However, local integration of worldviews, belief systems and local and Indigenous Knowledge into DRM activities improves feasibility (Bordner et al., 2020; Cuaton and Su, 2020; Hosen et al., 2020; Sharma and Sharma, 2021), including disability-inclusive and gender-focused DRM (Ruszczyk et al., 2020; Crawford et al., 2021). Data access and availability continues to challenge DRM despite advances in data analytics, especially in rapidly growing informal settlements, including population estimates and limited mobility data (Goniewicz and Burkle, 2019; Marchezini, 2020).

Moves towards community-based and ecosystem-based DRMs are promising but uneven (Klein et al., 2019; Seebauer et al., 2019; Almutairi et al., 2020; Bordner et al., 2020; Hosen et al., 2020; Murti et al., 2020; Sharma and Sharma, 2021), and may increase vulnerability if they fail to address underlying, structural determinants of vulnerability, particularly among marginalised groups and by gender (Sections 8.4.4 and 8.4.5) (Seleka et al., 2017; Hossen et al., 2019; Ramalho, 2019b; Atanga, 2020; Cuaton and Su, 2020; Gartrell et al., 2020; Kenney and Phibbs, 2020; Khalil et al., 2020; Ngin et al., 2020; Ruszczyk et al., 2020; Webb, 2020; Ali et al., 2021; Geekiyanage et al., 2021; Villeneuve, 2021).

CCB FEASIB.3.4.4 Climate services, including early warning systems

There is *robust evidence* (*high agreement*) that climate services aid adaptation decision making and build adaptive capacity, particularly where they are demand-driven and context-specific (Vaughan et al., 2018; Bruno Soares and Buontempo, 2019; Daniels et al., 2020; Hewitt et al., 2020a; Findlater et al., 2021). Climate service interventions are constrained by low capacity, inadequate institutions, difficulties in maintaining systems beyond pilot project stage (Vincent et al., 2017; Tall et al., 2018; Bruno Soares and Buontempo, 2019), and poor mapping between climate services and existing user capacities and demands (Williams et al., 2020) (*robust evidence*, *high agreement*). Metrics to assess outcomes of climate services remain project-based and insufficiently capture longer-term economic and non-economic benefits of interventions (Tall et al., 2018; Parton et al., 2019; Perrels, 2020). The technical feasibility of climate services is relatively strong and growing (Vaughan et al., 2016; Kihila, 2017; Findlater et al., 2021) but they can be made more inclusive by focusing on addressing uneven uptake based on location or gender (Amegnaglo et al., 2017; Daly and Dessai, 2018; Tall et al., 2018; Alexander and Dessai, 2019; Vaughan et al., 2019; Gumucio et al., 2020) and a more balanced focus on uptake rather than data production alone (Dorward et al., 2021; Findlater et al., 2021) that values co-production and different knowledge systems (Daniels et al., 2020; Martínez-Barón et al., 2021).

CCB FEASIB.3.4.5 Health and health systems adaptation

Climate change will exacerbate existing health challenges. Strong health systems can protect and promote the health of a population in the face of known and unexpected stressors and pressures (Watts et al., 2021), including climate change. The building blocks of strong health systems engender climate resilience, strong leadership and governance, and effective coordination across sectors, to prioritise the needs of the most vulnerable (Ebi et al., 2020). Options for enhancing current health services include providing access to safe water and sanitation, improving food security, enhancing access to essential services such as vaccinations, developing or strengthening integrated surveillance systems, and changing the timing and location of specific vector-control measures (WHO, 2015; Haines and Ebi, 2019). These measures can reduce the health system's vulnerability to climate change, especially if combined with iterative management that incorporates monitoring of (and resilience against) climate change impacts (Hanefeld et al., 2018; Haines and Ebi, 2019; Linares et al., 2020; Rudolph et al., 2020) (*medium evidence*, *high agreement*).

Health systems can provide sufficient and high-quality healthcare to all where capacity is well developed, and where options are aligned with national priorities, engage local to international communities, and address the needs of particularly vulnerable regions and population groups (Hanefeld et al., 2018; Austin et al., 2019; Nuzzo et al., 2019; Sheehan and Fox, 2020). Microeconomic feasibility and socioeconomic vulnerability reduction potential are high where a system's capacity is well developed. Economic feasibility poses a significant challenge in low-income settings, with many governments projected to require international climate finance for health systems which is not currently available (WHO, 2019; Watts et al., 2021), and where adequate household-level financial security is a cross-cutting barrier (Paudel and Pant, 2020). Risk mitigation potential is high where capacity is well developed, for example through technologies to monitor and alter environmental conditions (Lock-Wah-Hoon et al., 2020; Kouis et al., 2021; Ligsay et al., 2021). Social co-benefits of mainstreaming health and climate change are also present, such as the inclusion of environmental health in medical education curricula training programmes (Kligler et al., 2021). There is growing recognition that lack of institutional capacity and low availability of resources represent major barriers to health system adaptation options, particularly for health systems struggling to manage current health risks

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

(Ebi et al., 2018; Brooke-Sumner et al., 2019; Chersich and Wright, 2019; Gilfillan, 2019; Negev et al., 2019; Hussey and Arku, 2020), for neglected populations (Hanefeld et al., 2018; Negev et al., 2019), and where there are conflicting mandates or poor coordination across ministries (Austin et al., 2019; Fox et al., 2019; Gilfillan, 2019; Kendrovski and Schmoll, 2019; Sheehan and Fox, 2020). Barriers to adapting health systems to climate change include lack of institutional funding, staff and data access (Austin et al., 2019; Schramm et al., 2020; Opoku et al., 2021), inadequate resources for evaluation and management of adaptation (Pascal et al., 2021), competing stakeholder goals and costly technology (Negev et al., 2021). Within the healthcare community, surveillance systems generally lack ways to integrate climate observation data, as well as expertise to critically evaluate these data, limiting their ability to plan and prepare for climate hazards and hospital-associated vulnerabilities (Runkle et al., 2018; Chersich and Wright, 2019; Liao et al., 2019). Although understanding of health vulnerability is growing (Berry et al., 2018), knowledge on the health effects of climate change among health practitioners remains limited (Ebi et al., 2018; Brooke-Sumner et al., 2019; Chersich and Wright, 2019; Fox et al., 2019; Liao et al., 2019; Albright et al., 2020). Mechanisms to ensure transparency and accountability of implementing, monitoring and evaluating adaptation within the health sector are lacking, across scales and contexts (Gostin and Friedman, 2017; Huynh and Stringer, 2018; Parry et al., 2019).

CCB FEASIB.3.4.6 Human migration

Much climate-related migration is associated with labour migration. Rural–urban migrant networks are important channels for remittances and knowledge that help build resilience to hazards in sending areas (Bragg et al., 2018; Obokata and Veronis, 2018; Semenza and Ebi, 2019; Maharjan et al., 2020; Porst et al., 2020). Whether migration reduces vulnerability for migrants depends on levels of control over the migration decision and assets such as wealth, and education of the migrant household (Thober et al., 2018; Cattaneo, 2019; Hoffmann et al., 2020; Maharjan et al., 2020; Sedova and Kalkuhl, 2020). Individuals from households of all levels of wealth migrate. However, poorer households do so with lower levels of choice and often more likely under duress, and in these cases, migration can undermine well-being (Suckall et al., 2016; Mallick et al., 2017; Nawrotzki and DeWaard, 2018; Natarajan et al., 2019). In some cases, migration can increase poverty in sending communities (Jacobson et al., 2019). Women in the sending community can experience an increase or decrease in the vulnerability, depending on the livelihoods people are moving into and existing asset bases (Banerjee et al., 2018; Banerjee et al., 2019b; Goodrich et al., 2019; Maharjan et al., 2020; Rao et al., 2020; Singh and Basu, 2020; Singh et al., 2020b).

Migration has been highly politicised, and climate-related immigration has been conceptualised in public and media discourse as a potential threat which limits adaptation feasibility (Telford, 2018; Honarmand Ebrahimi and Ossewaarde, 2019; McLeman, 2019; Wiegel et al., 2019; Hauer et al., 2020). Existing international agreements provide potential frameworks for climate-related migration to benefit adaptive capacity and sustainable development (Warner, 2018; Kälin, 2019). However, agreements to facilitate temporary or circular migration and remittances are often informal and limited in scope (Webber and Donner, 2017b; Margaret and Matias, 2020) and migrant receiving areas, particularly urban areas, can be better assisted to prepare for population change (Deshpande et al., 2019; Adger et al., 2020; Hauer et al., 2020). Policies and planning are lacking that would ensure that positive migration outcomes for sending and receiving areas and the migrants themselves (Wrathall et al., 2019; Adger et al., 2020; de Salles Cavedon-Capdeville et al., 2020; Hughes, 2020).

Investing in building *in situ* adaptive capacity through climate resilient development is a precondition to supporting high agency migration (Cundill et. al. 2021). Migration only tends to occur when adaptation *in situ* has been exhausted and thresholds for living with risk have been crossed (Sections 8.2.2.1, 8.4.4, 8.4.5) (McLeman, 2018; Adams and Kay, 2019; Semenza and Ebi, 2019). The financial, emotional and social costs of leaving are high (Adams and Kay, 2019; McNamara et al., 2021), there are environmental, health and well-being risks in destination areas (Schwerdtle et al., 2018; Schwerdtle et al., 2020), and existential threats to identity and citizenship (Oakes, 2019; Piguet, 2019; Desai et al., 2021). In receiving areas, without appropriate policies to ensure equitable provision of services, there can be socio-cultural barriers to in-migration where there is the perception of a loss caused by new arrivals, although outcomes are mixed (Koubi et al., 2018; Linke et al., 2018; Spilker et al., 2020; Petrova, 2021).

CCB FEASIB.3.4.7 Planned relocation and resettlement

Few climate-related planned resettlement and relocation initiatives have taken place. However, initial findings, and experience from past development and disaster-related resettlement programmes, show that when implemented in a top-down manner and without the full participation of those affected, resettlement increases vulnerability by undermining livelihoods and negatively impacting health, community cohesion and emotional and psychological well-being (Wilmsen and Webber, 2015; Dannenberg et al., 2019; Piggott-McKellar et al., 2019; Tabe, 2019; Ajibade et al., 2020; Henrique and Tschakert, 2020; Desai et al., 2021). Planned relocation could also redistribute vulnerability for those who do not move (Thomas and Benjamin, 2018; Mach et al., 2019a; Piggott-McKellar et al., 2019; Johnson et al., 2021; Maldonado et al., 2021) and vulnerability generally is reproduced along existing social cleavages often worsening inequality (See and Wilmsen, 2020). Approaches that foreground participation, non-material and socio-cultural factors, livelihoods and local power dynamics can be addressed and adjusted to prevent planned relocation from reproducing inequality (See and Wilmsen, 2020; Alverio et al., 2021).

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

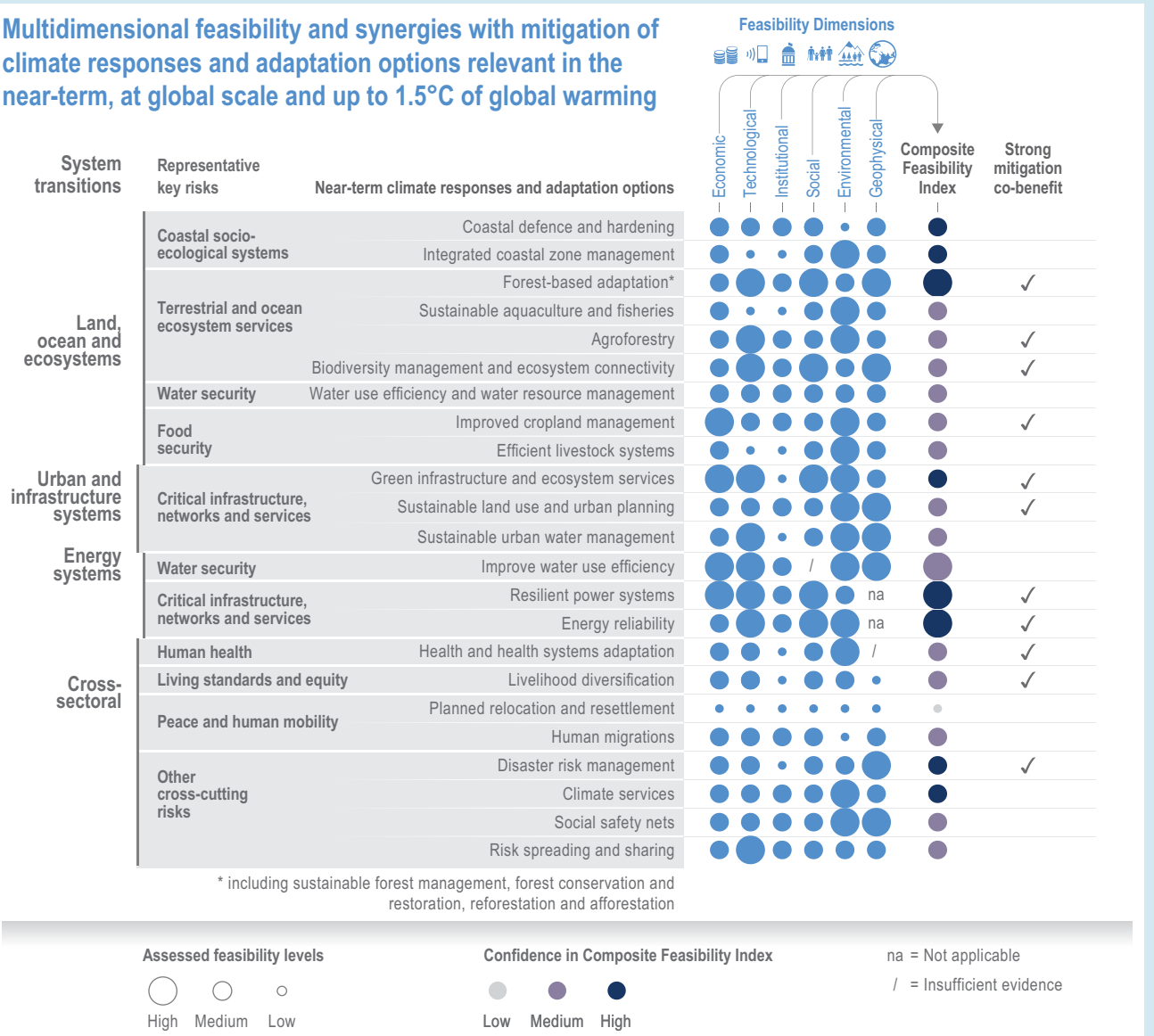


Figure Cross-Chapter Box FEASIB.2 | This figure summarizes the assessment results classifying options by System Transitions and Representative Key Risks. Each option is assessed across six dimensions: economic, technological, institutional, socio-cultural, environmental and geophysical. Each dimension is assessed as high (big circle), medium (medium circle), low (small circle) feasibility, and limited evidence or no evidence (LE/NE, as a dash). Composite feasibility is calculated across the six dimensions following the same key as above, with feasibility levels determined by circle size and confidence levels by shades of colour. The last column shows options with strong synergies with mitigation, which is then broken down in Fig. CCB FEASIB.3.

There is inadequate institutional capacity to enable movement relocation, with global and national policies identified as too abstract and lacking guidance on ensuring equity (Mortreux et al., 2018; Kelman et al., 2019; Ajibade et al., 2020; Hauer et al., 2020; Alverio et al., 2021). Lack of institutional capacity can lead to resettlements being stalled indefinitely. Climate-related resettlement can be facilitated by novel institutional structures that expand the definition of disaster to include slow onset events, adaptive management frameworks that facilitate a continuum of responses from supporting communities to community relocation and approaches that incorporate existing power dynamics (Bronen and Chapin, 2013; See and Wilmsen, 2020). In 2018, the Fiji Government provided a framework for climate change-related relocation and equipped communities with rights in the planned relocation process (McMichael and Katonivualiku, 2020). However, even with guidelines in place, local socio-cultural dynamics complicate planning, and relocation should take place only after cost–benefit analysis of all available adaptation options (Jolliffe, 2016; Bronen and Chapin, 2013; Albert et al., 2017; Mortreux et al., 2018). At a local level, issues around land tenure, a lack of financial support, dedicated governance frameworks and complex planning processes delay action (Albert et al., 2017). Funding for climate-related resettlement is currently not readily available, exacerbated by

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

a lack of appropriate mechanisms through which to deliver that funding (Boston et al., 2021). For example, planned relocation projects cannot access disaster relief funds in the USA because of the slow onset nature of the impacts (Bronen and Chapin, 2013).

Without consultation, relocated people can experience significant financial and emotional distress as cultural and spiritual bonds to place and livelihoods are disrupted (Neef et al., 2018; Roy et al., 2018b; Piggott-McKellar et al., 2019; Bertana, 2020; McMichael and Katonivualiku, 2020; McMichael et al., 2021; Jain et al. 2021). However, in some places, where climate risks are acute, political acceptance for planned relocation is high (e.g., (McNamara, 2015; Roy et al., 2018b) in Kiribati). Socio-cultural feasibility can be improved by participatory approaches and, where possible, moving within ancestral lands (McNamara, 2015). In this case, voluntary planned relocation can represent the assertion of people living in an area to preserve land and community-based social, cultural and spiritual ties.

A summary of feasible options to enable four 1.5°C-relevant system transitions is presented in Figure Cross-Chapter Box FEASIB.2.

CCB FEASIB.4 Synergies and trade-offs

The feasibility assessment focuses on individual adaptation options. However, systems transitions necessitate assessing how mitigation and adaptation options *interact* to mediate overall feasibility. To capture these linkages, this section reports synergies and trade-offs of (a) adaptation options for mitigation and (b) mitigation options for adaptation (following (de Coninck et al., 2018b) as the outcome of an iterative assessment between WGII and WGIII authors. Also assessed are synergies and trade-offs of adaptation with the SDGs, following (which was done for mitigation alone).

(a) Climate responses and adaptation options and their implications for mitigation

System transitions	Representative key risks	Near-term climate responses and adaptation options	Synergies with mitigation	Trade-offs with mitigation
Land, ocean and ecosystems	Coastal socio-ecological systems	Coastal defence and hardening	not applicable	●
		Integrated coastal zone management	●	●
	Terrestrial and ocean ecosystem services	Forest-based adaptation*	●●●	●
		Sustainable aquaculture and fisheries	●●	●
		Agroforestry	●	●
		Biodiversity management and ecosystem connectivity	●●●	●
	Water security	Water use efficiency and water resource management	●●	●
	Food security	Improved cropland management	●●●	●
		Efficient livestock systems	●	●
Urban and infrastructure systems	Critical infrastructure, networks and services	Green infrastructure and ecosystem services	●●●	●
		Sustainable land use and urban planning	●●	●
		Sustainable urban water management	●	●
Energy systems	Water security	Improve water use efficiency	●	not applicable
	Critical infrastructure, networks and services	Resilient power systems	●●●	●
		Energy reliability	●	●
Cross-sectoral	Human health	Population health and health systems	●●●	●
	Living standards and equity	Livelihood diversification	●●●	●
	Peace and human mobility	Planned relocation and resettlement	●	not applicable
		Human migration	●	not applicable
	Other cross-cutting risks	Disaster risk management	●●●	●
		Climate services		insufficient evidence
		Social safety nets	●	not applicable
		Risk spreading and sharing	●	●●

* Including sustainable forest management, forest conservation and restoration, avoided deforestation, reforestation and afforestation.

Overall strength of synergy/trade-off: None · Low ○ Medium ○ High ○

Overall confidence: Low ● Medium ● High ●

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

(b) Mitigation options and their implications for adaptation

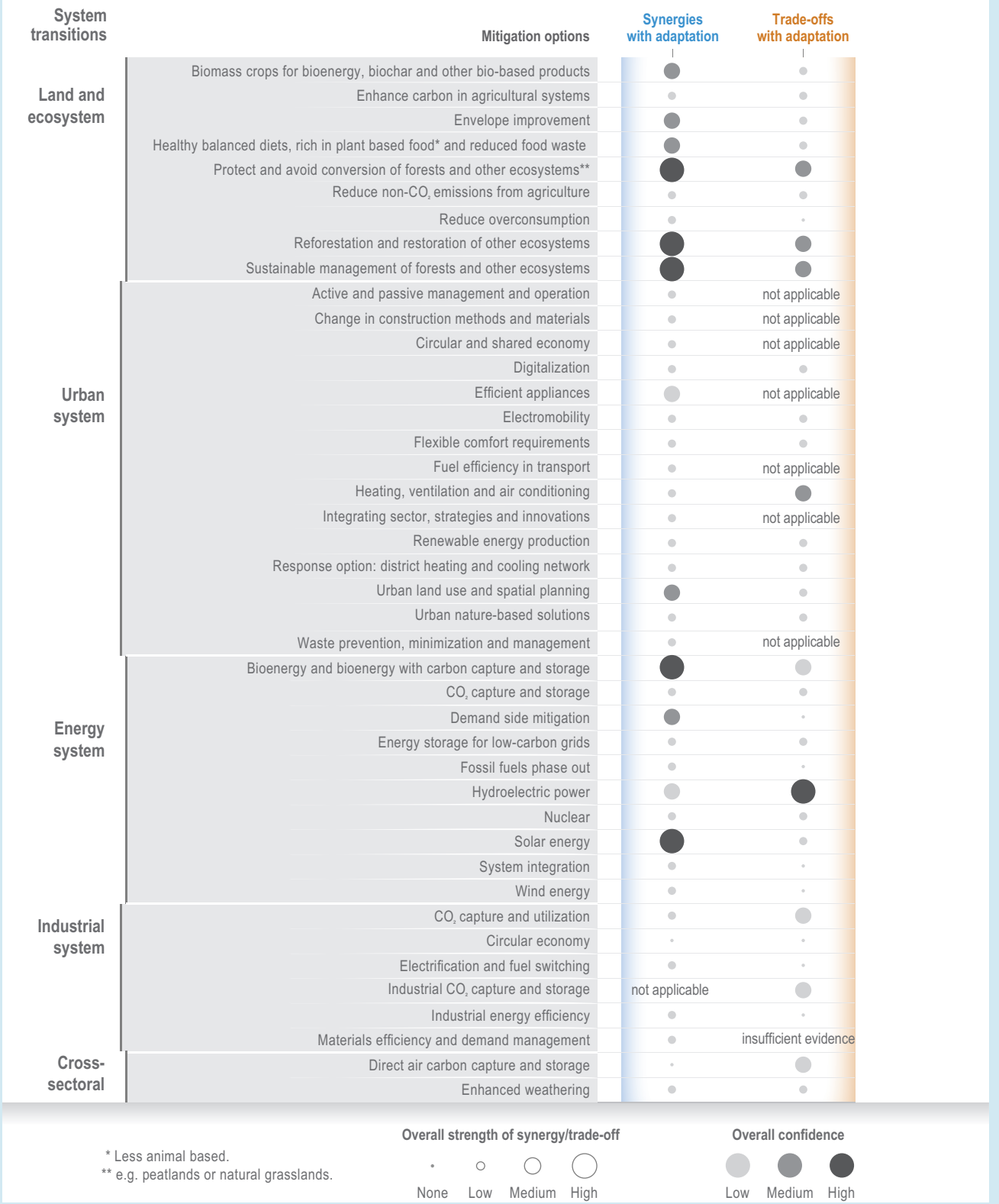


Figure Cross-Chapter Box FEASIB.3 | This figure shows a) adaptation options synergies and trade-offs with mitigation and b) mitigation options synergies and trade-offs with adaptation. The size of the circle denotes the strength of the synergy or trade-offs with big circles meaning strong synergy or trade-off and small circles denoting a weak synergy or trade-off.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

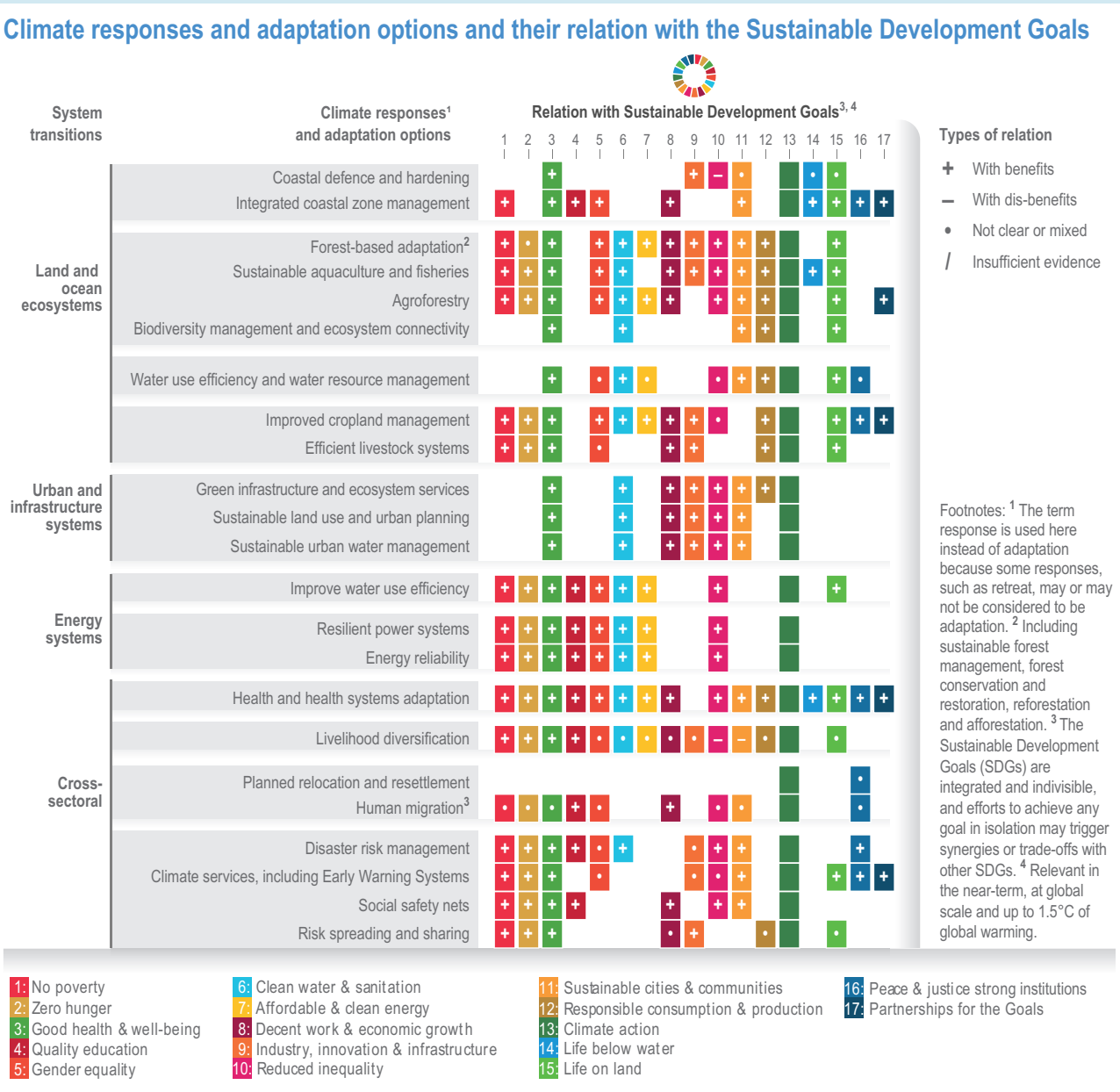


Figure Cross-Chapter Box FEASIB.4 | This figure summarises the assessment of the nexus of each adaptation option considered in this CCB with the 17 Sustainable Development Goals (SDGs). SDGs with which there is a nexus are colored and have a + for positive nexus, – for negative nexus and +/– for mixed nexus. Blank cells either don't have a nexus or there is no or limited evidence of such nexus.

CCB FEASIB.5 Knowledge Gaps

Despite the progress in new evidence since the SR1.5, there remain several knowledge gaps for the assessment of adaptation and mitigation options. They are underlying the Figure Cross-Chapter Box FEASIB.2 through the NE (no evidence) or LE (*limited evidence*).

Within energy system transitions, resilient power infrastructure has knowledge gaps on indicators of transparency and accountability potential, socio-cultural acceptability, social and regional inclusiveness, and intergenerational equity.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Under land and ecosystem system transitions, gaps include *limited evidence* for some of the institutional and socio-cultural feasibility dimensions indicators of Integrated Coastal Zone Management. Specifically, there is lack of evidence for transparency and accountability potential and for gender and intergenerational equity. For coastal defence and hardening, there is no or *limited evidence* on the indicators of employment and productivity enhancement, legal and regulatory acceptability, transparency and accountability potential, social and regional inclusiveness, benefits for gender equity, intergenerational equity and land use change enhancement potential. Sustainable aquaculture has knowledge gaps for the indicators of macroeconomic viability, legal and regulatory acceptability, transparency and accountability potential, social and regional inclusiveness, intergenerational equity and land use change enhancement potential. The geographical feasibility for migration and relocation is still an emerging area of research, however, there is *limited evidence* to assess this specific dimension.

The options of forest-based adaptation and biodiversity management and ecosystems connectivity have knowledge gaps for the indicators of risk mitigation potential, legal and regulatory feasibility, and social and regional inclusiveness. The option of improved cropland management has no or *limited evidence* for the indicators of legal and regulatory feasibility, transparency and accountability potential and hazard risk reduction potential. The efficient livestock systems option has no evidence for political acceptability and legal and regulatory feasibility, and *limited evidence* for overall institutional feasibility. Agro-forestry has knowledge gaps for employment and productivity enhancement, transparency and accountability potential and intergenerational equity. There is also *limited evidence* for the economic and technical feasibility dimensions for ecosystem connectivity.

For urban and infrastructure systems, the option of green infrastructure and ecosystem services has *limited evidence* for macroeconomic viability, employment and productivity enhancement, and political acceptability. Sustainable water management has gaps for macroeconomic viability, employment and productivity enhancement, and transparency and accountability potential.

For cross-cutting options, the main knowledge gaps identified are socio-cultural acceptability for social safety nets. While the evidence on resettlement, relocation and migration is large and growing, there is disagreement on several indicators, marking the need for more evidence synthesis. Geophysical feasibility for resettlement, relocation and migration has *limited evidence*, but is an emerging area of research.

In general, throughout most of the options, there is significantly less literature from the regions of Central and South America, and West and Central Asia, as compared with other world regions.

References

Accatino, F., et al., 2019: Trade-offs and synergies between livestock production and other ecosystem services. *Agric Syst*, **168**, 58–72, doi:10.1016/j.agsy.2018.08.002.

Acevedo, M., et al., 2020: A scoping review of adoption of climate-resilient crops by small-scale producers in low- and middle-income countries. *Nat. Plants*, **6**, 1231–1241, doi:10.1038/s41477-020-00783-z.

Adams, A.M., et al., 2020: Long-term effects of integrated soil fertility management practices on soil chemical properties in the Sahel. *Geoderma*, **366**, 114207, doi:10.1016/j.geoderma.2020.114207.

Adams, H. and S. Kay, 2019: Migration as a human affair: Integrating individual stress thresholds into quantitative models of climate migration. *Environ. Sci. Policy*, **93**, 129–138, doi:10.1016/j.envsci.2018.10.015.

Esmail, A. and L. Suleiman, 2020: Analyzing evidence of sustainable urban water management systems: a review through the lenses of sociotechnical transitions. *Sustainability*, **12**(11), doi:10.3390/su12114481.

Adger, W.N., et al., 2020: Urbanization, migration, and adaptation to climate change. *One Earth*, **3**, 396–399, doi:10.1016/j.oneear.2020.09.016.

Adham, A., et al., 2018: A GIS-based approach for identifying potential sites for harvesting rainwater in the Western Desert of Iraq. *Int. Soil Water Conserv. Res.*, **6**(4), 297–304, doi:10.1016/j.iswcr.2018.07.003.

Aerts, J.C.J.H., 2018: *A Review of Cost Estimates for Flood Adaptation*.

Agarwal, P.K. and D. Pandey, 2017, *Impact of pesticide: an overview.* Trends in Biosciences, (10)6, 1341–1344.

Agegnehu, G. and T. Amede, 2017: *Integrated Soil Fertility and Plant Nutrient Management in Tropical Agro-Ecosystems: A Review*. Soil Science Society of China, 662–680.

Ahmed, B., 2018: Who takes responsibility for the climate refugees? *Int. J. Clim. Chang. Strateg. Manag.*, **10**, 5–26, doi:10.1108/IJCCSM-10-2016-0149.

Ahmed, N., et al., 2018: Blue-green water nexus in aquaculture for resilience to climate change. *Rev. Fish. Sci. Aquac.*, **26**, 139–154, doi:10.1080/23308249.2017.1373743.

Ajibade, I., 2019: Planned retreat in global south megacities: disentangling policy, practice, and environmental justice. *Clim. Change*, doi:10.1007/s10584-019-02535-1.

Ajibade, I., M. Sullivan and M. Haeffner, 2020: Why climate migration is not managed retreat: Six justifications. *Glob. Environ. Chang.*, **65**, 102187, doi:10.1016/J.GLOENVCHA.2020.102187.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Albert, S., et al., 2017: Winners and losers as mangrove, coral and seagrass ecosystems respond to sea-level rise in Solomon Islands. *Environ. Res. Lett.*, **12**, 94009.
Albright, K., P. Shah, M. Santodomingo and J. Scandlyn, 2020: Dissemination of information about climate change by state and local public health departments: United States, 2019-2020. *Am J Public Health*, **110**, 1184–1190, doi:10.2105/AJPH.2020.305723.
Aleksandrova, M., 2020: Principles and considerations for mainstreaming climate change risk into national social protection frameworks in developing countries. *Clim. Dev.*, **12**, 511–520, doi:10.1080/17565529.2019.1642180.
Alexander, M. and S. Dessai, 2019: What can climate services learn from the broader services literature? *Clim. Change*, **157**, 133–149, doi:10.1007/s10584-019-02388-8.
Ali, B. and A. Kumar, 2016: Development of life cycle water footprints for gas-fired power generation technologies. *Energy Convers. Manag.*, **110**, 386–396, doi:10.1016/j.enconman.2015.12.048.
Ali, T., et al., 2021: Integrating Indigenous perspectives and community-based disaster risk reduction: a pathway for sustainable Indigenous development in Northern Pakistan. *Int. J. Disaster Risk Reduct.*, **59**, 102263, doi:10.1016/j.ijdrr.2021.102263.
Alleway, H.K., et al., 2018: The ecosystem services of marine aquaculture: valuing benefits to people and nature. *BioScience*, **69**, 59–68, doi:10.1093/biosci/biy137.
Almutairi, A., M. Mourshed and R.F.M. Ameen, 2020: *Coastal Community Resilience Frameworks for Disaster Risk Management*. Springer, 595–630.
Alobo Loison, S., 2015: Rural livelihood diversification in Sub-Saharan Africa: a literature review. *J. Dev. Stud.*, **51**, 1125–1138, doi:10.1080/00220388.2015.1046445.
Alverio, G.N., S.H. Hoagland, E.C. Perez and K.J. Mach, 2021: The role of international organizations in equitable and just planned relocation. *J Environ Stud Sci*, 1–12, doi:10.1007/S13412-021-00698-X.
Alves, A., et al., 2019: Assessing the co-benefits of green-blue-grey infrastructure for sustainable urban flood risk management. *J. Environ. Manag.*, **239**, 244–254, doi:10.1016/j.jenvman.2019.03.036.
Alves, B., D.B. Angnuureng, P. Morand and R. Almar, 2020: A review on coastal erosion and flooding risks and best management practices in West Africa: what has been done and should be done. *J. Coast. Conserv.*, **24**, 38, doi:10.1007/s11852-020-00755-7.
Ambrosino, C., et al., 2020: *Integrating climate adaptation, poverty reduction, and environmental conservation in Kwale county, Kenya*. Springer International Publishing, 1–19.
Amegnaglo, C.J., et al., 2017: Contingent valuation study of the benefits of seasonal climate forecasts for maize farmers in the Republic of Benin, West Africa. *Clim. Serv.*, **6**, 1–11, doi:10.1016/j.cliser.2017.06.007.
Amjath-Babu, T.S., P.K. Aggarwal and S. Vermeulen, 2019: Climate action for food security in South Asia? Analyzing the role of agriculture in nationally determined contributions to the Paris Agreement. *Clim. Policy*, **19**, 283–298, doi:10.1080/14693062.2018.1501329.
Anderson, C.C. and F.G. Renaud, 2021: A review of public acceptance of nature-based solutions: the 'why', 'when', and 'how' of success for disaster risk reduction measures. *Ambio*, **50**(8), 1552–1573, doi:10.1007/s13280-021-01502-4.
Anderson, S.C., et al., 2017: Benefits and risks of diversification for individual fishers. *Proc. Natl. Acad. Sci. U.S.A.*, **114**, 10797–10802, doi:10.1073/pnas.1702506114.
Anguelovski, I., et al., 2019a: New scholarly pathways on green gentrification: What does the urban 'green turn' mean and where is it going? *Prog Hum Geogr*, **43**, 1064–1086, doi:10.1177/0309132518803799.
Anguelovski, I., C. Irazábal-Zurita and J.J.T. Connolly, 2019b: Grabbed urban landscapes: Socio-spatial tensions in green infrastructure planning in Medellín. *Int. J. Urban Reg. Res.*, **43**, 133–156, doi:10.1111/1468-2427.12725.
Antunes do Carmo, J.S., 2018: *Climate Change, Adaptation Measures, and Integrated Coastal Zone Management: the New Protection Paradigm for the Portuguese Coastal Zone*. Coastal Education Research Foundation Inc., 687–703.
Apuri, I., K. Peprah and G.T.W. Achana, 2018: Climate change adaptation through agroforestry: The case of Kassena Nankana West District, Ghana. *Environ. Dev.*, **28**, 32–41, doi:10.1016/j.envdev.2018.09.002.
Araos, M., 2020: Democracy underwater: public participation and technical expertise in climate infrastructure planning in New York City. *Soc. Sci. Res. Netw.*
Araos, M., S.E. Austin, L. Berrang-Ford and J.D. Ford, 2016a: Public health adaptation to climate change in large cities: A global baseline. *Int J Health Serv*, **46**, 53–78, doi:10.1177/0020731415621458.
Araos, M., et al., 2016b: Climate change adaptation planning in large cities: A systematic global assessment. *Environ. Sci. Policy*, **66**, 375–382, doi:10.1016/j.envsci.2016.06.009.
Archer, D., 2016: Building urban climate resilience through community-driven approaches to development. *Int. J. Clim. Chang. Strateg. Manag.*, **8**, 654–669, doi:10.1108/IJCCSM-03-2014-0035.
Aryal, J.P., et al., 2018a: Adoption of multiple climate-smart agricultural practices in the Gangetic plains of Bihar, India. *Int. J. Clim. Chang. Strateg. Manag.*, **10**, 407–427, doi:10.1108/IJCCSM-02-2017-0025.
Aryal, J.P., M.B. Mehrotra, M.L. Jat and H.S. Sidhu, 2015a: Impacts of laser land leveling in rice–wheat systems of the north–western Indo-Gangetic plains of India. *Food Sec.*, **7**, 725–738, doi:10.1007/s12571-015-0460-y.
Aryal, J.P., et al., 2018b: Factors determining the adoption of laser land leveling in the irrigated rice–wheat system in Haryana, India. *J. Crop Improv.*, **32**, 477–492, doi:10.1080/15427528.2018.1457584.
Aryal, J.P., D.B. Rahut, S. Maharjan and O. Erenstein, 2018c: Factors affecting the adoption of multiple climate-smart agricultural practices in the Indo-Gangetic plains of India. *Nat Resour Forum*, **42**, 141–158, doi:10.1111/1477-8947.12152.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Aryal, J.P., T.B. Sapkota, M.L. Jat and D.K. Bishnoi, 2015b: On-farm economic and environmental impact of zero-tillage wheat: A case of North-West India. *Exp. Agric.*, **51**, 1–16, doi:10.1017/S001447971400012X.
Aryal, J.P., et al., 2020a: Climate change and agriculture in South Asia: adaptation options in smallholder production systems. *Environ. Dev. Sustain.*, **22**, 5045–5075, doi:10.1007/s10668-019-00414-4.
Aryal, J.P., T.B. Sapkota, D.B. Rahut and M.L. Jat, 2020b: Agricultural sustainability under emerging climatic variability: the role of climate-smart agriculture and relevant policies in India. *Int. J. Innov. Sustain. Dev.*, **14**, 219–245.
Asfaw, S., G. Pallante and A. Palma, 2018: Diversification strategies and adaptation deficit: evidence from rural communities in Niger. *World Dev*, **101**, 219–234, doi:10.1016/j.worlddev.2017.09.004.
Atanga, R.A., 2020: The role of local community leaders in flood disaster risk management strategy making in Accra. *Int. J. Disaster Risk Reduct.*, **43**, doi:10.1016/j.ijdrr.2019.101358.
Aubin, J., et al., 2019: Implementing ecological intensification in fish farming: definition and principles from contrasting experiences. *Rev. Aquac.*, **11**, 149–167, doi:10.1111/raq.12231.
Austin, S.E., et al., 2019: Enabling local public health adaptation to climate change. *Soc. Sci. Med.*, **220**, 236–244, doi:10.1016/j.socscimed.2018.11.002.
Awazi, N.P., M.N. Tchamba and L.F. Temgoua, 2021: Climate-smart practices of smallholder farmers in Cameroon confronted with climate variability and change: the example of agroforestry. *Agric. Res.*, **10**, 83–96, doi:10.1007/s40003-020-00477-0.
Bageant, E.R. and C.B. Barrett, 2017: Are there gender differences in demand for index-based livestock insurance? *J. Dev. Stud.*, **53**, 932–952, doi:10.1080/00220388.2016.1214717.
Baills, A., M. Garcin and T. Bulteau, 2020: Assessment of selected climate change adaptation measures for coastal areas. *Ocean. Coast. Manag.*, **185**, 105059, doi:10.1016/j.ocecoaman.2019.105059.
Baird, T.D. and J. Hartter, 2017: Livelihood diversification, mobile phones and information diversity in Northern Tanzania. *Land Use Policy*, **67**, 460–471, doi:10.1016/j.landusepol.2017.05.031.
Banerjee, S., et al., 2018: Assessing vulnerability of remittance-recipient and nonrecipient households in rural communities affected by extreme weather events: Case studies from S outh-W est. *Wiley Online Libr.*, **25**, doi:10.1002/psp.2157.
Banerjee, S., A. Hussain, S. Tuladhar and A. Mishra, 2019: Building capacities of women for climate change adaptation: insights from migrant-sending households in Nepal. *Clim. Change*, **157**, 587–609, doi:10.1007/S10584-019-02572-W.
Barnett, J., et al., 2015: From barriers to limits to climate change adaptation: Path dependency and the speed of change. *Ecol. Soc.*, **20**, doi:10.5751/ES-07698-200305.
Barragán Muñoz, J.M., 2020: Progress of coastal management in Latin America and the Caribbean. *Ocean. Coast. Manag.*, **184**, 105009, doi:10.1016/j.ocecoaman.2019.105009.
Barreto, G.C., M. Di Domenico and R.P. Medeiros, 2020: Human dimensions of marine protected areas and small-scale fisheries management: A review of the interpretations. *Mar. Policy.*, **119**, 104040, doi:10.1016/j.marpol.2020.104040.
Barrett, S., 2013: Local level climate justice? Adaptation finance and vulnerability reduction. *Glob. Environ. Change*, **23**(6), 1819–1829, doi:10.1016/j.gloenvcha.2013.07.015.
Bazaz, A., et al. (ed.), *Summary for Urban Policymakers – What the IPCC Special Report on 1.5C Means for Cities*.
Bedeke, S., et al., 2019: Adoption of climate change adaptation strategies by maize-dependent smallholders in Ethiopia. *Njas - Wageningen J. Life Sci.*, **88**, 96–104, doi:10.1016/j.njas.2018.09.001.
Belčáková, I., M. Świąder and M. Bartyna-Zielińska, 2019: The green infrastructure in cities as a tool for climate change adaptation and mitigation: Slovakian and Polish experiences. *Atmosphere*, **10**(9), doi:10.3390/atmos10090552.
Berrang-Ford, L., et al., 2019: Tracking global climate change adaptation among governments. *Nature Clim Change*, **9**, 440–449, doi:10.1038/s41558-019-0490-0.
Berry, P., et al., 2018: *Assessing Health Vulnerabilities and Adaptation to Climate Change: a Review of International Progress*. MDPI AG.
Bertana, A., 2020: The role of power in community participation: Relocation as climate change adaptation in Fiji. *Environ. Plan. C Polit. Space*, **38**(5), 902–919, doi:10.1177/2399654420909394.
Bhatta, G.D., et al., 2017: Agricultural innovation and adaptation to climate change: empirical evidence from diverse agro-ecologies in South Asia. *Environ. Dev. Sustain.*, **19**, 497–525, doi:10.1007/s10668-015-9743-x.
Bhattarai, B., 2020: How do gender relations shape a community's ability to adapt to climate change? Insights from Nepal's community forestry. *Clim. Dev.*, **12**, 876–887, doi:10.1080/17565529.2019.1701971.
Bhowmik, J., H.M. Irfanullah and S.A. Selim, 2021: Empirical evidence from Bangladesh of assessing climate hazard-related loss and damage and state of adaptive capacity to address them. *Clim. Risk Manag.*, **31**, 100273, doi:10.1016/j.crm.2021.100273.
Biernacka, M. and J. Kronenberg, 2018: Classification of institutional barriers affecting the availability, accessibility and attractiveness of urban green spaces. *Urban For. Urban Green.*, **36**, 22–33, doi:10.1016/j.ufug.2018.09.007.
Biesbroek, G.R., J.E.M. Klostermann, C.J.A.M. Termeer and P. Kabat, 2013: On the nature of barriers to climate change adaptation. *Reg Environ Change*, **13**, 1119–1129, doi:10.1007/s10113-013-0421-y.
Blasiak, R. and C.C.C. Wabnitz, 2018: Aligning fisheries aid with international development targets and goals. *Mar. Policy*, **88**, 86–92, doi:10.1016/j.marpol.2017.11.018.
Blasiak, R., et al., 2019: Towards greater transparency and coherence in funding for sustainable marine fisheries and healthy oceans. *Mar. Policy*, **107**, 103508, doi:10.1016/j.marpol.2019.04.012.
Bohnes, F.A., M.Z. Hauschild, J. Schlundt and A. Laurent, 2019: Life cycle assessments of aquaculture systems: a critical review of reported findings with recommendations for policy and system development. *Rev. Aquac.*, **11**, 1061–1079, doi:10.1111/raq.12280.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Booth, L., et al., 2020: Simulating synergies between climate change adaptation and disaster risk reduction stakeholders to improve management of transboundary disasters in europe. *Int. J. Disaster Risk Reduct.*, **49**, 101668, doi:10.1016/j.ijdrr.2020.101668.
Bordner, A.S., C.E. Ferguson and L. Ortolano, 2020: Colonial dynamics limit climate adaptation in Oceania: perspectives from the Marshall Islands. *Glob. Environ. Change*, **61**, 102054, doi:10.1016/j.gloenvcha.2020.102054.
Boston, J., A. Panda and S. Surminski, 2021: Designing a funding framework for the impacts of slow-onset climate change — insights from recent experiences with planned relocation. *Curr. Opin. Environ. Sustain.*, **50**, 159–168, doi:10.1016/j.cosust.2021.04.001.
Botero, C.M. and S. Zielinski, 2020: The implementation of a world-famous tourism ecolabel triggers political support for beach management. *Tour. Manag. Perspect.*, **35**, 100691, doi:10.1016/j.tmp.2020.100691.
Bowen, T., et al., 2020: *Adaptive Social Protection: Building Resilience to Shocks*. doi:10.1596/978-1-4648-1575-1. Adaptive Social Protection: Building Resilience to Shocks.
Boyd, C.E., et al., 2020: Achieving sustainable aquaculture: Historical and current perspectives and future needs and challenges. *J. World Aquac. Soc.*, **51**, 578–633, doi:10.1111/jwas.12714.
Bragg, C., et al., 2018: Remittances as aid following major sudden-onset natural disasters. *Disasters*, **42**, 3–18, doi:10.1111/DISA.12229.
Brand, U. and A. von Gleich, 2015: Transformation toward a secure and precaution-oriented energy system with the guiding concept of resilience – implementation of low-Exergy solutions in northwestern Germany. *Energies*, **8**, 6995–7019, doi:10.3390/en8076995.
Bricknell, I.R., et al., 2021: Resilience of cold water aquaculture: a review of likely scenarios as climate changes in the Gulf of Maine. *Rev. Aquac.*, **13**, 460–503, doi:10.1111/RAQ.12483.
Bronen, R. and F.S. Chapin, 2013: Adaptive governance and institutional strategies for climate-induced community relocations in Alaska. *Proc. Natl. Acad. Sci.*, **110**, 9320–9325, doi:10.1073/pnas.1210508110.
Bronen, R., et al., 2020: Usteq: integrating indigenous knowledge and social and physical sciences to coproduce knowledge and support community-based adaptation. *Polar Geogr.*, **43**(2-3), 188–205, doi:10.1080/1088937X.2019.1679271.
Brooke-Sumner, C., et al., 2019: 'Doing more with less': a qualitative investigation of perceptions of south African health service managers on implementation of health innovations. *Health Policy Plan.*, **34**, 132–140, doi:10.1093/heapol/czz017.
Brown, B., I. Nuberg and R. Llewellyn, 2017: Negative evaluation of conservation agriculture: perspectives from African smallholder farmers. *Int. J. Agric. Sustain.*, **15**, 467–481, doi:10.1080/14735903.2017.1336051.
Brown, P.R., et al., 2019: Constraints to the capacity of smallholder farming households to adapt to climate change in South and Southeast Asia. *Clim. Dev.*, **11**, 383–400, doi:10.1080/17565529.2018.1442798.
Bruno Soares, M. and C. Buontempo, 2019: Challenges to the sustainability of climate services in Europe. *WIREs Clim. Change*, **10**(4), e587, doi:10.1002/wcc.587.
Budhathoki, N.K., J.A. Lassa, S. Pun and K.K. Zander, 2019: Farmers' interest and willingness-to-pay for index-based crop insurance in the lowlands of Nepal. *Land Use Policy*, **85**, 1–10, doi:10.1016/j.landusepol.2019.03.029.
Buechler, S. and A. Lutz-Ley, 2019: Livelihoods with multiple stressors: Gendered youth decision-making under global change in rural Northwest Mexico. *Environ. Plan. E: Nat. Space*, **3**(4), 1096–1119, doi:10.1177/2514848619878603.
Buijs, A., et al., 2019: Mosaic governance for urban green infrastructure: Upscaling active citizenship from a local government perspective. *Urban For. Urban Green.*, **40**, 53–62, doi:10.1016/J.UFUG.2018.06.011.
Bustamante, M.M.C., et al., 2019: *Ecological restoration as a strategy for mitigating and adapting to climate change: lessons and challenges from Brazil*. Springer Netherlands, 1249–1270.
Butler, J.R.A., et al., 2020: How feasible is the scaling-out of livelihood and food system adaptation in Asia-Pacific islands? *Front. Sustain. Food Syst.*, **4**, 43, doi:10.3389/fsufs.2020.00043.
Cantasano, N., et al., 2021: Can ICZM contribute to the mitigation of erosion and of human activities threatening the natural and cultural heritage of the coastal landscape of Calabria? *Sustainability*, **13**, doi:10.3390/su13031122.
Carey, J., 2020: Core concept: managed retreat increasingly seen as necessary in response to climate change's fury. *Proc. Natl. Acad. Sci.*, **117**, 202008198, doi:10.1073/pnas.2008198117.
Carter, J.G., et al., 2015: Climate change and the city: Building capacity for urban adaptation. *Prog. Plann.*, **95**, 1–66, doi:10.1016/j.progress.2013.08.001.
Castells-Quintana, D., M.P. d. Lopez-Uribe and T.K.J. McDermott, 2018: Adaptation to climate change: A review through a development economics lens. *World Dev*, **104**, 183–196, doi:10.1016/j.worlddev.2017.11.016.
Castle, S.E., et al., 2021: The impacts of agroforestry interventions on agricultural productivity, ecosystem services, and human well-being in low- and middle-income countries: A systematic review. *Campbell Syst. Rev.*, **17**, e1167, doi:10.1002/CL2.1167.
Cattaneo, C., 2019: Migrant networks and adaptation. *Nature Clim Change*, **9**, 907–908, doi:10.1038/s41558-019-0646-y.
Caviedes, V., P. Arenas-Granados and J.M. Barragán-Muñoz, 2020: Regional public policy for integrated coastal zone management in Central America. *Ocean. Coast. Manag.*, **186**, 105114, doi:10.1016/j.ocecoaman.2020.105114.
Cechin, A., A. da Silva and L. Amand, 2021: Exploring the synergy between community supported agriculture and agroforestry: institutional innovation from smallholders in a Brazilian rural settlement. *J Rural Stud*, **81**, 246–258, doi:10.1016/j.jrurstud.2020.10.031.
Cedamon, E., I. Nuberg, B.H. Pandit and K.K. Shrestha, 2018: Adaptation factors and futures of agroforestry systems in Nepal. *Agrofor. Syst.*, **92**, 1437–1453, doi:10.1007/s10457-017-0090-9.
Centre, F. a. R. C. R. C. C. (ed.), *Managing Climate Risks Through Social Protection Reducing Rural Poverty and Building Resilient Agricultural Livelihoods*. Rome, ISBN 978-9251318843.
Chan, C.Y., et al., 2019: *Prospects and challenges of fish for food security in Africa*. Elsevier B.V., 17–25.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Chan, F.K.S., et al., 2018: "Sponge city" in China—A breakthrough of planning and flood risk management in the urban context. *Land Use Policy*, **76**, 772–778, doi:10.1016/J.LANDUSEPOL.2018.03.005.
Chausson, A., et al., 2020: Mapping the effectiveness of nature-based solutions for climate change adaptation. *Glob Change Biol*, **26**, 6134–6155, doi:10.1111/gcb.15310.
Chersich, M.F. and C.Y. Wright, 2019: *Climate change adaptation in South Africa: a case study on the role of the health sector*. BioMed Central Ltd.
Child, M. and C. Breyer, 2017: Transition and transformation: A review of the concept of change in the progress towards future sustainable energy systems. *Energy Policy*, **107**, 11–26, doi:10.1016/j.enpol.2017.04.022.
Chow, J., T. Khanom, R. Hossain and J. Khadim, 2019: Forest management for climate change adaptation in Bangladesh. In: Springer, Cham, pp. 39–50.
Chu, E. and K. Michael, 2018: Recognition in urban climate justice: marginality and exclusion of migrants in Indian cities. *SAGE journal.* **31**(1), 139–156, https://doi.org/10.1177%2F0956247818814449.
Chu, E., T. Schenk and J. Patterson, 2018: The dilemmas of citizen inclusion in urban planning and governance to enable a 1.5°C climate change scenario. *Urban Plan.*, **3**, 128–140, doi:10.17645/up.v3i2.1292.
Coe, R., F. Sinclair and E. Barrios, 2014: Scaling up agroforestry requires research 'in' rather than 'for' development. *Curr. Opin. Environ. Sustain.*, **6**, 73–77, doi:10.1016/j.cosust.2013.10.013.
Coirolo, C., S. Commins, I. Haque and G. Pierce, 2013: Climate change and social protection in Bangladesh: Are existing programmes able to address the impacts of climate change? *Dev Policy Rev*, **31**(o74), o90, doi:10.1111/dpr.12040.
Collier, S.J. and S. Cox, 2021: Governing urban resilience: insurance and the problematization of climate change. *Econ. Soc.*, **50**(2), 275–296, doi:10.1080/03085147.2021.1904621.
Colven, E., 2020: Thinking beyond success and failure: Dutch water expertise and friction in postcolonial Jakarta. *Environ. Plan. C: Polit. Space*, **38**, 961–979, doi:10.1177/2399654420911947.
Coulibaly, J.Y., B. Chiputwa, T. Nakelse and G. Kundhlande, 2017: Adoption of agroforestry and the impact on household food security among farmers in Malawi. *Agric. Syst.*, **155**, 52–69, doi:10.1016/j.agsy.2017.03.017.
Cowie, A.L., et al., 2021: Applying a science-based systems perspective to dispel misconceptions about climate effects of forest bioenergy. *GCB Bioenergy*, **13**(8), 1210–1231, doi:10.1111/gcbb.12844.
Crawford, T., et al., 2021: Disability inclusive disaster risk reduction with culturally and linguistically diverse (CALD) communities in the Hawkesbury-Nepean region: A co-production approach. *Int. J. Disaster Risk Reduct.*, **63**, 102430, doi:10.1016/j.ijdrr.2021.102430.
Cuaton, G.P. and Y. Su, 2020: Local-indigenous knowledge on disaster risk reduction: insights from the Mamanwa indigenous peoples in Basey, Samar after Typhoon Haiyan in the Philippines. *Int. J. Disaster Risk Reduct.*, **48**, 101596, doi:10.1016/j.ijdrr.2020.101596.
Custódio, M., S. Villasante, R. Calado and A.I. Lillebø, 2020: Valuation of ecosystem services to promote sustainable aquaculture practices. *Rev. Aquac.*, **12**, 392–405, doi:10.1111/raq.12324.
D'Aloia, C.C., et al., 2019: Coupled networks of permanent protected areas and dynamic conservation areas for biodiversity conservation under climate change. *Front. Ecol. Evol.*, **7**, 27, doi:10.3389/fevo.2019.00027.
Dai, L., R. Wörner and H.F.M.W. van Rijswick, 2018: Rainproof cities in the Netherlands: approaches in Dutch water governance to climate-adaptive urban planning. *Int. J. Water Resour. Dev.*, **34**, 652–674, doi:10.1080/07900627.2017.1372273.
Daly, M. and S. Dessai, 2018: Examining the goals of the regional climate outlook forums: what role for user engagement? *Weather Clim. Soc.*, **10**(4), 693–708, doi:10.1175/WCAS-D-18-0015.1.
Daniels, E., et al., 2020: Refocusing the climate services lens: Introducing a framework for co-designing "transdisciplinary knowledge integration processes" to build climate resilience. *Clim. Serv.*, **19**, 100181, doi:10.1016/j.cliser.2020.100181.
Dannenberg, A.L., H. Frumkin, J.J. Hess and K.L. Ebi, 2019: Managed retreat as a strategy for climate change adaptation in small communities: public health implications. *Clim. Change*, **153**(1), 1–14, doi:10.1007/s10584-019-02382-0.
Darzi-Naftchali, A. and H. Ritzema, 2018: Integrating irrigation and drainage management to sustain agriculture in northern Iran. *Sustainability*, **10**(6), doi:10.3390/su10061775.
Dasgupta, S. and J. Roy, 2017: Analysing energy intensity trends and decoupling of growth from energy use in Indian manufacturing industries during 1973–1974 to 2011–2012. *Energy Effic.*, **10**, 925–943, doi:10.1007/s12053-016-9497-9.
Davies, C.M., et al., 2019: *Potential of precision livestock farming in small ruminant farming systems*. Wageningen Academic Publishers. 717 pp.
De Beenhouwer, M., R. Aerts and O. Honnay, 2013: A global meta-analysis of the biodiversity and ecosystem service benefits of coffee and cacao agroforestry. *Agric. Ecosyst. Environ.*, **175**, 1–7, doi:10.1016/j.agee.2013.05.003.
de Coninck, H., A. Revi, M. Babiker, P. Bertoldi, M. Buckeridge, A. Cartwright, W. Dong, J. Ford, S. Fuss, J.-C. Hourcade, D. Ley, R. Mechler, P. Newman, A. Revokatova, S. Schultz, L. Steg, and T. Sugiyama, 2018: Strengthening and Implementing the Global Response. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.
De la Sota, C., V.J. Ruffato-Ferreira, L. Ruiz-García and S. Alvarez, 2019: Urban green infrastructure as a strategy of climate change mitigation. A case study in northern Spain. *Urban For. Urban Green.*, **40**, 145–151, doi:10.1016/j.ufug.2018.09.004.
de Salles Cavedon-Capdeville, F., et al., 2020: *Climate change, extreme events and human mobility in Latin America: exploring the links through national laws and policies*.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Debie, E., 2020: Multi-criteria evaluation of soil conservation practices to sustainable cropland management in northwest highlands of Ethiopia. *Authorea Prepr.*, doi:10.22541/AU.159221547.73795848.
DeNooyer, T.A., J.M. Peschel, Z. Zhang and A.S. Stillwell, 2016: Integrating water resources and power generation: The energy-water nexus in Illinois. *Appl Energy*, **162**, 363–371, doi:10.1016/j.apenergy.2015.10.071.
Depietri, Y. and T. McPhearson, 2017: *Integrating the Grey, Green, and Blue in Cities: Nature-Based Solutions for Climate Change Adaptation and Risk Reduction*.
Desai, B., et al., 2021: Addressing the human cost in a changing climate. *Science*, **372**, 1284–1287, doi:10.1126/SCIENCE.ABH4283.
Deshpande, T., K. Michael and K. Bhaskara, 2019: Barriers and enablers of local adaptive measures: a case study of Bengaluru's informal settlement dwellers. *Local Environ.*, **24**, 167–179, doi:10.1080/13549839.2018.1555578.
Dhyani, S., et al., 2021: *Agroforestry to achieve global climate adaptation and mitigation targets: are South Asian countries sufficiently prepared?* MDPI AG. 303 pp.
Di Gregorio, M., et al., 2019: Multi-level governance and power in climate change policy networks. *Glob. Environ. Chang.*, **54**, 64–77, doi:10.1016/j.gloenvcha.2018.10.003.
Donatti, C.I., et al., 2020: Indicators to measure the climate change adaptation outcomes of ecosystem-based adaptation. *Clim Change*, **158**, 413–433, doi:10.1007/s10584-019-02565-9.
Dong, X., et al., 2020: Vulnerability of urban water infrastructures to climate change at city level. *Resour. Conserv. Recycl.*, **161**, doi:10.1016/J.RESCONREC.2020.104918.
Dooley, K., E. Harrould-Kolieb and A. Talberg, 2021: Carbon-dioxide removal and biodiversity: a threat identification framework. *Glob Policy*, **12**, 34–44, doi:10.1111/1758-5899.12828.
Dorst, H., A. van der Jagt, R. Raven and H. Runhaar, 2019: Urban greening through nature-based solutions – key characteristics of an emerging concept. *Sustain. Cities Soc.*, **49**, 101620, doi:10.1016/j.scs.2019.101620.
Dorward, P., G. Clarkson, S. Poskitt and R. Stern, 2021: Putting the farmer at the center of climate services. *One Earth*, **4**(8), 1059–1061, doi:10.1016/j.oneear.2021.08.004.
Dougill, A.J., et al., 2017: Mainstreaming conservation agriculture in Malawi: Knowledge gaps and institutional barriers. *J. Environ. Manag.*, **195**, 25–34, doi:10.1016/j.jenvman.2016.09.076.
Du, S., et al., 2020: Hard or soft flood adaptation? Advantages of a hybrid strategy for Shanghai. *Glob. Environ. Change*, **61**, 102037, doi:10.1016/j.gloenvcha.2020.102037.
Du, X., J. Jian, C. Du and R.D. Stewart, 2021: Conservation management decreases surface runoff and soil erosion. *Int. Soil Water Conserv. Res.*, doi:10.1016/j.iswcr.2021.08.001.
Duffy, C., et al., 2021: Agroforestry contributions to smallholder farmer food security in Indonesia. *Agrofor. Syst.*, **95**(6), 1109–1124, doi:10.1007/S10457-021-00632-8.
DuPuis, E.M. and M. Greenberg, 2019: The right to the resilient city: progressive politics and the green growth machine in New York City. *J Environ Stud Sci*, **9**, 352–363, doi:10.1007/s13412-019-0538-5.
Ebi, K.L., et al., 2018: Stress testing the capacity of health systems to manage climate change-related shocks and stresses. *IJERPH*, **15**, doi:10.3390/ijerph15112370.
Ebi, K.L., et al., 2020: Transdisciplinary research priorities for human and planetary health in the context of the 2030 agenda for sustainable development. *IJERPH*, **17**(23), doi:10.3390/ijerph17238890.
Eisenack, K., et al., 2014: Explaining and overcoming barriers to climate change adaptation. *Nature Clim Change*, **4**, 867–872, doi:10.1038/nclimate2350.
Elagib, N.A. and M. Al-Saidi, 2020: *Balancing the benefits from the water–energy–land–food nexus through agroforestry in the Sahel*. Elsevier B.V. 140509 pp.
Elliott, R., 2019: 'Scarier than another storm': values at risk in the mapping and insuring of US floodplains. *Br. J. Sociol.*, **70**, 1067–1090, doi:10.1111/1468-4446.12381.
Ellison, A.M., A.J. Felson and D.A. Friess, 2020: Mangrove rehabilitation and restoration as experimental adaptive management. *Front. Mar. Sci.*, **7**, 327, doi:10.3389/fmars.2020.00327.
Erftemeijer, P.L.A., et al., 2020: Mangrove planting on dredged material: Three decades of nature-based coastal defence along a causeway in the Arabian Gulf. *Mar. Freshw. Res.*, **71**, 1062–1072, doi:10.1071/MF19289.
Ericksen, P. and T. Crane (eds.), *The feasibility of low emissions development interventions for the East African livestock sector: Lessons from Kenya and Ethiopia*. International Livestock Research Institute, ISBN 978-9291465422. The feasibility of low emissions development interventions for the East African livestock sector: Lessons from Kenya and Ethiopia.
Erlinghagen, S. and J. Markard, 2012: Smart grids and the transformation of the electricity sector: ICT firms as potential catalysts for sectoral change. *Energy Policy*, **51**, 895–906, doi:10.1016/j.enpol.2012.09.045.
Escarcha, J.F., J.A. Lassa and K.K. Zander, 2018: Livestock under climate change: A systematic review of impacts and adaptation. *Climate*, **6**, 54, doi:10.3390/cli6030054.
Escobedo, F.J., et al., 2019: Urban forests, ecosystem services, green infrastructure and nature-based solutions: Nexus or evolving metaphors? *Urban For. Urban Green.*, **37**, 3–12, doi:10.1016/J.UFUG.2018.02.011.
Evans, L.S., et al., 2016: Structural and psycho-social limits to climate change adaptation in the Great Barrier Reef region. *PLoS ONE*, **11**, e150575.
Fainstein, S.S., 2018: Resilience and justice: planning for New York City. *Urban. Geogr.*, 1–8, doi:10.1080/02723638.2018.1448571.
FAO (ed.), *The State of World Fisheries and Aquaculture 2018*. Rome, Italy. 227 pp.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Farnworth, C.R., et al., 2017: Gender and inorganic nitrogen: what are the implications of moving towards a more balanced use of nitrogen fertilizer in the tropics? *Int. J. Agric. Sustain.*, **15**, 136–152, doi:10.1080/14735903.2017.1295343.
Favretto, N., et al., 2020: Delivering climate-development co-benefits through multi-stakeholder forestry projects in Madagascar: opportunities and challenges. *Land*, **9**, 157, doi:10.3390/land9050157.
Feingold, D., S. Koop and K. van Leeuwen, 2018: The city blueprint approach: Urban water management and governance in cities in the U.S. *Environ Manage*, **61**, 9–23, doi:10.1007/S00267-017-0952-Y.
Filazzola, A., N. Shrestha and J.S. MacIvor, 2019: The contribution of constructed green infrastructure to urban biodiversity: A synthesis and meta-analysis. *J Appl Ecol*, **56**, 2131–2143, doi:10.1111/1365-2664.13475.
Findlater, K., S. Webber, M. Kandlikar and S. Donner, 2021: Climate services promise better decisions but mainly focus on better data. *Nat. Clim. Change*, **11**(9), 731–737, doi:10.1038/s41558-021-01125-3.
Findlater, K.M., M. Kandlikar and T. Satterfield, 2019: Misunderstanding conservation agriculture: Challenges in promoting, monitoring and evaluating sustainable farming. *Environ. Sci. Policy*, **100**, 47–54, doi:10.1016/j.envsci.2019.05.027.
Fischer, H.W., 2020: Policy innovations for pro-poor climate support: social protection, small-scale infrastructure, and active citizenship under India's MGNREGA. *Clim. Dev.*, **12**, 689–702, doi:10.1080/17565529.2019.1676690.
Fitzgibbons, J. and C. Mitchell, 2019: Just urban futures? Exploring equity in "100 Resilient Cities". *World Dev*, **122**, 648–659, doi:10.1016/j.worlddev.2019.06.021.
Fleischman, F., et al., 2020: Pitfalls of tree planting show why we need people-centered natural climate solutions. *BioScience*, **70**, 947–950, doi:10.1093/biosci/biaa094.
Ford, J.D., et al., 2015: Adaptation tracking for a post-2015 climate agreement. *Nature Clim Change*, **5**, 967–969, doi:10.1038/nclimate2744.
Ford, J.D., J. Labbé, M. Flynn and M. Araos, 2017: Readiness for climate change adaptation in the Arctic: a case study from Nunavut, Canada. *Clim Change*, **145**, 85–100, doi:10.1007/s10584-017-2071-4.
Ford, J.D., et al., 2014: Adapting to the effects of climate change on Inuit health. *Am J Public Health*, **104**, e9–e17, doi:10.2105/AJPH.2013.301724.
Forster, E.J., J.R. Healey, C. Dymond and D. Styles, 2021: Commercial afforestation can deliver effective climate change mitigation under multiple decarbonisation pathways. *Nat Commun*, **12**(1), 3831, doi:10.1038/s41467-021-24084-x.
Foti, E., R.E. Musumeci and M. Stagnitti, 2020: Coastal defence techniques and climate change: a review. *Rendiconti Lincei*, **31**, 123–138, doi:10.1007/s12210-020-00877-y.
Fox, M., et al., 2019: *Integrating public health into climate change policy and planning: State of practice update*. MDPI AG.
Freduah, G., P. Fidelman and T.F. Smith, 2018: Mobilising adaptive capacity to multiple stressors: Insights from small-scale coastal fisheries in the western region of Ghana. *Geoforum*, **91**, 61–72, doi:10.1016/j.geoforum.2018.02.026.
Fuss, S., et al., 2018: Negative emissions – Part 2: Costs, potentials and side effects. *Environ. Res. Lett.*, **13**, 63002, doi:10.1088/1748-9326/aabf9 f.
Galappaththi, E.K., J.D. Ford and E.M. Bennett, 2019: *A framework for assessing community adaptation to climate change in a fisheries context*. Elsevier Ltd, 17–26.
Galappaththi, E.K., et al., 2020: Climate change adaptation in aquaculture. *Rev. Aquac.*, **12**, 2160–2176, doi:10.1111/raq.12427.
García Romero, H. and A. Molina (eds.), *Agriculture and Adaptation to Climate Change: The Role of Insurance in Risk Management: The Case of Colombia*. Inter-American Development Bank (IDB), Washington DC, USA. 49 pp.
Gartrell, A., E. Calgaro, G. Goddard and N. Saorath, 2020: Disaster experiences of women with disabilities: barriers and opportunities for disability inclusive disaster risk reduction in Cambodia. *Glob. Environ. Change*, **64**, 102134, doi:10.1016/j.gloenvcha.2020.102134.
Gautam, Y. and P. Andersen, 2016: Rural livelihood diversification and household well-being: Insights from Humla, Nepal. *J Rural Stud*, **44**, 239–249, doi:10.1016/j.jrurstud.2016.02.001.
Geekiyanage, D., K. Keraminiyage, T. Fernando and T. Jayawickrama, 2021: Factors influencing acceptance or rejection regarding being the host community for post-disaster resettlements in developing countries. *Int. J. Disaster Risk Reduct.*, **53**, 101973, doi:10.1016/J.IJDRR.2020.101973.
Georgeson, L., M. Maslin, M. Poessinouw and S. Howard, 2016: Adaptation responses to climate change differ between global megacities. *Nature Clim Change*, **6**, 584–588, doi:10.1038/nclimate2944.
Ghiasian, M., et al., 2021: Dissipation of wave energy by a hybrid artificial reef in a wave simulator: implications for coastal resilience and shoreline protection. *Limnol. Oceanogr. Methods*, **19**(1), 1–7, doi:10.1002/lom3.10400.
Ghosh-Jerath, S., et al., 2021: Pathways of climate change impact on agroforestry, food consumption pattern, and dietary diversity among indigenous subsistence farmers of Sauria Paharia tribal community of India: a mixed methods study. *Front. Sustain. Food Syst.*, **0**, 174, doi:10.3389/FSUFS.2021.667297.
Gibb, R., L.H.V. Franklinos, D.W. Redding and K.E. Jones, 2020: Ecosystem perspectives are needed to manage zoonotic risks in a changing climate. *BMJ*, **371**, doi:10.1136/bmj.m3389.
Gilfillan, D., 2019: The health sector's role in governance of climate change adaptation in Myanmar. *Clim. Dev.*, **11**, 574–584, doi:10.1080/17565529.2018.1510364.
Glaas, E., E.C.H. Keskitalo and M. Hjerpe, 2017: Insurance sector management of climate change adaptation in three Nordic countries: the influence of policy and market factors. *J. Environ. Plan. Manag.*, **60**, 1601–1621, doi:10.1080/09640568.2016.1245654.
Glantz, M.H. and G.E. Pierce, 2021: Forecast hesitancy: why are people reluctant to believe, accept, or respond to various weather, water, and climate hazard-related forecasts? *Int. J. Disaster Risk Sci.*, **12**(4), 600–609, doi:10.1007/s13753-021-00353-7.
Goetz, E. G., R.A. Williams and A. Damiano, 2020: *Whiteness and Urban Planning*. Routledge, 142–156.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Goh, K., 2020: Flows in formation: The global-urban networks of climate change adaptation. *Urban Stud.*, **57**, 2222–2240, doi:10.1177/0042098018807306.
Gómez Martín, E., M. Máñez Costa and K. Schwerdtner Máñez, 2020: An operationalized classification of nature based solutions for water-related hazards: from theory to practice. *Ecol. Econ.*, **167**, 106460, doi:10.1016/j.ecolecon.2019.106460.
Goniewicz, K. and F.M. Burkle, 2019: Challenges in implementing Sendai framework for disaster risk reduction in Poland. *Int. J. Environ. Res. Public Health*, **16**(14), doi:10.3390/ijerph16142574.
Gonzalez-Sanchez, E.J., et al., 2019: meta-analysis on carbon sequestration through conservation agriculture in Africa. *Soil Tillage Res.*, **190**, 22–30, doi:10.1016/j.still.2019.02.020.
Goodrich, C.G., A. Prakash and P.B. Udas, 2019: Gendered vulnerability and adaptation in Hindu-Kush Himalayas: Research insights. *Environ. Dev.*, **31**, 1–8, doi:10.1016/J.ENVDEV.2019.01.001.
Gopal, N., et al., 2020: Expanding the horizons for women in fisheries and aquaculture. *Gend. Technol. Dev.*, **24**, 1–9, doi:10.1080/09718524.2020.1736353.
Goryushina, E.M., 2021: Challenges of the Sendai framework for disaster risk reduction adaption in Russia. *IOP Conf. Ser. Earth Environ. Sci.*, **720**(1), 12101, doi:10.1088/1755-1315/720/1/012101.
Gostin, L.O. and E.A. Friedman, 2017: Global health: a pivotal moment of opportunity and peril. *Health Aff.*, **36**(1), 159–165, doi:10.1377/hlthaff.2016.1492.
Goulden, M.C., W.N. Adger, E.H. Allison and D. Conway, 2013: Limits to resilience from livelihood diversification and social capital in lake social–ecological systems. *Ann. Assoc. Am. Geogr.*, **103**, 906–924, doi:10.1080/00045608.2013.765771.
Griscom, B.W., et al., 2017: Natural climate solutions. *Proc. Natl. Acad. Sci.*, **114**, 11645–11650, doi:10.1073/pnas.1710465114.
Gu, L., et al., 2019: The contribution of internal climate variability to climate change impacts on droughts. *Sci. Total. Environ.*, **684**, 229–246, doi:10.1016/j.scitotenv.2019.05.345.
Gumucio, T., J. Hansen, S. Huyer and T. van Huysen, 2020: Gender-responsive rural climate services: a review of the literature. *Clim. Dev.*, **12**(3), 241–254, doi:10.1080/17565529.2019.1613216.
Gundersen, P., et al., 2021: Old-growth forest carbon sinks overestimated. *Nature*, **591**(7851), E21–E23, doi:10.1038/s41586-021-03266-z.
Gutiérrez, J.M., R.G. Jones, G.T. Narisma, L.M. Alves, M. Amjad, I. V. Gorodetskaya, M. Grose, N.A.B. Klutse, S. Krakovska, J. Li, D. Martínez-Castro, L.O. Mearns, S.H. Mernild, T. Ngo-Duc, B. van den Hurk, and J.-H. Yoon, 2021: Atlas. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Available from http://interactive-atlas.ipcc.ch/.
Haines, A. and K. Ebi, 2019: The imperative for climate action to protect health. *N. Engl. J. Med.*, 380, 263–273, 10.1056/nejmra1807873.
Hamin, E., et al., 2018: Pathways to coastal resiliency: the adaptive gradients framework. *Sustainability*, **10**, 2629, doi:10.3390/su10082629.
Han, D., et al., 2018: Large soil organic carbon increase due to improved agronomic management in the North China Plain from 1980s to 2010s. *Glob Change Biol*, **24**, 987–1000, doi:10.1111/gcb.13898.
Hanefeld, J., et al., 2018: Towards an understanding of resilience: Responding to health systems shocks. *Health Policy Plan.*, **33**, 355–367, doi:10.1093/heapol/czx183.
Hanley, M. E., T.J. Bouma and H.L. Mossman, 2020a: The gathering storm: Optimizing management of coastal ecosystems in the face of a climate-driven threat. *Ann Bot*, **125**, 197–212, doi:10.1093/aob/mcz204.
Hanley, M. E., T.J. Bouma and H.L. Mossman, 2020b: *The gathering storm: Optimizing management of coastal ecosystems in the face of a climate-driven threat*. Oxford University Press, 197–212.
Hansen, J., et al., 2019: Climate risk management and rural poverty reduction. *Agric Syst*, **172**, 28–46, doi:10.1016/j.agsy.2018.01.019.
Hargan, K.E., et al., 2020: Understanding the fate of shrimp aquaculture effluent in a mangrove ecosystem: Aiding management for coastal conservation. *J Appl Ecol*, **57**, 754–765, doi:10.1111/1365-2664.13579.
Hasan, M.R., M. Nasreen and M. A. Chowdhury, 2019: *Gender-inclusive disaster management policy in Bangladesh: A content analysis of national and international regulatory frameworks*. Elsevier Ltd.
Hassanali, K., 2017: Challenges in mainstreaming climate change into productive coastal sectors in a Small Island State – The case of Trinidad and Tobago. *Ocean. Coast. Manag.*, **142**, 136–142, doi:10.1016/j.ocecoaman.2017.04.001.
Hauer, M. E., et al., 2020: Sea-level rise and human migration. *Nat. Rev. Earth Environ.*, **1**, 28–39, doi:10.1038/s43017-019-0002-9.
Heikkinen, M., T. Ylä-Anttila and S. Juhola, 2019: Incremental, reformistic or transformational: what kind of change do C40 cities advocate to deal with climate change? *J. Environ. Policy Plan.*, **21**, 90–103, doi:10.1080/1523908X.2018.1473151.
Henrique, K.P. and P. Tschakert, 2020: Pathways to urban transformation: From dispossession to climate justice. *Prog Hum Geogr*, **0**(0), doi:10.1177/0309132520962856. 0309132520962856.
Hermwille, L., W. Obergassel, H.E. Ott and C. Beuermann, 2017: UNFCCC before and after Paris – what's necessary for an effective climate regime? *Clim. Policy*, **17**, 150–170, doi:10.1080/14693062.2015.1115231.
Hernández-Morcillo, M., et al., 2018: Scanning agroforestry-based solutions for climate change mitigation and adaptation in Europe. *Environ. Sci. Policy*, **80**, 44–52, doi:10.1016/j.envsci.2017.11.013.
Herrero, M., et al., 2016: Climate change and pastoralism: impacts, consequences and adaptation. *Rev. Sci. Tech. Off. Int. Epiz*, **35**, 417–433, doi:10.20506/rst/35.2.2533.
Herslund, L. and P. Mguni, 2019: Examining urban water management practices – Challenges and possibilities for transitions to sustainable urban water management in Sub-Saharan cities. *Sustain. Cities Soc.*, **48**, doi:10.1016/J.SCS.2019.101573.
Hewitt, C.D., et al., 2020a: Making society climate resilient: international progress under the global framework for climate services. *Bull. Am. Meteorol. Soc.*, **101**(2), E237–E252, doi:10.1175/BAMS-D-18-0211.1.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Hewitt, C.N., K. Ashworth and A.R. MacKenzie, 2020b: Using green infrastructure to improve urban air quality (GI4AQ). *Ambio*, **49**, 62–73, doi:10.1007/S13280-019-01164-3.
Hobbie, S.E. and N.B. Grimm, 2020: Nature-based approaches to managing climate change impacts in cities. *Philos. Trans. Royal Soc. B Biol. Sci.*, **375**(1794), 20190124, doi:10.1098/rstb.2019.0124.
Hoegh-Guldberg, O., et al. (ed.), *The Ocean as a Solution to Climate Change: Five Opportunities for Action*.
Hoffmann, R., et al., 2020: A meta-analysis of country-level studies on environmental change and migration. *Nat. Clim. Chang.*, **10**(10), 904–912, doi:10.1038/s41558-020-0898-6.
Honarmand Ebrahimi, S. and M. Ossewaarde, 2019: Not a security issue: How policy experts de-politicize the climate change-migration nexus. *Soc Sci*, **8**, 214, doi:10.3390/socsci8070214.
Hörner, D. and M. Wollni, 2020: *RTG 1666 GlobalFood Transformation of Global Agri-Food Systems: Trends, Driving Forces, and Implications for Developing Countries Does Integrated Soil Fertility Management increase returns to land and labor? Plot-level evidence from Ethiopia*.
Hosen, N., H. Nakamura and A. Hamzah, 2020: Adaptation to climate change: does traditional ecological knowledge hold the key? *Sustainability*, **12**(2), doi:10.3390/su12020676.
Hossen, et al., 2019: Governance challenges in addressing climatic concerns in coastal Asia and Africa. *Sustainability*, **11**, 2148, doi:10.3390/su11072148.
Hughes, S., 2020: Principles, drivers, and policy tools for just climate change adaptation in legacy cities. *Environ. Sci. Policy*, **111**, 35–41, doi:10.1016/j.envsci.2020.05.007.
Hussey, L.K. and G. Arku, 2020: Are we ready for it? Health systems preparedness and capacity towards climate change-induced health risks: perspectives of health professionals in Ghana. *Clim. Dev.*, **12**, 170–182, doi:10.1080/17565529.2019.1610350.
Huynh, L.T.M. and L.C. Stringer, 2018: Multi-scale assessment of social vulnerability to climate change: an empirical study in coastal Vietnam. *Clim. Risk Manag.*, **20**, 165–180, doi:10.1016/j.crm.2018.02.003.
IPCC, 2018: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.
IPCC, 2019: *Clim. Chang.*, 1–864.
Islam, S., C. Chu and J.C.R. Smart, 2020a: Challenges in integrating disaster risk reduction and climate change adaptation: Exploring the Bangladesh case. *Int. J. Disaster Risk Reduct.*, **47**, doi:10.1016/j.ijdrr.2020.101540.
Islam, S., C. Chu, J.C.R. Smart and L. Liew, 2020b: *Integrating disaster risk reduction and climate change adaptation: a systematic literature review*. Taylor and Francis Ltd., 255–267.
Jacobson, C., S. Crevello, C. Chea and B. Jarihani, 2019: When is migration a maladaptive response to climate change? *Reg Environ Change*, **19**, 101–112, doi:10.1007/s10113-018-1387-6.
Jayanthi, M., S. Thirumurthy, M. Muralidhar and P. Ravichandran, 2018: Impact of shrimp aquaculture development on important ecosystems in India. *Glob. Environ. Chang.*, **52**, 10–21, doi:10.1016/j.gloenvcha.2018.05.005.
Jenkins, K., S. Surminski, J. Hall and F. Crick, 2017: Assessing surface water flood risk and management strategies under future climate change: Insights from an Agent-Based Model. *Sci. Total. Environ.*, **595**, 159–168, doi:10.1016/j.scitotenv.2017.03.242.
Jensen, O. and S. Nair, 2019: Integrated urban water management and water security: A comparison of Singapore and Hong Kong. *Water (switzerland)*, **11**, doi:10.3390/W11040785.
Ji, H. and D. Lee, 2021: Disaster risk reduction, community resilience, and policy effectiveness: the case of the Hazard Mitigation Grant Program in the United States. *Disasters*, **45**, 378–402, doi:10.1111/disa.12424.
Jin, J., W. Wang and X. Wang, 2016: Farmers' risk preferences and agricultural weather index insurance uptake in rural China. *Int. J. Disaster Risk Sci.*, **7**, 366–373, doi:10.1007/s13753-016-0108-3.
Johnson, K., S. Mortensen, C. Gueguen-Teil and A.R. Torre, 2021: Displaced by climate and disaster-induced relocations: Experiences of cascading displacement in Fiji and the Philippines. *Disasters*, doi:10.1111/DISA.12475.
Jolliffe, J., 2016: *Economic dimensions of relocation as an adaptation strategy to climate change: A case study of the Narikoso Relocation Project, Fiji*.
Jones, H.P., et al., 2020a: Global hotspots for coastal ecosystem-based adaptation. *PLoS ONE*, **15**, e233005, doi:10.1371/journal.pone.0233005.
Jones, K.W., K. Powlen, R. Roberts and X. Shinbrot, 2020b: Participation in payments for ecosystem services programs in the Global South: A systematic review. *Ecosyst. Serv.*, **45**, 101159, doi:10.1016/j.ecoser.2020.101159.
Jordon, M.W., et al., 2020: Implications of temperate agroforestry on sheep and cattle productivity, environmental impacts and enterprise economics. A systematic evidence map. *Forests*, **11**, 1321, doi:10.3390/F11121321.
Joy, A. and A. Gopinath, 2021: *The Application of Reefs in Shoreline Protection*, 295–315.
Joyette, A.R.T., L.A. Nurse and R.S. Pulwarty, 2015: Disaster risk insurance and catastrophe models in risk-prone small Caribbean islands. *Disasters*, **39**, 467–492, doi:10.1111/disa.12118.
Kälin, W., 2019: The Global Compact on Migration: A Ray of Hope for Disaster-Displaced Persons. *Int. J. Refug. Law*, **30**, 664–667, doi:10.1093/ijrl/eey047.
Kannan, E. and K.B. Ramappa, 2017: Analysis of farm-level adoption of soil nutrient management technology by paddy farmers in Karnataka, India. *Environ. Dev. Sustain.*, **19**, 2317–2331, doi:10.1007/s10668-016-9858-8.
Keeler, B.L., et al., 2019: *Social-ecological and technological factors moderate the value of urban nature*. Nature Publishing Group, 29–38.
Keenan, J.M., T. Hill and A. Gumber, 2018: Climate gentrification: from theory to empiricism in Miami-Dade county, Florida. *Environ. Res. Lett.*, **13**, doi:10.1088/1748-9326/aabb32.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Keil, A., A. Mitra, A.K. Srivastava and A. McDonald, 2019: Social inclusion increases with time for zero-tillage wheat in the Eastern Indo-Gangetic Plains. *World Dev.*, **123**, 104582, doi:10.1016/j.worlddev.2019.06.006.
Kelman, I., et al., 2019: Does climate change influence people's migration decisions in Maldives? *Clim Change*, **153**, 285–299, doi:10.1007/s10584-019-02376-y.
Kendrovski, V. and O. Schmoll, 2019: *Priorities for protecting health from climate change in the WHO European region: recent regional activities*. Springer Verlag, 537–545.
Kenney, C. and S. Phibbs, 2020: Indigenous peoples and climate change: situating culture, identity, and place in climate change risk mitigation and resilience. In: *Handbook of Climate Change Management: Research, Leadership, Transformation* [Leal Filho, W., J. Luetz and D. Ayal(eds.)]. Springer International Publishing, Cham, pp. 1–27. ISBN 978-3030227593.
Khalil, M.B., B.C. Jacobs, K. McKenna and N. Kuruppu, 2020: Female contribution to grassroots innovation for climate change adaptation in Bangladesh. *Clim. Dev.*, **12**(7), 664–676, doi:10.1080/17565529.2019.1676188.
Khatri-Chhetri, A., P.K. Aggarwal, P.K. Joshi and S. Vyas, 2017: Farmers' prioritization of climate-smart agriculture (CSA) technologies. *Agric Syst*, **151**, 184–191, doi:10.1016/j.agsy.2016.10.005.
Khatri-Chhetri, A., J.P. Aryal, T.B. Sapkota and R. Khurana, 2016: Economic benefits of climate-smart agricultural practices to smallholder farmers in the Indo-Gangetic Plains of India. *Curr. Sci.*, **110**, 1251–1256, doi:10.18520/cs/v110/i7/1251-1256.
Kihila, J.M., 2017: Indigenous coping and adaptation strategies to climate change of local communities in Tanzania: a review. *Clim. Dev.*, 1–11, doi:10.1080/17565529.2017.1318739.
Kihila, J.M., 2018: *Indigenous coping and adaptation strategies to climate change of local communities in Tanzania: a review*. Taylor and Francis Ltd., 406–416.
Kim, H. and D.W. Marcouiller, 2020: Making sense of resilience planning and policy in the pursuit of sustainable development and disaster risk reduction. *Clim. Dev.*, **12**, 228–240, doi:10.1080/17565529.2019.1613215.
Kind, J., W. Botzen and J.C.J.H. Aerts, 2017: Accounting for risk aversion, income distribution and social welfare in cost-benefit analysis for flood risk management. *Wires Clim. Chang.*, **8**, e446, doi:10.1002/wcc.446.
Klein, J.A., et al., 2019: An integrated community and ecosystem-based approach to disaster risk reduction in mountain systems. *Environ. Sci. Policy*, **94**, 143–152, doi:10.1016/j.envsci.2018.12.034.
Kligler, B., et al., 2021: The impact of integrating environmental health into medical school curricula: a survey-based study. *BMC Med. Educ.*, **21**(1), 40, doi:10.1186/s12909-020-02458-x.
Klinenberg, E., 2018: *Palaces for the people : how social infrastructure can help fight inequality, polarization, and the decline of civic life*. ISBN 978-1524761165. 1524761168 9781524761172 1524761176 9781984822413 1984822411.
Kmoch, L., T. Pagella, M. Palm and F. Sinclair, 2018: Using local agroecological knowledge in climate change adaptation: A study of tree-based options in Northern Morocco. *Sustain. (switzerland)*, **10**, 3719, doi:10.3390/su10103719.
Kodali, R. K. and B. S. Sarjerao (eds.), A low cost smart irrigation system using MQTT protocol. 2017 IEEE Region 10 Symposium (TENSYMP), 14-16 July 2017, 1-5 pp.
Koslov, L., 2019: Avoiding climate change: "agnostic adaptation" and the politics of public silence. *Ann. Am. Assoc. Geogr.*, **109**, 568–580, doi:10.1080/24694452.2018.1549472.
Koubi, V., et al., 2018: *The Determinants of Environmental Migrants' Conflict Perception*. cambridge.org.
Kouis, P., et al., 2021: The MEDEA childhood asthma study design for mitigation of desert dust health effects: implementation of novel methods for assessment of air pollution exposure and lessons learned. *BMC Pediatr.*, **21**(1), 13, doi:10.1186/s12887-020-02472-4.
Kousky, C., H. Wiley and L. Shabman, 2021: Can parametric microinsurance improve the financial resilience of low-income households in the United States? *Econ. Disasters Clim. Chang.*, doi:10.1007/s41885-021-00088-1.
Krauss, K.W. and M.J. Osland, 2020: Tropical cyclones and the organization of mangrove forests: A review. *Ann Bot*, **125**, 213–234, doi:10.1093/aob/mcz161.
Krosby, M., J. Tewksbury, N.M. Haddad and J. Hoekstra, 2010: Ecological connectivity for a changing climate. *Conserv. Biol.*, **24**, 1686–1689, doi:10.1111/j.1523-1739.2010.01585.x.
Krueger, E., P.S.C. Rao and D. Borchardt, 2019: Quantifying urban water supply security under global change. *Glob. Environ. Chang.*, **56**, 66–74, doi:10.1016/J.GLOENVCHA.2019.03.009.
Lalani, B., P. Dorward and G. Holloway, 2017: Farm-level economic analysis - is conservation agriculture helping the poor? *Ecol. Econ.*, **141**, 144–153, doi:10.1016/j.ecolecon.2017.05.033.
Lamari, M., J. Bouchard, J. Jacob and L. Poulin-Larivière, 2016: *Monitoring and Evaluation of Climate Change Adaptation in Coastal Zones: Overview of the Indicators in Use*. Springer, 3–20.
Lange, W., et al., 2019: *Ecosystem-based approaches for disaster risk reduction and climate change adaptation in Rio de Janeiro state*. Springer, Cham, 345–359.
Langemeyer, J., et al., 2020: Creating urban green infrastructure where it is needed – A spatial ecosystem service-based decision analysis of green roofs in Barcelona. *Sci. Total. Environ.*, **707**, 135487, doi:10.1016/j.scitotenv.2019.135487.
Lardizabal, C.C., 2015: Basin comanagement plans – A participative approach to water governance: a case study in Honduras, Central America. *Sustain. Integr. Water Resour. Manag. Water Gov. Clim. Ecohydrol.*, 345–363, doi:10.1007/978-3-319-12194-9_19.
Lashley, J.G. and K. Warner, 2015: Evidence of demand for microinsurance for coping and adaptation to weather extremes in the Caribbean. *Clim Change*, **133**, 101–112, doi:10.1007/s10584-013-0922-1.
Lausche, B., et al. (ed.), *The Legal Aspects of Connectivity Conservation A Concept Paper*.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Lavorel, S., B. Locatelli, M.J. Colloff and E. Bruley, 2020: Co-producing ecosystem services for adapting to climate change. *Philos. Trans. Royal Soc. B: Biol. Sci.*, **375**, doi:10.1098/rstb.2019.0119.
Le Cornu, E., et al., 2018: Spatial management in small-scale fisheries: A potential approach for climate change adaptation in Pacific Islands. *Mar. Policy.*, **88**, 350–358, doi:10.1016/j.marpol.2017.09.030.
Leakhena, C., et al., 2018: *Aiming for Improved Gender Equity in Cambodian Aquaculture*.
Leigh, N.G. and H. Lee, 2019: Sustainable and resilient urban water systems: The role of decentralization and planning. *Sustain. (switzerland)*, **11**, doi:10.3390/SU11030918.
Li, Z., et al., 2020: Biochar-supported nanoscale zero-valent iron as an efficient catalyst for organic degradation in groundwater. *J. Hazard. Mater.*, **383**, doi:10.1016/j.jhazmat.2019.121240.
Liang, Y., M. Du, X. Wang and X. Xu, 2020: Planning for urban life: A new approach of sustainable land use plan based on transit-oriented development. *Eval Program Plann*, **80**, 101811, doi:10.1016/j.evalprogplan.2020.101811.
Liao, W., et al., 2019: Preparing the next generation of health professionals to tackle climate change: Are China's medical students ready? *Environ. Res.*, **168**, 270–277, doi:10.1016/j.envres.2018.10.006.
Ligsay, A., O. Telle and R. Paul, 2021: Challenges to mitigating the urban health burden of mosquito-borne diseases in the face of climate change. *Int. J. Environ. Res. Public Health*, **18**(9), doi:10.3390/ijerph18095035.
Lima, M. and C. Coelho, 2021: Integrated methodology for physical and economic assessment of coastal interventions impacts. *J. Model. Optim.*, **13**, 22–43, doi:10.32732/jmo.2021.13.1.22.
Lin, T.Y., V.M.V. Onselen and L.P. Vo, 2021: Coastal erosion in Vietnam: Case studies and implication for integrated coastal zone management in the Vietnamese south-central coastline. *Iop Conf. Series: Earth Environ. Sci.*, **652**, 12009, doi:10.1088/1755-1315/652/1/012009.
Linares, C., et al., 2020: *Impacts of climate change on the public health of the Mediterranean Basin population - Current situation, projections, preparedness and adaptation*. Academic Press Inc.
Lincke, D. and J. Hinkel, 2018: Economically robust protection against 21st century sea-level rise. *Glob. Environ. Chang.*, **51**, 67–73, doi:10.1016/j.gloenvcha.2018.05.003.
Linke, A., F. Witmer and J. O. L.-E. … and u., 2018: *The consequences of relocating in response to drought: human mobility and conflict in contemporary Kenya*. iopscience.iop.org.
Linnerooth-Bayer, J. and S. Hochrainer-Stigler, 2015: Financial instruments for disaster risk management and climate change adaptation. *Clim Change*, **133**, 85–100, doi:10.1007/s10584-013-1035-6.
Liu, L. and M.B. Jensen, 2018: Green infrastructure for sustainable urban water management: Practices of five forerunner cities. *Cities*, **74**, 126–133, doi:10.1016/j.cities.2017.11.013.
Lochhead, K., S. Ghafghazi, V. LeMay and G.Q. Bull, 2019: Examining the vulnerability of localized reforestation strategies to climate change at a macroscale. *J. Environ. Manag.*, **252**, 109625, doi:10.1016/j.jenvman.2019.109625.
Lock-Wah-Hoon, J., et al., 2020: Exploring vector-borne disease surveillance and response systems in Beijing, China: a qualitative study from the health system perspective. *Int. J. Environ. Res. Public Health*, **17**(22), doi:10.3390/ijerph17228512.
Lunduka, R.W., K.I. Mateva, C. Magorokosho and P. Manjeru, 2019: Impact of adoption of drought-tolerant maize varieties on total maize production in south Eastern Zimbabwe. *Clim. Dev.*, **11**, 35–46, doi:10.1080/17565529.2017.1372269.
Luqman, M., et al., 2018: Socio-economic impacts of agro-forestry on livelihoods of rural households in southern region of the Punjab, Pakistan. *SJA*, **34**, doi:10.17582/journal.sja/2018/34.4.880.887.
Strøbech, L. and R. Bordon, 2020: *Addressing the risk of Maladaptation in Social Protection: The case of World Food Programme*.
Mach, K.J., et al., 2019: Managed retreat through voluntary buyouts of flood-prone properties. **5**, doi:10.1126/SCIADV.AAX8995.
Magnan, A.K. and V.K.E. Duvat, 2018: Unavoidable solutions for coastal adaptation in Reunion Island (Indian Ocean). *Environ. Sci. Policy*, **89**, 393–400, doi:10.1016/j.envsci.2018.09.002.
Maharjan, A., et al., 2020: Migration and household adaptation in climate-sensitive hotspots in south Asia. *Curr Clim Change Rep*, **6**, doi:10.1007/S40641-020-00153-Z.
Makate, C., R. Wang, M. Makate and N. Mango, 2016: Crop diversification and livelihoods of smallholder farmers in Zimbabwe: Adaptive management for environmental change. *SpringerPlus*, **5**, 1–18, doi:10.1186/s40064-016-2802-4.
Maldonado, J., et al., 2021: Addressing the challenges of climate-driven community-led resettlement and site expansion: knowledge sharing, storytelling, healing, and collaborative coalition building. *J Environ Stud Sci*, 1–11, doi:10.1007/S13412-021-00695-0.
Mallick, B., B. Ahmed and J. V.-. Environments and u., 2017: *Living with the risks of cyclone disasters in the south-western coastal region of Bangladesh*. mdpi.com.
Marchezini, V., 2020: "What is a sociologist doing here?" an unconventional people-centered approach to improve warning implementation in the Sendai framework for disaster risk reduction. *Int. J. Disaster Risk Sci.*, **11**(2), 218–229, doi:10.1007/s13753-020-00262-1.
Margaret, D. and S. Matias, 2020: Climate humanitarian visa: international migration opportunities as post-disaster humanitarian intervention. *Clim Change*, **160**, 143–156, doi:10.1007/s10584-020-02691-9.
Margerum, R.D. and C.J. Robinson, 2015: Collaborative partnerships and the challenges for sustainable water management. *Curr. Opin. Environ. Sustain.*, **12**, 53–58, doi:10.1016/j.cosust.2014.09.003.
Martin, G., et al., 2020: Potential of multi-species livestock farming to improve the sustainability of livestock farms: A review. *Agric Syst*, **181**, 102821, doi:10.1016/j.agsy.2020.102821.
Martin, S.M. and K. Lorenzen, 2016: Livelihood diversification in rural Laos. *World Dev*, **83**, 231–243, doi:10.1016/j.worlddev.2016.01.018.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Martínez-Barón, D., et al., 2021: *Strengthening the climate services chain in Central America*.
Martuti, N.K.T., R. Pribadi, W.A.B.N. Sidiq and D.P. Mutiatari, 2020: *Community-Based Integrated Coastal Management Strategy in Tugurejo Subdistrict, Semarang*. Atlantis Press, 73–80.
Masud, M.M., et al., 2017: Adaptation barriers and strategies towards climate change: Challenges in the agricultural sector. *J Clean Prod*, **156**, 698–706, doi:10.1016/j.jclepro.2017.04.060.
Mayer, A., Z. Hausfather and W. Silver, 2018: The potential of agricultural land management to contribute to lower global surface temperatures. *Sci. Adv.*, **4**, doi:10.1126/sciadv.aaq0932.
McFadden, J., D. Smith, S. Wechsler and S. Wallander (eds.), *Development, Adoption, and Management of Drought-Tolerant Corn in the United States*.
McLeman, R., 2018: Migration and displacement risks due to mean sea-level rise. *Bull. At. Sci.*, **74**(3), 148–154, doi:10.1080/00963402.2018.1461951.
McLeman, R., 2019: International migration and climate adaptation in an era of hardening borders. *Nat. Clim. Chang.*, **9**(12), 911–918, doi:10.1038/s41558-019-0634-2.
McMichael, C., et al., 2021: Rising seas, immobilities, and translocality in small island states: case studies from Fiji and Tuvalu. *Popul Environ*, **43**(1), 82–107, doi:10.1007/s11111-021-00378-6.
McMichael, C. and M. Katonivualiku, 2020: Thick temporalities of planned relocation in Fiji. *Geoforum*, **108**, 286–294, doi:10.1016/j.geoforum.2019.06.012.
McNamara, K.E., 2015: Cross-border migration with dignity in Kiribati. *Forced Migr. Rev.*, **49**, 62.
McNamara, K.E., R. Westoby and A. Chandra, 2021: Exploring climate-driven non-economic loss and damage in the Pacific Islands. *Curr. Opin. Environ. Sustain.*, **50**, 1–11, doi:10.1016/j.cosust.2020.07.004.
Meerow, S., 2019: A green infrastructure spatial planning model for evaluating ecosystem service tradeoffs and synergies across three coastal megacities. *Environ. Res. Lett.*, **14**, doi:10.1088/1748-9326/ab502c.
Mena, R. and D. Hilhorst, 2021: The (im)possibilities of disaster risk reduction in the context of high-intensity conflict: the case of Afghanistan. *Environ. Hazards*, **20**(2), 188–208, doi:10.1080/17477891.2020.1771250.
Mestanza-Ramón, C., M.S. Capa, H.F. Saavedra and J.R. Paredes, 2019: Integrated coastal zone management in continental Ecuador and Galapagos Islands: Challenges and opportunities in a changing tourism and economic context. *Sustainability*, **11**, 6386, doi:10.3390/su11226386.
Miller, F., 2020: Exploring the consequences of climate-related displacement for just resilience in Vietnam. *Urban Stud.*, **57**, 1570–1587, doi:10.1177/0042098019830239.
Mills, M., et al., 2016: Reconciling development and conservation under coastal squeeze from rising sea level. *CONSERVATION LETTERS*, **9**, 361–368, doi:10.1111/conl.12213.
Minang, P.A., et al., 2014: *Prospects for agroforestry in REDD+ landscapes in Africa*. Elsevier, 78–82.
Monstadt, J. and A. Wolff, 2015: Energy transition or incremental change? Green policy agendas and the adaptability of the urban energy regime in Los Angeles. *Energy Policy*, **78**, 213–224, doi:10.1016/j.enpol.2014.10.022.
Morecroft, M.D., et al., 2019: Measuring the success of climate change adaptation and mitigation in terrestrial ecosystems. *Science*, **366**, doi:10.1126/science.aaw9256.
Morris, R., et al., 2019: Developing a nature-based coastal defence strategy for Australia. *Aust. J. Civ. Eng.*, **17**, 167–176, doi:10.1080/14488353.2019.1661062.
Morris, R.L., T.M. Konlechner, M. Ghisalberti and S. Swearer, 2018: *From grey to green: Efficacy of eco-engineering solutions for nature-based coastal defence*. Blackwell Publishing Ltd, 1827–1842.
Mortreux, C., et al., 2018: Political economy of planned relocation: A model of action and inaction in government responses. *Glob. Environ. Chang.*, **50**, 123–132, doi:10.1016/j.gloenvcha.2018.03.008.
Mottaleb, K. A., et al., 2017: Benefits of the development and dissemination of climate-smart rice: ex ante impact assessment of drought-tolerant rice in South Asia. *Mitig Adapt Strateg Glob Change*, **22**, 879–901, doi:10.1007/s11027-016-9705-0.
Mponela, P., et al., 2016: Determinants of integrated soil fertility management technologies adoption by smallholder farmers in the Chinyanja Triangle of Southern Africa. *Land Use Policy*, **59**, 38–48, doi:10.1016/j.landusepol.2016.08.029.
Mueller, V., C. Gray, S. Handa and D. Seidenfeld, 2020: Do social protection programs foster short-term and long-term migration adaptation strategies? *Envir. Dev. Econ.*, **25**, 135–158, doi:10.1017/S1355770X19000214.
Muench, S., S. Thuss and E. Guenther, 2014: What hampers energy system transformations? The case of smart grids. *Energy Policy*, **73**, 80–92, doi:10.1016/j.enpol.2014.05.051.
Müller, B., L. Johnson and D. Kreuer, 2017: Maladaptive outcomes of climate insurance in agriculture. *Glob. Environ. Chang.*, **46**, 23–33, doi:10.1016/j.gloenvcha.2017.06.010.
Muricho, D.N., D.J. Otieno, W. Oluoch-Kosura and M. Jirström, 2019: Building pastoralists' resilience to shocks for sustainable disaster risk mitigation: lessons from west Pokot county, Kenya. *Int. J. Disaster Risk Reduct.*, **34**, 429–435, doi:10.1016/j.ijdrr.2018.12.012.
Murti, R., S.L. Mathez-Stiefel, V.R. Garcia and S. Rist, 2020: *Engaging national policy makers in ecosystem based disaster risk reduction through social learning: Lessons from workshops in Africa, oceania, Latin America and the Caribbean*. Elsevier Ltd.
Mustafa, S., et al., 2021: Technological applications and adaptations in aquaculture for progress towards sustainable development and seafood security. *(Tall et al.) Conf. Series: Earth Environ. Sci.*, **718**, 12041, doi:10.1088/1755-1315/718/1/012041.
Mustapha, U.F., A.-W. Alhassan, D.-N. Jiang and G.-L. Li, 2021: Sustainable aquaculture development: a review on the roles of cloud computing, internet of things and artificial intelligence (CIA). *Rev. Aquac.*, doi:10.1111/raq.12559.
Mutuku, E.A., et al., 2020: Maize production under combined conservation agriculture and integrated soil fertility management in the sub-humid and semi-arid regions of Kenya. *Field Crop. Res.*, **254**, 107833, doi:10.1016/j.fcr.2020.107833.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Nabuurs, G.-J., et al., 2017: By 2050 the mitigation effects of EU forests could nearly double through climate smart forestry. *Forests*, **8**(12), doi:10.3390/f8120484.
Natarajan, N. and K.B.-E.P. a. … u, 2019: Climate change adaptation and precarity across the rural–urban divide in Cambodia: Towards a 'climate precarity' approach. **2**, 899–921, doi:10.1177/2514848619858155. journals.sagepub.com.
Nawrotzki, R.J. and J. DeWaard, 2018: Putting trapped populations into place: climate change and inter-district migration flows in Zambia. *Reg. Environ. Change*, **18**, 533–546, doi:10.1007/S10113-017-1224-3.
Neef, A., et al., 2018: Climate adaptation strategies in Fiji: the role of social norms and cultural values. *World Dev.*, **107**, 125–137, doi:10.1016/j.worlddev.2018.02.029.
Negev, M., et al., 2021: Regional lessons from the COVID-19 outbreak in the Middle East: from infectious diseases to climate change adaptation. *Sci. Total Environ.*, **768**, 144434, doi:10.1016/j.scitotenv.2020.144434.
Negev, M., et al., 2019: Adaptation of health systems to climate-related migration in Sub-Saharan Africa: Closing the gap. *Int J Hyg Environ Health*, **222**, 311–314, doi:10.1016/j.ijheh.2018.10.004.
Ngin, C., J.H. Grayman, A. Neef and N. Sanunsilp, 2020: The role of faith-based institutions in urban disaster risk reduction for immigrant communities. *Nat. Hazards*, **103**(1), 299–316, doi:10.1007/s11069-020-03988-9.
Nguyen Mai, T.H. and D. Hoang, 2018: Gender role in mangrove resource management: case study in Trieu Phong district of Quang Tri province, Vietnam. *J. Vietnamese Environ.*, **9**(2), doi:10.13141/jve.vol9.no2.pp92-98.
Nguyen, T.T., et al., 2019: Implementation of a specific urban water management - sponge city. *Sci. Total. Environ.*, **652**, 147–162, doi:10.1016/J.SCITOTENV.2018.10.168.
Nicholls, R., J. Hinkel, D. Lincke and T.D. van der Pol, 2019: *Global Investment Costs for Coastal Defense Through the 21st Century*. *World Bank Policy Research Working Paper Series*.
Nieuwenhuijsen, M.J., 2021: Green Infrastructure and Health. *Annu. Rev. Public Health*, **42**(1), 317–328, doi:10.1146/annurev-publhealth-090419-102511.
Nightingale, A.J., 2017: Power and politics in climate change adaptation efforts: Struggles over authority and recognition in the context of political instability. *Geoforum*, **84**, 11–20, doi:10.1016/j.geoforum.2017.05.011.
Ntshangase, N.L., B. Muroyiwa and M. Sibanda, 2018: Farmers' perceptions and factors influencing the adoption of no-till conservation agriculture by small-scale farmers in Zashuke, KwaZulu-Natal province. *Sustain. (switzerland)*, **10**, 555, doi:10.3390/su10020555.
Nunes, S., et al., 2020: *Challenges and opportunities for large-scale reforestation in the Eastern Amazon using native species*. Elsevier B.V. 118120 pp.
Nuzzo, J.B., et al., 2019: What makes health systems resilient against infectious disease outbreaks and natural hazards? Results from a scoping review. *Bmc Public Health*, **19**, doi:10.1186/s12889-019-7707-z.
Nyantakyi-Frimpong, H., 2017: Agricultural diversification and dietary diversity: A feminist political ecology of the everyday experiences of landless and smallholder households in northern Ghana. *Geoforum*, **86**, 63–75, doi:10.1016/j.geoforum.2017.09.003.
O'Donnell, T., 2019: Contrasting land use policies for climate change adaptation: A case study of political and geo-legal realities for Australian coastal locations. *Land Use Policy*, **88**, doi:10.1016/J.LANDUSEPOL.2019.104145.
O'Mahony, C., S. Gray, J. Gault and V. Cummins, 2020: ICZM as a framework for climate change adaptation action – Experience from Cork Harbour, Ireland. *Mar. Policy.*, **111**, 102223, doi:10.1016/j.marpol.2015.10.008.
O'Hare, P., I. White and A. Connelly, 2016: Insurance as maladaptation: resilience and the 'business as usual' paradox. *Environ. Plan. C Gov. Policy*, **34**, 1175–1193, doi:10.1177/0263774X15602022.
Oakes, R., 2019: Culture, climate change and mobility decisions in Pacific small island developing states. *Popul. Environ.*, **40**, 480–503, doi:10.1007/s11111-019-00321-w.
Ober, K. and P. Sakdapolrak, 2020: Whose climate change adaptation 'barriers'? Exploring the coloniality of climate change adaptation policy assemblages in Thailand and beyond. *Singap J Trop Geogr*, **41**(1), 86–104, doi:10.1111/sjtg.12309.
Obokata, R. and L. Veronis, 2018: Transnational approaches to remittances, risk reduction, and disaster relief: evidence from post-Typhoon Haiyan experiences of Filipino immigrants in Canada. In: *Routledge Handbook of Environmental Displacement and Migration*, pp. 270–276. doi:10.4324/9781315638843-21.
Ogada, M.J., et al., 2020: Climate-smart agriculture, household income and asset accumulation among smallholder farmers in the Nyando basin of Kenya. *World Dev. Perspect.*, **18**, 100203–100203, doi:10.1016/j.wdp.2020.100203.
Ogle, S.M., et al., 2019: Climate and soil characteristics determine where no-till management can store carbon in soils and mitigate greenhouse gas emissions. *Sci. Rep.*, **9**, 1–8, doi:10.1038/s41598-019-47861-7.
Ojea, E., S.E. Lester and D. Salgueiro-Otero, 2020: *Adaptation of Fishing Communities to Climate-Driven Shifts in Target Species*. Cell Press, 544–556.
Ontl, T.A., et al., 2020: Forest management for carbon sequestration and climate adaptation. *J. For.*, **118**, 86–101, doi:10.1093/jofore/fvz062.
Opoku, S.K., W.L. Filho, F. Hubert and O. Adejumo, 2021: Climate change and health preparedness in Africa: analysing trends in six African countries. *Int. J. Environ. Res. Public Health*, **18**(9), doi:10.3390/ijerph18094672.
Oral, H.V., et al., 2020: A review of nature-based solutions for urban water management in European circular cities: a critical assessment based on case studies and literature. *Blue-green Syst.*, **2**, 112–136, doi:10.2166/BGS.2020.932.
Orchard, S.E., L.C. Stringer and C.H. Quinn, 2016: Mangrove system dynamics in Southeast Asia: linking livelihoods and ecosystem services in Vietnam. *Reg. Environ. Change*, **16**(3), 865–879, doi:10.1007/s10113-015-0802-5.
Osmundsen, T.C., et al., 2020: The operationalisation of sustainability: Sustainable aquaculture production as defined by certification schemes. *Glob. Environ. Chang.*, **60**, 102025, doi:10.1016/j.gloenvcha.2019.102025.
Ossola, A. and B.B. Lin, 2021: *Making nature-based solutions climate-ready for the 50°C world*. Elsevier Ltd, 151–159.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Ota, L., J. Herbohn, N. Gregorio and S. Harrison, 2020: Reforestation and smallholder livelihoods in the humid tropics. *Land Use Policy*, **92**, 104455, doi:10.1016/j.landusepol.2019.104455.
Owen, G., 2020: What makes climate change adaptation effective? A systematic review of the literature. *Glob. Environ. Chang.*, **62**, 102071, doi:10.1016/j.gloenvcha.2020.102071.
Paganini, Z., 2019: Underwater: Resilience, racialized housing, and the national flood insurance program in Canarsie, Brooklyn. *Geoforum*, **104**, 25–35, doi:10.1016/j.geoforum.2019.06.003.
Pardo, G. and A. del Prado, 2020: Guidelines for small ruminant production systems under climate emergency in Europe. *Small Rumin. Res.*, **193**, 106261, doi:10.1016/j.smallrumres.2020.106261.
Parihar, C.M., et al., 2020: Soil quality and carbon sequestration under conservation agriculture with balanced nutrition in intensive cereal-based system. *Soil Tillage Res.*, **202**, 104653, doi:10.1016/j.still.2020.104653.
Parry, L., et al., 2019: The (in)visible health risks of climate change. *Soc. Sci. Med.*, **241**, 112448, doi:10.1016/j.socscimed.2019.112448.
Parton, K. A., J. Crean and P. Hayman, 2019: The value of seasonal climate forecasts for Australian agriculture. *Agric. Syst.*, **174**, 1–10, doi:10.1016/j.agsy.2019.04.005.
Pascal, M., et al., 2021: Evolving heat waves characteristics challenge heat warning systems and prevention plans. *Int. J. Biometeorol.*, doi:10.1007/s00484-021-02123-y.
Patel, R., G. Walker, M. Bhatt and V. Pathak, 2017: The demand for disaster microinsurance for small businesses in urban slums: the results of surveys in three Indian cities. *Plos Curr. Disasters*, **9**.
Paudel, U. and K.P. Pant, 2020: Estimation of household health cost and climate adaptation cost with its health related determinants: empirical evidences from western Nepal. *Heliyon*, **6**(11), e5492, doi:10.1016/j.heliyon.2020.e05492.
Paul, S., et al., 2020: Development of an indicator based composite measure to assess livelihood sustainability of shifting cultivation dependent ethnic minorities in the disadvantageous Northeastern region of India. *Ecol Indic*, **110**, 105934, doi:10.1016/j.ecolind.2019.105934.
Pearson, J., K.E. McNamara and P.D. Nunn, 2019: Gender-specific perspectives of mangrove ecosystem services: Case study from Bua Province, Fiji Islands. *Ecosyst. Serv.*, **38**, 100970, doi:10.1016/j.ecoser.2019.100970.
Pelling, M. and M. Garschagen, 2019: *Put equity first in climate adaptation*. Nature Publishing Group, 327–329.
Pelling, M., et al., 2018: Africa's urban adaptation transition under a 1.5° climate. *Curr. Opin. Environ. Sustain.*, **31**, 10–15, doi:10.1016/j.cosust.2017.11.005.
Peng, L.L.H., et al., 2020: Cooling effects of block-scale facade greening and their relationship with urban form. *Build. Environ.*, **169**, 106552, doi:10.1016/j.buildenv.2019.106552.
Perera-Valderrama, S., et al., 2020: Increasing marine ecosystems conservation linking marine protected areas and integrated coastal management in southern Cuba. *Ocean. Coast. Manag.*, **196**, 105300, doi:10.1016/j.ocecoaman.2020.105300.
Pérez-Cayeiro, M.L. and J.A. Chica-Ruiz, 2015: Evaluation of a programme of integrated coastal zone management: the Ecoplata programme (Uruguay). *Mar. Policy.*, **51**, 527–535, doi:10.1016/j.marpol.2014.09.008.
Perrels, A., 2020: Quantifying the uptake of climate services at micro and macro level. *Clim. Serv.*, **17**, 100152, doi:10.1016/j.cliser.2020.100152.
Perrotti, D. and S. Stremke, 2018: Can urban metabolism models advance green infrastructure planning? Insights from ecosystem services research. **47**(4), 678–694, doi:10.1177/2399808318797131. doi:10.1177/2399808318797131.
Petrova, K., 2021: Natural hazards, internal migration and protests in Bangladesh. *J Peace Res*, **58**, 33–49, doi:10.1177/0022343320973741.
Phillips, M.R., A.L. Jones and T. Thomas, 2018: Climate change, coastal management and acceptable risk: consequences for tourism. *J. Coast. Res.*, **85**, 1411–1415, doi:10.2112/SI85-283.1.
Piggott-McKellar, A.E., K.E. McNamara, P.D. Nunn and S.T. Sekinini, 2019: Moving people in a changing climate: Lessons from two case studies in Fiji. *Soc Sci*, **8**, 133, doi:10.3390/socsci8050133.
Piguet, E., 2019: Climatic statelessness: risk assessment and policy options. *Popul. Dev. Rev.*, **45**(4), 865–883, doi:10.1111/padr.12295.
Porst, L., P.S. Population, S. Place and u, 2020: Gendered translocal connectedness: Rural–urban migration, remittances, and social resilience in Thailand. *Wiley Online Libr.*, **26**, doi:10.1002/psp.2314.
Pour, S.H., et al., 2020: Low impact development techniques to mitigate the impacts of climate-change-induced urban floods: current trends, issues and challenges. *Sustain. Cities Soc.*, **62**, 102373, doi:10.1016/j.scs.2020.102373.
Prestele, R., et al., 2018: A spatially explicit representation of conservation agriculture for application in global change studies. *Glob. Change Biol.*, **24**, 4038–4053, doi:10.1111/gcb.14307.
Propato, M., J.S. Clough and A. Polaczyk, 2018: Evaluating the costs and benefits of marsh-management strategies while accounting for uncertain sea-level rise and ecosystem response. *PLoS ONE*, **13**, e200368, doi:10.1371/journal.pone.0200368.
Quandt, A., H. Neufeldt and J.T. McCabe, 2017: The role of agroforestry in building livelihood resilience to floods and drought in semiarid Kenya. *Ecol. Soc.*, **22**, 10, doi:10.5751/ES-09461-220310.
Qurani, I.Z., N.I. Fawzi, R. Fadilah and W. Kismorodati, 2021: Empowering fish-farmer through coastal field school: towards sustainable aquaculture practice. *Iop Conf. Series: Earth Environ. Sci.*, **750**, 12054, doi:10.1088/1755-1315/750/1/012054.
Radel, C., B. Schmook, L. Carte and S. Mardero, 2018: Toward a political ecology of migration: land, labor migration, and climate change in northwestern Nicaragua. *World Dev*, **108**, 263–273, doi:10.1016/j.worlddev.2017.04.023.
Rahman, A.T.M.S., et al., 2017: Drought analysis and its implication in sustainable water resource management in Barind area, Bangladesh. *J Geol Soc India*, **89**(1), 47–56, doi:10.1007/s12594-017-0557-3.
Rahman, S., M.S. Islam, M.N.H. Khan and M. Touhiduzzaman, 2019: Climate change adaptation and disaster risk reduction (DRR) through coastal afforestation in South-Central Coast of Bangladesh. *Manag. Environ. Qual. Int. J.*, **30**, 498–517, doi:10.1108/MEQ-01-2018-0021.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Rahut, D.B., J.P. Aryal and P. Marenya, 2021: *Understanding climate-risk coping strategies among farm households: Evidence from five countries in Eastern and Southern Africa*. **769**, 145236.
Ramalho, J., 2019: Worlding aspirations and resilient futures: Framings of risk and contemporary city-making in Metro Cebu, the Philippines. *Asia Pac Viewp*, **60**, 24–36, doi:10.1111/apv.12208.
Ranganathan, M. and E. Bratman, 2021: From urban resilience to abolitionist climate justice in Washington, DC. *Antipode*, **53**(1), 115–137, doi:10.1111/anti.12555.
Rao, N., et al., 2020: Managing risk, changing aspirations and household dynamics: Implications for wellbeing and adaptation in semi-arid Africa and India. *World Dev*, **125**, 104667, doi:10.1016/J.WORLDDEV.2019.104667.
Rasmussen, D., M. Oppenheimer, R.E. Kopp and R. Shwom, 2020: The political complexity of coastal flood risk reduction: lessons for climate adaptation public works in the U.S. *Earth Space Sci. Open Arch.*, doi:10.1002/essoar.10502705.3.
Ratter, B., A. Hennig and Zahid, 2019: Challenges for shared responsibility – Political and social framing of coastal protection transformation in the Maldives. *Die Erde – J. Geogr. Soc. Berl.*, **150**, doi:10.12854/erde-2019-426.
Raymond, C.M., et al., 2017: A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. *Environ. Sci. Policy*, **77**, 15–24, doi:10.1016/j.envsci.2017.07.008.
Reddy, V.R., T. Chiranjeevi and G. Syme, 2020: Inclusive sustainable intensification of agriculture in West Bengal, India: policy and institutional approaches. *Int. J. Agric. Sustain.*, **18**, 70–83, doi:10.1080/14735903.2019.1698489.
Reguero, B.G., et al., 2018: Comparing the cost effectiveness of nature-based and coastal adaptation: a case study from the Gulf Coast of the United States. *PLoS ONE*, **13**(4), e192132, doi:10.1371/journal.pone.0192132.
Rigg, J. and K. Oven, 2015: Building liberal resilience? A critical review from developing rural Asia. *Glob. Environ. Chang.*, **32**, 175–186, doi:10.1016/j.gloenvcha.2015.03.007.
Rogelj, J., et al., 2018: Scenarios towards limiting global mean temperature increase below 1.5°C. *Nature Clim Change*, **8**, 325–332, doi:10.1038/s41558-018-0091-3.
Romañach, S.S., et al., 2018: Conservation and restoration of mangroves: Global status, perspectives, and prognosis. *Ocean. Coast. Manag.*, **154**, 72–82, doi:10.1016/j.ocecoaman.2018.01.009.
Rosendo, S., L. Celliers and M. Mechisso, 2018: Doing more with the same: a reality-check on the ability of local government to implement integrated coastal management for climate change adaptation. *Mar. Policy*, **87**, 29–39, doi:10.1016/j.marpol.2017.10.001.
Rosenzweig, C., et al., 2018: *Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network*. Cambridge University Press, 17–42.
Rosyida, I., W. Ullah, A. Helmi and M. Sasaoka, 2019: *Adapting livelihoods to the impacts of tin mining in Indonesia: options and constraints*. Vol. 6, 1302–1313.
Roy, J., et al., 2018: Sustainable development, poverty eradication and reducing inequalities. In: *Global warming of 1.5° C*.
Rudolph, L., N. Maizlish, S. North and K. Dervin, 2020: A public health learning collaborative on climate change for urban health departments, 2016-2018. *Public Health Rep*, **135**, 189–201, doi:10.1177/0033354920902468.
Runkle, J., et al., 2018: *Population Health Adaptation Approaches to the Increasing Severity and Frequency of Weather-Related Disasters Resulting From our Changing Climate: A Literature Review and Application to Charleston, South Carolina*. Springer, 439–452.
Ruszczyk, H.A., et al., 2020: Empowering women through participatory action research in community-based disaster risk reduction efforts. *Int. J. Disaster Risk Reduct.*, **51**, 101763, doi:10.1016/j.ijdrr.2020.101763.
Salam, S. and S. Bauer, 2020: Rural non-farm economy and livelihood diversification strategies: evidence from Bangladesh. *GeoJournal*, 1–13, doi:10.1007/s10708-020-10269-2.
Salmon, G., et al., 2018: Trade-offs in livestock development at farm level: Different actors with different objectives. *Glob Food Sec*, **17**, 103–112, doi:10.1016/j.gfs.2018.04.002.
Sampantamit, T., et al., 2020: Aquaculture production and its environmental sustainability in Thailand: challenges and potential solutions. *Sustainability*, **12**, doi:10.3390/su12052010.
Sani Ibrahim, S., H. Ozdeser and B. Cavusoglu, 2019: Financial inclusion as a pathway to welfare enhancement and income equality: Micro-level evidence from Nigeria. *Dev. South. Afr.*, **36**, 390–407, doi:10.1080/0376835X.2018.1498766.
Santoro, A., M. Venturi, R. Bertani and M. Agnoletti, 2020: A review of the role of forests and agroforestry systems in the FAO globally important agricultural heritage systems (GIAHS) programme. *Forests*, **11**, 860, doi:10.3390/F11080860.
Sarkar, D., et al., 2018: Can sustainability of maize-mustard cropping system be achieved through balanced nutrient management? *Field Crop. Res.*, **225**, 9–21, doi:10.1016/j.fcr.2018.05.018.
Scheres, B. and H. Schüttrumpf, 2019: *Enhancing the Ecological Value of Sea Dikes*.
Schoeneberger, M., et al., 2012: Branching out: Agroforestry as a climate change mitigation and adaptation tool for agriculture. *J. Soil Water Conserv.*, **67**, 128A–136A, doi:10.2489/jswc.67.5.128A.
Schoonees, T., et al., 2019: Hard structures for coastal protection, towards greener designs. *Estuaries Coasts*, **42**, 1709–1729, doi:10.1007/s12237-019-00551-z.
Schramm, P.J., et al., 2020: How indigenous communities are adapting to climate change: insights from the climate-ready tribes initiative. *Health Aff.*, **39**(12), 2153–2159, doi:10.1377/hlthaff.2020.00997.
Schuhbauer, A., et al., 2017: How subsidies affect the economic viability of small-scale fisheries. *Mar. Policy.*, **82**, 114–121, doi:10.1016/j.marpol.2017.05.013.
Schulte, L.A., et al., 2017: Prairie strips improve biodiversity and the delivery of multiple ecosystem services from corn–soybean croplands. *Proc. Natl. Acad. Sci. U.S.A.*, **114**, 11247–11252, doi:10.1073/pnas.1620229114.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Schwerdtle, P., K. Bowen and C. McMichael, 2018: The health impacts of climate-related migration. *BMC Med*, **16**(1), 1–7, doi:10.1186/S12916-017-0981-7.
Schwerdtle, P., C. McMichael and I. M.-E. and u., 2020: Health and migration in the context of a changing climate: a systematic literature assessment . doi:10.1088/1748-9326/ab9ece. iopscience.iop.org.
Seddon, N., et al., 2020a: *Understanding the value and limits of nature-based solutions to climate change and other global challenges*. Royal Society Publishing.
Seddon, N., et al., 2020b: Global recognition of the importance of nature-based solutions to the impacts of climate change. *Glob. Sustain.*, **3**, doi:10.1017/sus.2020.8.
Seddon, N., et al., 2019: *Grounding nature-based climate solutions in sound biodiversity science*. Nature Publishing Group, 84–87.
Sedova, B. and M. Kalkuhl, 2020: Who are the climate migrants and where do they go? Evidence from rural India. *World Dev.*, **129**, 104848, doi:10.1016/j.worlddev.2019.104848.
See, J. and B. Wilmsen, 2020: Just adaptation? Generating new vulnerabilities and shaping adaptive capacities through the politics of climate-related resettlement in a Philippine coastal city. *Glob. Environ. Chang.*, **65**, 102188, doi:10.1016/J.GLOENVCHA.2020.102188.
Seebauer, S., S. Ortner, P. Babcicky and T. Thaler, 2019: Bottom-up citizen initiatives as emergent actors in flood risk management: Mapping roles, relations and limitations. *J. Flood Risk Manag.*, **12**, doi:10.1111/jfr3.12468.
Seleka, M., B. Lough, E. Combaz and M.L. Seleka, 2017: *African Young Graduates and Scholars Conference Paper*.
Semenza, J.C. and K.L. Ebi, 2019: Climate change impact on migration, travel, travel destinations and the tourism industry. *J. Travel Med.*, **26**, doi:10.1093/jtm/taz026.
Serre, D. and C. Heinzlef, 2018: Assessing and mapping urban resilience to floods with respect to cascading effects through critical infrastructure networks. *Int. J. Disaster Risk Reduct.*, **30**, 235–243, doi:10.1016/j.ijdrr.2018.02.018.
Shackleton, S., et al., 2015: Why is socially-just climate change adaptation in sub-Saharan Africa so challenging? A review of barriers identified from empirical cases. *Wiley Interdiscip. Rev. Clim. Chang.*, **6**, 321–344, doi:10.1002/wcc.335.
Shaffril, H.A.M., A. Abu Samah and J.L. D'Silva, 2017: Adapting towards climate change impacts: Strategies for small-scale fishermen in Malaysia. *Mar. Policy.*, **81**, 196–201, doi:10.1016/j.marpol.2017.03.032.
Shah, F. and W. Wu, 2019: Soil and crop management strategies to ensure higher crop productivity within sustainable environments. *Sustainability*, **11**, 1485, doi:10.3390/su11051485.
Shang, Z., et al., 2021: Can cropland management practices lower net greenhouse emissions without compromising yield? *Glob Change Biol*, doi:10.1111/gcb.15796.
Shannon, P.D., et al., 2019: *Adaptation strategies and approaches for forested watersheds*. Elsevier B.V., 51–64.
Shapiro, S., 2016: The realpolitik of building codes: overcoming practical limitations to climate resilience. *Build. Res. Inf.*, **44**, 490–506, doi:10.1080/09613218.2016.1156957.
Sharma, H., D. Kumar, L. and K.S. Pant, 2020: Agroforestry- A sustainable tool for climate change adaptation and mitigation. *Agric. Rev.*, doi:10.18805/ag.r-1924.
Sharma, R. and R. Sharma, 2021: Community based flood risk management: local knowledge and actor's involvement approach from lower Karnali river basin of Nepal. *J. Geosci. Environ. Prot.*, **9**(6), 35–65, doi:10.4236/GEP.2021.96003.
Sheehan, M.C. and M. A. Fox, 2020: Early warnings: the lessons of COVID-19 for public health climate preparedness. *Int J Health Serv*, **50**, 264–270, doi:10.1177/0020731420928971.
Shi, L., 2019: Promise and paradox of metropolitan regional climate adaptation. *Environ. Sci. Policy*, **92**, 262–274, doi:10.1016/j.envsci.2018.11.002.
Shi, L. and A.M. Varuzzo, 2020: Surging seas, rising fiscal stress: Exploring municipal fiscal vulnerability to climate change. *Cities*, **100**, doi:10.1016/j.cities.2020.102658.
Shokry, G., J.J. Connolly and I. Anguelovski, 2020: Understanding climate gentrification and shifting landscapes of protection and vulnerability in green resilient Philadelphia. *Urban Clim.*, **31**, 100539, doi:10.1016/j.uclim.2019.100539.
Siders, A.R., 2019: Social justice implications of US managed retreat buyout programs. *Clim Change*, **152**, 239–257, doi:10.1007/s10584-018-2272-5.
Siders, A.R. and J.M. Keenan, 2020: Variables shaping coastal adaptation decisions to armor, nourish, and retreat in North Carolina. *Ocean. Coast. Manag.*, **183**, 105023, doi:10.1016/j.ocecoaman.2019.105023.
Sietsma, A.J., J.D. Ford, M.W. Callaghan and J.C. Minx, 2021: Progress in climate change adaptation research. *Environ. Res. Lett.*, **16**, 54038, doi:10.1088/1748-9326/abf7 f3.
Sina, D., A.Y. Chang-Richards, S. Wilkinson and R. Potangaroa, 2019: What does the future hold for relocated communities post-disaster? Factors affecting livelihood resilience. *Int. J. Disaster Risk Reduct.*, **34**, 173–183, doi:10.1016/j.ijdrr.2018.11.015.
Singh, B.P., R. Setia, M. Wiesmeier and A. Kunhikrishnan, 2018a: *Agricultural management practices and soil organic carbon storage*. Elsevier, 207–244.
Singh, C. and R. Basu, 2020: Moving in and out of vulnerability: Interrogating migration as an adaptation strategy along a rural–urban continuum in India. *Geogr. J.*, **186**, 87–102, doi:10.1111/geoj.12328.
Singh, C., et al., 2020a: Assessing the feasibility of climate change adaptation options in the water sector: Examples from rural and urban landscapes. *Water Secur.*, **11**, 100071, doi:10.1016/j.wasec.2020.100071.
Singh, C., et al., 2018b: The utility of weather and climate information for adaptation decision-making: current uses and future prospects in Africa and India. *Clim. Dev.*, **10**, 389–405, doi:10.1080/17565529.2017.1318744.
Singh, C., et al., 2020b: Assessing the feasibility of adaptation options: methodological advancements and directions for climate adaptation research and practice. *Clim Change*, doi:10.1007/s10584-020-02762-x.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Singh, C., G. Jain, V. Sukhwani and R. Shaw, 2021a: Losses and damages associated with slow-onset events: urban drought and water insecurity in Asia. *Curr. Opin. Environ. Sustain.*, **50**, 72–86, doi:10.1016/j.cosust.2021.02.006.
Singh, C., M. Madhavan, J. Arvind and A. Bazaz, 2021b: Climate change adaptation in Indian cities: A review of existing actions and spaces for triple wins. *Urban Clim.*, **36**, 100783, doi:10.1016/j.uclim.2021.100783.
Singh, C., A. Rahman, A. Srinivas and A. Bazaz, 2018c: Risks and responses in rural India: Implications for local climate change adaptation action. *Clim. Risk Manag.*, **21**, 52–68, doi:10.1016/j.crm.2018.06.001.
Singh, D., et al., 2020c: *A review on feedstocks, production processes, and yield for different generations of biodiesel*. Elsevier Ltd.
Siriwardane-de Zoysa, R., 2020: Beyond the wall: Dyking as an object of everyday governance in the Bay of Manila, Philippines. *Mar. Policy.*, **112**, 103661, doi:10.1016/j.marpol.2019.103661.
Sletto, B., S. Tabory and K. Strickler, 2019: Sustainable urban water management and integrated development in informal settlements: The contested politics of co-production in Santo Domingo, Dominican Republic. *Glob. Environ. Chang.*, **54**, 195–202, doi:10.1016/J.GLOENVCHA.2018.12.004.
Smith, J., B.D. Pearce and M.S. Wolfe, 2013: Reconciling productivity with protection of the environment: Is temperate agroforestry the answer? *Renew. Agric. Food Syst.*, **28**(1), 80–92, doi:10.1017/S1742170511000585.
Smucker, T.A., M. Oulu and R. Nijbroek, 2020: Foundations for convergence: sub-national collaboration at the nexus of climate change adaptation, disaster risk reduction, and land restoration under multi-level governance in Kenya. *Int. J. Disaster Risk Reduct.*, **51**, 101834, doi:10.1016/j.ijdrr.2020.101834.
Sojka, M., et al., 2019: Sustainable water management in agriculture—the impact of drainage water management on groundwater table dynamics and subsurface outflow. *Sustainability*, **11**(15), doi:10.3390/su11154201.
Sollen-Norrlin, M., B.B. Ghaley and N.L. Rintoul, 2020: Agroforestry Benefits and Challenges for Adoption in Europe and Beyond. *Sustainability*, **12**(17), doi:10.3390/su12177001.
Somasundaram, J., et al., 2020: No-till farming and conservation agriculture in south asia–issues, challenges, prospects and benefits. *CRC Crit Rev Plant Sci*, **39**, 236–279, doi:10.1080/07352689.2020.1782069.
Sommer, R., B.K. Paul, J. Mukalama and J. Kihara, 2018: Reducing losses but failing to sequester carbon in soils – the case of conservation agriculture and integrated soil fertility management in the humid tropical agro-ecosystem of western Kenya. *Agric. Ecosyst. Environ.*, **254**, 82–91, doi:10.1016/j.agee.2017.11.004.
Son, H.N., A. Kingsbury and H.T. Hoa, 2021: Indigenous knowledge and the enhancement of community resilience to climate change in the northern mountainous region of Vietnam. *Agroecol. Sustain. Food Syst.*, **45**(4), 499–522, doi:10.1080/21683565.2020.1829777.
Sova, C.A., et al., 2018: *Bringing the Concept of Climate-Smart Agriculture to Life*. doi:10.1596/31064. Bringing the Concept of Climate-Smart Agriculture to Life.
Spaans, M. and B. Waterhout, 2017: Building up resilience in cities worldwide–Rotterdam as participant in the 100 resilient cities programme. *Cities*, **61**, 109–116.
Spilker, G., Q. Nguyen, V. Koubi and T. Böhmelt, 2020: Attitudes of urban residents towards environmental migration in Kenya and Vietnam. *Nature Clim Change*, **10**, 622–627, doi:10.1038/s41558-020-0805-1.
Stefanakis, A.I., 2019: The role of constructed wetlands as green infrastructure for sustainable urban water management. *Sustainability*, **11**(24), doi:10.3390/su11246981.
Stentiford, G.D., et al., 2020: Sustainable aquaculture through the one health lens. *Nat. Food*, **1**, 468–474, doi:10.1038/s43016-020-0127-5.
Suckall, N., E. Fraser and P. F.-C. a. Development and u, 2017: 2016: reduced migration under climate change: evidence from Malawi using an aspirations and capabilities framework. *Taylor Francis*, **9**, 298–312, doi:10.1080/17565529.2016.1149441.
Surminski, S., L.M. Bouwer and J. Linnerooth-Bayer, 2016: How insurance can support climate resilience. *Nature Clim Change*, **6**, 333–334, doi:10.1038/nclimate2979.
Szewrański, S., et al., 2018: *Socio-Environmental Vulnerability Mapping for Environmental and Flood Resilience Assessment: The Case of Ageing and Poverty in the City of Wrocław, Poland*. Wiley-Blackwell, 592–597.
Tabe, T., 2019: Climate change migration and displacement: learning from past relocations in the pacific. *Soc Sci*, **8**(7), doi:10.3390/socsci8070218.
Tagliari, M.M., et al., 2021: *Collaborative management as a way to enhance Araucaria Forest resilience*. Associacao Brasileira de Ciencia Ecologica e Conservacao, 131–142.
Tall, A., J.Y. Coulibaly and M. Diop, 2018: Do climate services make a difference? A review of evaluation methodologies and practices to assess the value of climate information services for farmers: Implications for Africa. *Clim. Serv.*, **11**, 1–12, doi:10.1016/j.cliser.2018.06.001.
Tanaya, T., et al., 2021: Improvement of the coral growth and cost-effectiveness of hybrid infrastructure by an innovative breakwater design in Naha Port, Okinawa, Japan. *Coast. Eng. J.*, doi:10.1080/21664250.2021.1889823.
Tanner, T., et al., 2015: *Livelihood resilience in the face of climate change*. Nature Publishing Group, 23–26.
Tavenner, K. and T.A. Crane, 2018: Gender power in Kenyan dairy: cows, commodities, and commercialization. *Agric Hum Values*, **35**(3), 701–715, doi:10.1007/s10460-018-9867-3.
Telave, A.B. and S.R. Chandankar, 2021: Integrated coastal zone management: An Indian perspective-A Review. *Ecol. Environ. Conserv.*, 162–167.
Telford, A., 2018: A threat to climate-secure European futures? Exploring racial logics and climate-induced migration in US and EU climate security discourses. *Geoforum*, **96**, 268–277, doi:10.1016/j.geoforum.2018.08.021.
TerAvest, D., P.R. Wandschneider, C. Thierfelder and J.P. Reganold, 2019: Diversifying conservation agriculture and conventional tillage cropping systems to improve the wellbeing of smallholder farmers in Malawi. *Agric Syst*, **171**, 23–35, doi:10.1016/j.agsy.2019.01.004.
Terêncio, D.P.S., et al., 2018: Rainwater harvesting in catchments for agro-forestry uses: A study focused on the balance between sustainability values and storage capacity. *Sci. Total. Environ.*, **613-614**, 1079–1092, doi:10.1016/j.scitotenv.2017.09.198.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Tesselaar, M., W.J.W. Botzen and J.C.J.H. Aerts, 2020: Impacts of climate change and remote natural catastrophes on EU flood insurance markets: an analysis of soft and hard reinsurance markets for flood coverage. *Atmosphere*, **11**, doi:10.3390/atmos11020146.
Thierfelder, C., et al., 2017: How climate-smart is conservation agriculture (CA)? – its potential to deliver on adaptation, mitigation and productivity on smallholder farms in southern Africa. *Food Sec.*, **9**, 537–560, doi:10.1007/s12571-017-0665-3.
Thober, J., N. Schwarz and K. Hermans, 2018: Agent-based modeling of environment-migration linkages: A review. *Ecol. Soc.*, **23**, doi:10.5751/ES-10200-230241.
Thomas, A. and L. Benjamin, 2018: Policies and mechanisms to address climate-induced migration and displacement in Pacific and Caribbean small island developing states. *Int. J. Clim. Chang. Strateg. Manag.*, **10**, 86–104, doi:10.1108/IJCCSM-03-2017-0055.
Thomas, M., et al., 2021: When more is more: taking advantage of species diversity to move towards sustainable aquaculture. *Biol Rev*, **96**, 767–784, doi:10.1111/brv.12677.
Thompson, P.L., B. Rayfield and A. Gonzalez, 2017: Loss of habitat and connectivity erodes species diversity, ecosystem functioning, and stability in metacommunity networks. *Ecography*, **40**, 98–108, doi:10.1111/ecog.02558.
Thorne, C.R., et al., 2018: Overcoming uncertainty and barriers to adoption of blue-green infrastructure for urban flood risk management. *J. Flood Risk Manag.*, **11**(S2), 960–972, doi:10.1111/jfr3.12218.
Tian, Q. and M.C. Lemos, 2018: Household livelihood differentiation and vulnerability to climate hazards in rural China. *World Dev*, **108**, 321–331, doi:10.1016/j.worlddev.2017.10.019.
Tiggeloven, T., et al., 2020: Global-scale benefit–cost analysis of coastal flood adaptation to different flood risk drivers using structural measures. *Nat. Hazards Earth Syst. Sci.*, **20**, 1025–1044, doi:10.5194/nhess-20-1025-2020.
Torell, E., C. McNally, B. Crawford and G. Majubwa, 2017: Coastal livelihood diversification as a pathway out of poverty and vulnerability: experiences from Tanzania. *Coast. Manag.*, **45**(3), 199–218, doi:10.1080/08920753.2017.1303718.
Tschora, H. and F. Cherubini, 2020: Co-benefits and trade-offs of agroforestry for climate change mitigation and other sustainability goals in West Africa. *Glob. Ecol. Conserv.*, **22**, doi:10.1016/J.GECCO.2020.E00919.
Turolla, E., G. Castaldelli, E.A. Fano and E. Tamburini, 2020: *Life Cycle Assessment (LCA) Proves that Manila Clam Farming (Ruditapes Philippinarum) is a Fully Sustainable Aquaculture Practice and a Carbon Sink*.
Uddin, M.S., C.E. Haque and M.N. Khan, 2020: Good governance and local level policy implementation for disaster-risk-reduction: actual, perceptual and contested perspectives in coastal communities in Bangladesh. *Disaster Prev. Manag. Int. J.*, **30**, 94–111, doi:10.1108/DPM-03-2020-0069.
Ulrichs, M., R. Slater and C. Costella, 2019: Building resilience to climate risks through social protection: from individualised models to systemic transformation. *Disasters*, **43**, 368–387, doi:10.1111/disa.12339.
Valenti, W.C., J.M. Kimpara, B.L. Preto and P. Moraes-Valenti, 2018: Indicators of sustainability to assess aquaculture systems. *Ecol Indic*, **88**, 402–413, doi:10.1016/j.ecolind.2017.12.068.
van den Brandeler, F., J. Gupta and M. Hordijk, 2019: Megacities and rivers: scalar mismatches between urban water management and river basin management. *J. Hydrol.*, **573**, 1067–1074, doi:10.1016/j.jhydrol.2018.01.001.
Van Hulst, F.J. and H. Posthumus, 2016: Understanding (non-) adoption of conservation agriculture in Kenya using the reasoned action approach. *Land Use Policy*, **56**, 303–314, doi:10.1016/j.landusepol.2016.03.002.
Van Langevelde, F., et al. (ed.), *The link between biodiversity loss and the increasing spread of zoonotic diseases Policy Department for Economic, Scientific and Quality of Life Policies Directorate-General for Internal Policies*.
Van Loon-Steensma, J.M. and P. Vellinga, 2019: How "wide green dikes" were reintroduced in The Netherlands: a case study of the uptake of an innovative measure in long-term strategic delta planning. *J. Environ. Plan. Manag.*, **62**, 1525–1544, doi:10.1080/09640568.2018.1557039.
Van Oijstaeijen, W., S. Van Passel and J. Cools, 2020: Urban green infrastructure: A review on valuation toolkits from an urban planning perspective. *J. Environ. Manag.*, **267**, 110603, doi:10.1016/j.jenvman.2020.110603.
van Valkengoed, A.M. and L. Steg, 2019: Meta-analyses of factors motivating climate change adaptation behaviour. *Nature Clim Change*, **9**, 158–163, doi:10.1038/s41558-018-0371-y.
Vanden Bygaart, A.J., 2016: *The myth that no-till can mitigate global climate change*. Elsevier B.V., 98–99.
Vargas-Hernández, J.G. and J. Zdunek-Wielgołaska, 2021: Urban green infrastructure as a tool for controlling the resilience of urban sprawl. *Environ. Dev. Sustain.*, **23**(2), 1335–1354, doi:10.1007/s10668-020-00623-2.
Vaughan, C., L. Buja, A. Kruczkiewicz and L. Goddard, 2016: Identifying research priorities to advance climate services. *Clim. Serv.*, **4**, 65–74, doi:10.1016/j.cliser.2016.11.004.
Vaughan, C., S. Dessai and C. Hewitt, 2018: Surveying climate services: what can we learn from a bird's-eye view? *Weather. Clim. Soc.*, **10**, 373–395, doi:10.1175/WCAS-D-17-0030.1.
Vaughan, C., et al., 2019: Evaluating agricultural weather and climate services in Africa: evidence, methods, and a learning agenda. *WIREs Clim. Change*, **10**(4), e586, doi:10.1002/wcc.586.
Velasco-Muñoz, J.F., J.A. Aznar-Sánchez, L.J. Belmonte-Ureña and M.J. López-Serrano, 2018: Advances in water use efficiency in agriculture: a bibliometric analysis. *Water*, **10**(4), doi:10.3390/w10040377.
Venter, Z.S., et al., 2020: Green Apartheid: Urban green infrastructure remains unequally distributed across income and race geographies in South Africa. *Landsc Urban Plan*, **203**, 103889, doi:10.1016/j.landurbplan.2020.103889.
Viani, F., M. Bertolli, M. Salucci and A. Polo, 2017: Low-cost wireless monitoring and decision support for water saving in agriculture. *IEEE Sensors J.*, **17**(13), 4299–4309, doi:10.1109/JSEN.2017.2705043.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Villamizar, A., et al., 2017: Climate adaptation in South America with emphasis in coastal areas: the state-of-the-art and case studies from Venezuela and Uruguay. *Clim. Dev.*, **9**, 364–382, doi:10.1080/17565529.2016.1146120.
Villeneuve, M., 2021: Building a roadmap for inclusive disaster risk reduction in Australian communities. *Prog. Disaster Sci.*, **10**, 100166, doi:10.1016/j.pdisas.2021.100166.
Vincent, K., et al., 2017: Identifying climate services needs for national planning: insights from Malawi. *Clim. Policy*, **17**(2), 189–202, doi:10.1080/14693062.2015.1075374.
von Holle, B., S. Yelenik and E.S. Gornish, 2020: Restoration at the landscape scale as a means of mitigation and adaptation to climate change. *Curr. Landsc. Ecol. Reports*, **5**, 85–97, doi:10.1007/s40823-020-00056-7.
Vousdoukas, M.I., et al., 2020: Economic motivation for raising coastal flood defenses in Europe. *Nat Commun*, **11**, 2119, doi:10.1038/s41467-020-15665-3.
Walsh, C., 2019: Integration of expertise or collaborative practice?: Coastal management and climate adaptation at the Wadden Sea. *Ocean. Coast. Manag.*, **167**, 78–86, doi:10.1016/j.ocecoaman.2018.10.004.
Wang, X., et al., 2020: Cutting carbon footprints of vegetable production with integrated soil - crop system management: A case study of greenhouse pepper production. *J Clean Prod*, **254**, 120158, doi:10.1016/j.jclepro.2020.120158.
Warner, K., 2018: Coordinated approaches to large-scale movements of people: contributions of the Paris Agreement and the global compacts for migration and on refugees. *Popul Environ*, **39**, 384–401, doi:10.1007/S11111-018-0299-1.
Warnken, J. and R. Mosadeghi, 2018: Challenges of implementing integrated coastal zone management into local planning policies, a case study of Queensland, Australia. *Mar. Policy*, **91**, 75–84, doi:10.1016/j.marpol.2018.01.031.
Waryszak, P., et al., 2021: Combining gray and green infrastructure to improve coastal resilience: lessons learnt from hybrid flood defenses. *Coast. Eng. J.*, 1–16, doi:10.1080/21664250.2021.1920278.
Watts, N., et al., 2021: The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises. *Lancet*, **397**(10269), 129–170, doi:10.1016/s0140-6736(20)32290-x.
Webb, J., 2020: What difference does disaster risk reduction make? Insights from Vanuatu and tropical cyclone Pam. *Reg. Environ. Change*, **20**, doi:10.1007/s10113-020-01584-y.
Webber, J.L., et al., 2020: Is green infrastructure a viable strategy for managing urban surface water flooding? *Urban Water Journal*, **17**(7), 598–608, doi:10.1080/1573062X.2019.1700286.
Webber, S. and S.D. Donner, 2017: Climate service warnings: cautions about commercializing climate science for adaptation in the developing world. *Wiley Interdiscip. Rev. Clim. Chang.*, **8**, e424, doi:10.1002/wcc.424.
Weng, W., L. Costa, M.K.B. Lüdeke and D.C. Zemp, 2019: Aerial river management by smart cross-border reforestation. *Land Use Policy*, **84**, 105–113, doi:10.1016/j.landusepol.2019.03.010.
WHO, 2015: *Operational framework for building climate resilient health systems*. World Health Organisation, 56.
WHO, 2019: *2018 WHO health and climate change survey report: Tracking global progress*.
Wiegel, H., I. Boas and J. Warner, 2019: A mobilities perspective on migration in the context of environmental change. *Wiley Online Libr.*, **10**, doi:10.1002/wcc.610.
Willems, J.J., A.V. Kenyon, L. Sharp and A. Molenveld, 2021: How actors are (dis)integrating policy agendas for multi-functional blue and green infrastructure projects on the ground. *J. Environ. Policy Plan.*, **23**(1), 84–96, doi:10.1080/1523908X.2020.1798750.
Williams, D.S., M.M. Costa, L. Celliers and C. Sutherland, 2018: Informal settlements and flooding: Identifying strengths and weaknesses in local governance for water management. *Water (Switzerland)*, **10**, doi:10.3390/W10070871.
Williams, D.S., et al., 2020: A method of assessing user capacities for effective climate services. *Clim. Serv.*, **19**, 100180, doi:10.1016/j.cliser.2020.100180.
Williams, P.A., et al., 2021: Feasibility assessment of climate change adaptation options across Africa: An evidence-based review. *Environ. Res. Lett.*, **16**, 73004, doi:10.1088/1748-9326/ac092d.
Wilmsen, B. and M. Webber, 2015: What can we learn from the practice of development-forced displacement and resettlement for organised resettlements in response to climate change? *Geoforum*, **58**, 76–85, doi:10.1016/j.geoforum.2014.10.016.
Wilson, N.J., 2014: The politics of adaptation: subsistence livelihoods and vulnerability to climate change in the Koyukon Athabascan village of Ruby, Alaska. *Hum Ecol*, **42**, 87–101, doi:10.1007/s10745-013-9619-3.
Winters, M. A., B. Leslie, E.B. Sloane and T.W. Gallien, 2020: *Observations and Preliminary Vulnerability Assessment of a Hybrid Dune-Based Living Shoreline*.
Wolfrom, L. and M. Yokoi-Arai, 2015: Financial instruments for managing disaster risks related to climate change. *OECD Journal: Financial Mark. Trends*, 25–47, doi:10.1787/fmt-2015-5jrqdkpxk5d5.
Woodhouse, E. and J.T. McCabe, 2018: Well-being and conservation: diversity and change in visions of a good life among the Maasai of northern Tanzania. *Ecol. Soc.*, **23**, 9986–230143, doi:10.5751/ES-09986-230143. Published online: Mar 26, 2018.
Woodruff, S., T.K. BenDor and A.L. Strong, 2018: Fighting the inevitable: infrastructure investment and coastal community adaptation to sea level rise. *Syst. Dyn. Rev.*, **34**, 48–77, doi:10.1002/sdr.1597.
Worboys, G.L., et al. (ed.), *Connectivity conservation area guidelines [definition, types, selection criteria and governance]*. advanced draft, may 2016.
Woroniecki, S., C. Wamsler and E. Boyd, 2019: The promises and pitfalls of ecosystem-based adaptation to climate change as a vehicle for social empowerment. *Ecol. Soc.*, **24**(2), doi:10.5751/ES-10854-240204.
Wrathall, D.J., et al., 2019: Meeting the looming policy challenge of sea-level change and human migration. *Nat. Clim. Chang.*, **9**(12), 898–901, doi:10.1038/s41558-019-0640-4.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

Cross-Chapter Box FEASIB (continued)

Xuan, B.B., E.D. Sandorf and Q.T.K. Ngoc, 2021: Stakeholder perceptions towards sustainable shrimp aquaculture in Vietnam. *J. Environ. Manag.*, **290**, 112585, doi:10.1016/j.jenvman.2021.112585.

Yumagulova, L., et al., 2021: The role of disaster volunteering in Indigenous communities. *Environ. Hazards*, **20**(1), 45–62, doi:10.1080/17477891.2019.1657791.

Zen, I.S., A.Q. Al-Amin and B. Doberstein, 2019: *Mainstreaming Climate adaptation and Mitigation Policy: Towards Multi-Level Climate Governance in Melaka, Malaysia*. Elsevier B.V.

Zhang, C., L. Zhong and J. Wang, 2018: Decoupling between water use and thermoelectric power generation growth in China. *Nat. Energy*, **3**, 792–799, doi:10.1038/s41560-018-0236-7.

Zhang, Z., S. Meerow, J.P. Newell and M. Lindquist, 2019: Enhancing landscape connectivity through multifunctional green infrastructure corridor modeling and design. *Urban For. Urban Green.*, **38**, 305–317, doi:10.1016/j.ufug.2018.10.014.

Zobeidi, T., et al., 2021: Factors affecting smallholder farmers' technical and non-technical adaptation responses to drought in Iran. *J. Environ. Manag.*, **298**, 113552, doi:10.1016/j.jenvman.2021.113552.

Zomer, R.J., D.A. Bossio, R. Sommer and L.V. Verchot, 2017: Global sequestration potential of increased organic carbon in cropland soils. *Sci. Rep.*, **7**, 1–8, doi:10.1038/s41598-017-15794-8.

Zwierzchowska, I., et al., 2019: Introducing nature-based solutions into urban policy – facts and gaps. Case study of Poznań. *Land Use Policy*, **85**, 161–175, doi:10.1016/j.landusepol.2019.03.025.

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press

https://doi.org/10.1017/9781009325844.027 Published online by Cambridge University Press