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Conceptual and analytical paper

Towards Sustainable Adaptation Pathways

A concept for integrative actions to achieve the 2030 Agenda, Paris Agreement and Sendai Framework.

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Abstract: Sustainable Adaptation Pathways

2015 was a watershed year for addressing global challenges. Under the umbrella of the United Nations, the 2030 Agenda for Sustainable Development, the Paris Agreement on Climate Change and the Sendai Framework for Disaster Risk Reduction were adopted. Six years after their adoption, implementation of these post-2015 agendas lags behind in many aspects, raising the need for exploring pathways that enhance their effective implementation. One way forward is working towards identifying and using synergies between them. The underlying policy fields of climate change adaptation, disaster risk reduction and sustainable development are linked through a common emphasis on reducing vulnerabilities. Operational and policy instruments are available to realize synergies at the implementation level. Nevertheless, a lack of institutional capacities, policy-making in silos instead of cross-sectoral coordination and insufficient funding are just some of the barriers hindering coherent policies in practice. This report introduces the concept of Sustainable Adaptation Pathways (SAPs) that can act as guidance when planning and implementing integrated policies that aim to foster sustainable adaptation measures. SAPs describe a coherent set of alternative adaptation strategies and procedures composed of measures and policies to strengthen the capacities of populations, institutions and ecosystems to adapt to climate-related risks over time while enhancing the social justice, environmental integrity and economic sustainability of socio-ecological systems. Case studies are used to illustrate specific aspects of applying the concept in practice. In addition, practical recommendations for implementing SAPs are derived, taking into account both enabling contextual factors and lock-in effects.

Kurzbeschreibung: Sustainable Adaptation Pathways

2015 war ein entscheidendes Jahr für die Bewältigung globaler Herausforderungen. Unter dem Dach der Vereinten Nationen wurden die 2030-Agenda für nachhaltige Entwicklung, das Pariser Klimaabkommen und das Sendai Rahmenwerk für Katastrophenvorsorge verabschiedet. Sechs Jahre nach ihrer Verabschiedung hinkt die Umsetzung dieser Post-2015-Agenden in vielen Aspekten hinterher. Ein Weg zur beschleunigten Umsetzung der Agenden liegt in der Identifizierung und Nutzung von Synergien zwischen diesen. Die zugrundeliegenden Politikfelder Anpassung an den Klimawandel, Katastrophenvorsorge und nachhaltige Entwicklung sind durch den gemeinsamen Fokus auf eine Reduzierung von Vulnerabilitäten miteinander verbunden. Um Synergien auf der Umsetzungsebene zu realisieren, stehen operative und politische Instrumente zur Verfügung. Dennoch sind fehlende institutionelle Kapazitäten, eine Politikgestaltung in Silos statt sektorübergreifender Koordination und eine unzureichende Finanzierung nur einige der Barrieren, die eine kohärente Politik in der Praxis behindern. In diesem Bericht wird das Konzept der nachhaltigen Anpassungspfade (Sustainable Adaptation Pathways, SAPs) vorgestellt, das bei der Planung und Umsetzung integrierter Politiken zur Förderung nachhaltiger Anpassungsmaßnahmen als Orientierungsrahmen dienen kann. SAPs beschreiben ein kohärentes Set von alternativen Anpassungsstrategien und -verfahren, die aus Maßnahmen und Politiken bestehen, um Kapazitäten der lokalen Bevölkerung, Institutionen und Ökosysteme stärken, um sich im Laufe der Zeit an klimabedingte Risiken anzupassen. Gleichzeitig zielen SAPs darauf ab, die soziale Gerechtigkeit, die ökologische Integrität und die wirtschaftliche Nachhaltigkeit sozio-ökologischer Systeme zu verbessern. Anhand von Fallstudien werden spezifische Aspekte der Anwendung des Konzepts in der Praxis veranschaulicht. Zudem werden praktische Empfehlungen zur Umsetzung von SAPs gegeben, wobei sowohl förderliche Kontextfaktoren als auch Lock-in-Effekte berücksichtigt werden.

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List of abbreviations

2030 Agenda	United Nations 2030 Agenda for Sustainable Development
ACCCRN	Asian Cities Climate Change Resilience Network
BDP 2100	Bangladesh Delta Plan 2100
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit)
CCA	Climate Change Adaptation
CDKN	Climate and Development Knowledge Network
CMA	Conference of the Parties serving as the meeting of the Parties to the Paris Agreement
DRR	Disaster Risk Reduction
EEA	European Environment Agency
EbA	Ecosystem-based Adaptation
ECBI	European Capacity Building Initiative
Eco-DRR	Ecosystem-based Disaster Risk Reduction
EPA	Environmental Protection Agency
ETC/CCA	European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation
EWS	Early Warning System
FAO	Food and Agriculture Organization of the United Nations
GEAG	Gorakhpur Environmental Action Group
GSDR	Global Sustainable Development Report
GWP	Global Water Partnership
IIED	International Institute for Environment and Development
ILO	International Labour Organization
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
ISDR	International Strategy for Disaster Reduction
IUCN	International Union for the Conservation of Nature
KE4CAP	Knowledge Exchange Between Climate Adaptation Knowledge Platforms
M&E	Monitoring and Evaluation
MRS	Metropolitan Region of Santiago de Chile
NADMO	National Disaster Management Organization
NAP	National Adaptation Plan
NAPA	National Adaptation Programmes of Action
NbS	Nature-based Solutions
NDC	Nationally Determined Contribution
NEC	National Environment Commission of Bhutan
NGO	Non-Governmental Organization
OECD	Organisation for Economic Co-operation and Development
PA	Paris Agreement on Climate Change

RCP	Rotterdam Climate Proof Programme
SAP	Sustainable Adaptation Pathway
SCBD	Secretariat of the Convention on Biological Diversity
SD	Sustainable Development
SDG	Sustainable Development Goal
Sendai Framework	Sendai Framework for Disaster Risk Reduction
UBA	German Environment Agency (Umweltbundesamt)
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN-Habitat	United Nations Human Settlements Programme
UNU-EHS	Institute for Environment and Human Security
US	United States of America
WCED	World Commission on Environment and Development
WEF	Water-Energy-Food
WMO	World Meteorological Organization

Executive summary

2015 was a watershed year for addressing global challenges. Under the umbrella of the United Nations (UN), the 2030 Agenda for Sustainable Development (2030 Agenda), the Paris Agreement on Climate Change (PA) and the Sendai Framework for Disaster Risk Reduction (Sendai Framework) were adopted. Six years after their adoption, implementation of these post-2015 agendas lags behind in many aspects, raising the need for exploring pathways that enhance their effective implementation. One way forward is working towards identifying and using synergies between them. Potential for interlinkages between the agendas exists both at the level of objectives and at the level of operational and policy instruments [e.g. National Adaptation Plans (NAPs) or development plans]. A number of SDG goals and targets link to climate change adaptation (CCA) and disaster risk reduction (DRR), e.g. SDG 1, SDG 2 etc. A challenge, however, remains to put integrative approaches into practice. The underlying policy fields of CCA, DRR and sustainable development (SD) are linked through a common emphasis on reducing vulnerabilities. Operational vehicles and policy instruments are available to realise synergies at the implementation level.

Nevertheless, a lack of institutional capacities, policy-making in silos instead of cross-sectoral coordination and insufficient funding are just some of the barriers hindering coherent policies in practice. In particular, the complexity of each of the three post-2015 agendas challenges full integration. At the same time, fully integrating all agendas would risk losing the individual relevance of each of them. Connected to this are differences between DRR and its operational character on the one hand, and CCA and SD with a predominant long-term approach on the other hand. The current trend in DRR policy and research to move away from the idea of DRR as purely operational and ad-hoc is a precondition for effective integration.

This report introduces the concept of Sustainable Adaptation Pathways (SAPs) that considers these challenges and aims to act as guidance when planning and implementing integrated policies and measures for sustainable adaptation. This novel concept brings together academic pathway literature with policy-oriented literature on the three post-2015 agendas. SAPs describe a coherent set of alternative adaptation strategies and procedures composed of measures and policies to strengthen the capacities of local populations, institutions and ecosystems to adapt to climate-related risks over time while enhancing the social justice, environmental integrity and economic sustainability of socio-ecological systems.

SAPs are explicitly context-specific and interlinked with a dynamic set of institutional, socio-political and cultural as well as financial elements, which both enable and characterize SAPs. The development of SAPs is conceptualized as a result of complex and context-specific interactions and feedback loops. Deep uncertainties regarding aspects such as climate impacts or the effectiveness of CCA measures lead to an understanding of SAPs as iterative processes, which are in need of regular re-adjustments.

Dynamic elements are identified as important characteristics of SAPs, but certain elements are dominant in practice while some others might be present only to a weaker extent, not observable or entirely absent based on the specific socio-ecological context. Institutional elements include the coordination across scales and levels, flexible and adjustable governance structures, the consideration of multi-benefit approaches such as ecosystem-based approaches to enable no-regret measures with multiple benefits for diverse socio-ecological challenges. Funding streams should take an integrative view and prioritize projects targeting multiple socio-ecological challenges. Important socio-political and cultural elements are e.g. consideration of local context, integration of social learning processes, political leadership embracing sustainable adaptation and the consideration of path dependencies and lock-ins among others. The third

category - financial elements - include aspects such as provision of funding by governments or internal donors and the involvement of private sectors. A stronger alignment of different sources of funding, such as public and private funding can also foster cross-sectoral benefits.

This report also presents summaries of 16 case studies to illustrate specific aspects of applying the concept in practice. An extensive description of these case studies can be found in the separate appendix (Bueb et al., 2021). These case studies provide good practice examples illustrating specific aspects of the SAP concept. They demonstrate possibilities for implementing SAPs, the relevance of particular dynamic elements as well as challenges and lock-ins that complicate this process.

Based on the case studies, a sequence of 10 steps has been suggested to provide guidance when implementing SAPs. The sequence of steps provides a clear but flexible structure adjustable to the respective context and unforeseen changes and feedback loops. These steps cover (1) the assessment of the socio-ecological context and a screening of dynamic elements present in this context. Furthermore, (2) institutional framework and climate vulnerabilities should be assessed to build the basis for (3) identifying objectives of the SAP and (4) relevant actors, scales and sectors to be focused on. An important step is (5) to ensure openness to potential alternative pathways to reach the objectives and to screen and (6) define entry points and potential institutional integration of the SAP, e.g. via national adaptation frameworks, NAPs, national and subnational development plans, disaster risk reduction strategies, as well as territorial planning instruments. Once entry points have been defined, (7) measures to enhance SAP objectives should be selected. Local or national adaptation action plans or strategies can help to define roles, responsibilities, timeline and resources for the (8) implementation of the SAP. Any SAP should contain a (9) M&E framework, including a set of robust indicators. In light of the iterative character of the SAP, (10) regular readjustments should be considered. Updated available knowledge and outcomes of learning processes can be incorporated, followed by an adjustment of measures or even SAP objectives. Enhanced data sharing between key actors can enable holistic vulnerability assessments, help to identify potential for stronger alignment and increase efficiency within relevant institutions.

Throughout this process, a participatory approach open to diverse forms of knowledge as well as different narratives of sustainable adaptation can increase stakeholder buy-in from the outset. It can also enhance the effectiveness of measures planned, address gender inequalities and ensure consideration of vulnerable groups. An inclusive approach that considers vulnerabilities of different groups in a differentiated way is also key to put the central narrative of the SDGs, “Leave no one behind” into practice. However, in practice, participatory approaches often tend to reproduce the status quo rather than changing it (Blühdorn, 2018; Oels, 2019) and if designed without taking underlying power relations into account the process can be challenged by low acceptance (Oels, 2019). This calls for bottom-up formats to co-produce SAPs which are sensitive to local settings as well as power constellations and build on existing fora of participation.

1 Introduction

2015 was a watershed year for international cooperation and for addressing sustainable development (SD) and climate challenges. Under the umbrella of the United Nations (UN), the 2030 Agenda for Sustainable Development (2030 Agenda), the Paris Agreement (PA) and the Sendai Framework for Disaster Risk Reduction (Sendai Framework) were adopted.

The PA, adopted on 12 December 2015, entered into force in November 2016 and committed both industrialized and developing countries to concrete measures for climate protection and adaptation to climate change (CCA) for the first time. It aims to strengthen the global response to the threat of climate change in the context of SD and efforts to eradicate poverty (Art. 2 PA). In addition to the goal of limiting the rise of the global average temperature to well below 2°C – and, if possible, to 1.5°C (cf. Art. 2 para 1 a PA), the parties agreed on a "global goal of adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to SD and ensuring an adequate adaptation response in the context of the temperature goal referred to in Article 2".

In September 2015, paving the way for the adoption of the PA, the member states of the UN agreed on the 2030 Agenda. "Leave no one behind" is the central, transformative promise of the 2030 Agenda, which is embodied in its 17 Sustainable Development Goals (SDGs). The SDGs cover different objectives such as eliminating poverty, achieving sustainable economies, combating climate change, protecting livelihoods and enhancing global partnerships for SD. Each goal has several associated targets and indicators to track its progress. The UN member states aim to reach these goals by 2030. The 2030 Agenda also contains a specific goal to take urgent action to combat climate change and its impacts (cf. SDG 13).

Another international policy framework is the Sendai Framework (UNISDR, 2015). It addresses the risk of small-scale and large-scale, frequent and infrequent, sudden and slow-onset disasters, caused by natural or manmade hazards. The Framework defines several objectives and priorities for action to reduce and prevent disaster risks through the implementation of integrated and inclusive measures that prevent and reduce hazard exposure and vulnerability to disasters (UNDRR, 2020).

Six years after their adoption, implementation of these post-2015 agendas lags behind in many aspects, raising the need for exploring pathways that enhance their effective implementation. One way forward is working towards identifying and using synergies between these post-2015 agendas. The SDGs, in particular, have received the attention of scholars, highlighting their potential for more coherent policies by breaking down "silos" that policymakers and planners are often operating in (Nilsson et al., 2016). Nilsson et al. (2016), for instance, proposed a taxonomy on how negative interactions between the SDGs can be avoided while enhancing positive ones. Overlaps exist at the level of objectives as well as at the level of measures. The successful implementation of more holistic policies for SD is, however, challenging and implementing such a systemic view is a process replete with politics and power (Leach et al., 2010). In practice, potential for synergies thus remains largely untapped and different commitments and priorities of different actors at different administrative levels often lead to contradictory outcomes (Sandholz et al., 2020). At the same time, scholars have highlighted the importance of not glossing over trade-offs and externalities between different policy agendas and call for putting special emphasis on underlying political factors that influence implementation locally (Brand et al., 2021)

Methodology, structure and aim of the Paper

This study first examines interlinkages and overlaps between the post-2015 agendas to identify potential synergies and entry points for strengthening coherence, effectiveness and efficiency of the agendas (chapter 2). Existing concepts that aim at coherence between SD, disaster risk reduction (DRR) and CCA are presented and discussed in order to reflect the current state of the debate in academic and policy circles (chapter 3). The focus of the paper is on CCA and its interlinkages with the other two agendas while climate change mitigation is not explicitly referred to in this paper and in the concept presented.

Building on this, a concept for "Sustainable Adaptation Pathways" (SAPs) was synthesized (chapter 4). This novel concept brings together academic pathway literature with policy-oriented literature on the three post-2015 agendas, and diverse SAPs are illustrated using case studies from around the world. While acknowledging the existence of alternative understandings, we provide a starting point for practical implementation by defining key terms and how they relate to each other in the SAP concept. SAPs describe a coherent set of alternative adaptation strategies and procedures composed of measures and policies to strengthen the capacities of populations, institutions and ecosystems to adapt to climate-related risks over time while enhancing the social justice, environmental integrity and economic sustainability of socio-ecological systems. This is based on the observation that CCA and DRR measures are often not aligned with overarching strategies of SD (Dazé et al., 2019). Based on this, the extent to which the pathways could initiate incremental and transformative CCA is discussed (chapter 4.4). Several case study examples are critically analyzed to discuss good practices of SAPs. Findings from the application of the SAP approach to these case studies will feed into a stepwise approach to pathway design and implementation for practitioners (chapter 5.3). This approach can act as guidance when planning and implementing integrated policies that aim to foster sustainable adaptation measures. Different types of integrative measures which enhance SAPs will be discussed. In the end, practical recommendations are derived to enhance realizing SAPs while taking enabling context factors as well as lock-in effects into account. The concept presented thus explicitly aims to bridge the science-policy gap by using the three international processes as a framework to guide the integration of CCA, SD and DRR in practice.

2 Interlinkages between the different policy agendas: Sendai Framework, 2030 Agenda and Paris Agreement

2.1 Overview of post-2015 agendas

A clear overlap of objectives exists between the 2030 Agenda, the Sendai Framework and the PA. This chapter addresses these overlaps and their legal and institutional relationship.

While in the treaty text of the PA, neither the 2030 Agenda nor the Sendai Framework are explicitly mentioned, COP decision 1/CP.21, which adopted the PA, includes a reference to the 2030 Agenda and the Sendai Framework by welcoming their adoption. The 2030 Agenda, on the other hand, includes a footnote in SDG 13 acknowledging that the United Nations Framework Convention on Climate Change (UNFCCC) is the primary international, intergovernmental forum for negotiating the global response to climate change. The Sendai Framework also refers to UNFCCC as the relevant forum to address climate change. According to para 13 fn. 8 of the Sendai Framework, the climate change issues mentioned in the Sendai Framework remain within the mandate of the UNFCCC under the competences of the Parties to the Convention. Hence, from a legal point of view, there is a relevant forum to address CCA, which is the climate regime with the UNFCCC and the PA in particular. At the same time, CCA and DRR aspects are relevant to a number of SDGs (e.g. 2, 6, 11) (see Table 2). Addressing CCA only within the UNFCCC would thus risk falling short of capturing the various interlinkages of CCA with other policy fields relevant to SD.

The PA includes a mandatory obligation for all parties to submit, implement and periodically update nationally determined contributions (NDC) to reduce greenhouse gas emissions and report on their implementation (cf. Art. 4, 13 para. 7 PA). In contrast, with regard to adaptation the obligations are similar but not as strict and elaborate. There is a legal obligation to "engage in adaptation planning processes and the implementation of actions", but it is softened by the qualifier "as appropriate", and the list of elements is explicitly optional (Art. 7 para 9 PA). Parties merely "should, as appropriate," submit and periodically update an adaptation communication and provide information related to climate change impacts and adaptation (Art. 7 para 10, 13 para 8 PA).[1] The Conference of the Parties to the Paris Agreement (CMA) has adopted guidance on the submission and content on adaptation communications (Decision 9/CMA.1, cf. 1/CMA.2 para 13). Hence, while there is a general obligation to engage in "adaptation planning processes" and to implement actions, there is only a soft obligation to submit an adaptation communication, and specifics are optional. As of May 2021, 16 parties have submitted an adaptation communication (UNFCCC, 2021). Reporting is also voluntary under the Sendai Framework and the 2030 Agenda.

The following table gives an overview of the three agendas, their respective purposes, goals, monitoring requirements and their implementation in Germany (cf. for a good overview Teebken et al., 2021)

[1] For NAPs under the UNFCCC see https://unfccc.int/topics/adaptation-and-resilience/workstreams/national-adaptation-plans).

Table 1 Overview of the three post-2015 agendas

	2030 Agenda	Sendai Framework	Paris Agreement
Legal status	International document adopted by UN member states, and by the UN GA. The Agenda is non-binding	International document adopted by UN member states, endorsed by the UN GA. The framework is non-binding.	Multilateral environmental treaty, binding.
Parties	-	-	191
Scope / purpose	The 2030 Agenda, adopted in 2015, defines 17 SDGs and 169 targets. All UN member states committed themselves to achieve these goals by 2030. The different goals range from the fight against hunger and poverty to climate protection, nature conservation, livelihood protection, peace and justice.	The Sendai Framework applies to the risk of small-scale and large-scale, frequent and infrequent, sudden and slow-onset disasters, caused by natural or manmade hazards as well as related environmental, technological and biological hazards and risks. It aims to guide the multi-hazard management of disaster risk in development at all levels as well as within and across all sectors	The PA aims to strengthen the global response to the threat of climate change, in the context of SD and efforts to eradicate poverty (Art. 2 PA) In order to limit the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C in the long term (Art. 2 lit.a PA). Parties aim to reach global peaking of greenhouse gas emissions as soon as possible. Parties are also obliged to undertake rapid reductions to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century (Art. 4 PA) Parties further should engage in adaptation planning processes and the implementation of actions (Art. 7 para 9 PA)
Goals / Targets	17 goals and 169 targets and 231 indicators (247 indicators in total) to measure the progress in the implementation of goals and targets with several of them relevant to CCA and DRR (see table 2)	7 targets entailing 38 indicators to measure global progress in the implementation of the Sendai Framework	Relevant to adaptation: Art. 2.1(b) PA: Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not theaten food production; and (c) Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development. Art. 7: The “global goal of adaptation” is to enhance adaptive capacity and resilience and to reduce vulnerability, with a view to contributing to SD and ensuring an adequate adaptation response in the context of the temperature goal of the PA

Monitoring / Reporting	UN High-level Political Forum on Sustainable Development is the main global forum for reviewing successes, challenges and lessons learned on achieving the 2030 Agenda UN Secretary General prepares an annual progress report to inform the UN High-level Political Forum (UN GA A/RES/70/1 para 83) The UN High-level Political Forum is also informed by the Global Sustainable Development Report, a quadrennial report by an independent group of scientists (IGS) supported by a task team of six UN entities (DESA, UNCTAD, UNDP, UNEP, UNESCO and the World Bank) Voluntary reviews at the national level: All UN Member States are encouraged to conduct regular and inclusive reviews (UN GA A/RES/70/1 para 83)	UN Secretary General prepares an annual report on the implementation of the Sendai Framework. The Sendai Framework Monitor provides a system for national reporting on the global Sendai Framework targets and the DRR-related indicators of the SDGs 1, 11 and 13 (UNDRR, 2021b) Sendai Framework monitoring tool: Member States report against the set of 38 indicators for measuring the global targets of the Sendai Framework using the Sendai Framework Monitor	Soft obligations on submitting and updating an adaptation communication and to report information related to climate change impacts and adaptation (Art. 13 para 8 PA) Adaptation is also part of the "global stocktake" of Paris Agreement Art. 14, by which the CMA "periodically take[s] stock of the implementation of this Agreement to assess the collective progress towards achieving the purpose [...]. It shall do so in a comprehensive and facilitative manner, considering [...] adaptation" National Adaptation Plans: Each Party shall, as appropriate, engage in adaptation planning processes and the implementation of actions, which may include the process to formulate and implement national adaptation plans (Art. 7 para 9 PA). The national adaptation plan process was established under the Cancun Adaptation Framework to strengthen action on adaptation in developing countries.

Implementation in Germany	German Sustainability Strategy sets the frame for the national implementation. The State Secretariat Committee for Sustainable Development has the following tasks, among others, to continue developing the sustainability strategy and to monitor how the indicators are developing. One state secretary from each ministry, together with the head of the Chancellor's Office, form the State Secretaries' Committee for Sustainable Development. The Federal Statistical Office regularly evaluates the implementation of the German Sustainability Targets.	An interministerial working group coordinates the implementation of the Sendai Framework in Germany. According to the Sendai Framework, national contact points are to be established at the government level.	Gesetz zur Umsetzung des Pariser Übereinkommens (BGBl. 2016 II p. 1082) Climate Change Act and various other laws
German contribution	Last voluntary national review is from 2016; Germany will participate in the voluntary national reviews to take place at the 2021 HLPF	Voluntary reporting by Germany is still in progress	Germany has a National Adaptation Strategy and Adaptation Action Plans. Adaptation is not part of the First NDC nor the updated NDC of the EU.

Responsible authority in Germany	Federal Chancellery (Prime Minister's Office) is lead agency for the German Sustainable Development Strategy. (Cf. for a good overview Teebken et al. 2021) Focal points for the 2030 agenda are the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety and the Federal Ministry for Economic Cooperation and Development	The Federal Ministry of the Interior, the Federal Foreign Office and the Federal Ministry for Economic Cooperation have commissioned the Federal Office of Civil Protection and Disaster Assistance (Bundesamt für Bevölkerungsschutz und Katastrophenhilfe) to establish the national contact point.	The Federal Environment Ministry leads policy-making on climate mitigation and adaptation. (Cf. for a good overview Teebken et al. , 2021)

2.2 Entry points for synergies at the level of objectives

Identifying synergies between SD, DRR and CCA is a precondition for the implementation of coherent, efficient and effective measures for the joint integration of these three processes. Making interlinkages and synergies visible requires breaking the agendas down into two different lines of integration: First, integration through common objectives and second, integration through operational vehicles and policy instruments. The first will be described below, while the latter, i.e. entry points at the operational level, will be discussed in detail in chapter 5.3.6.

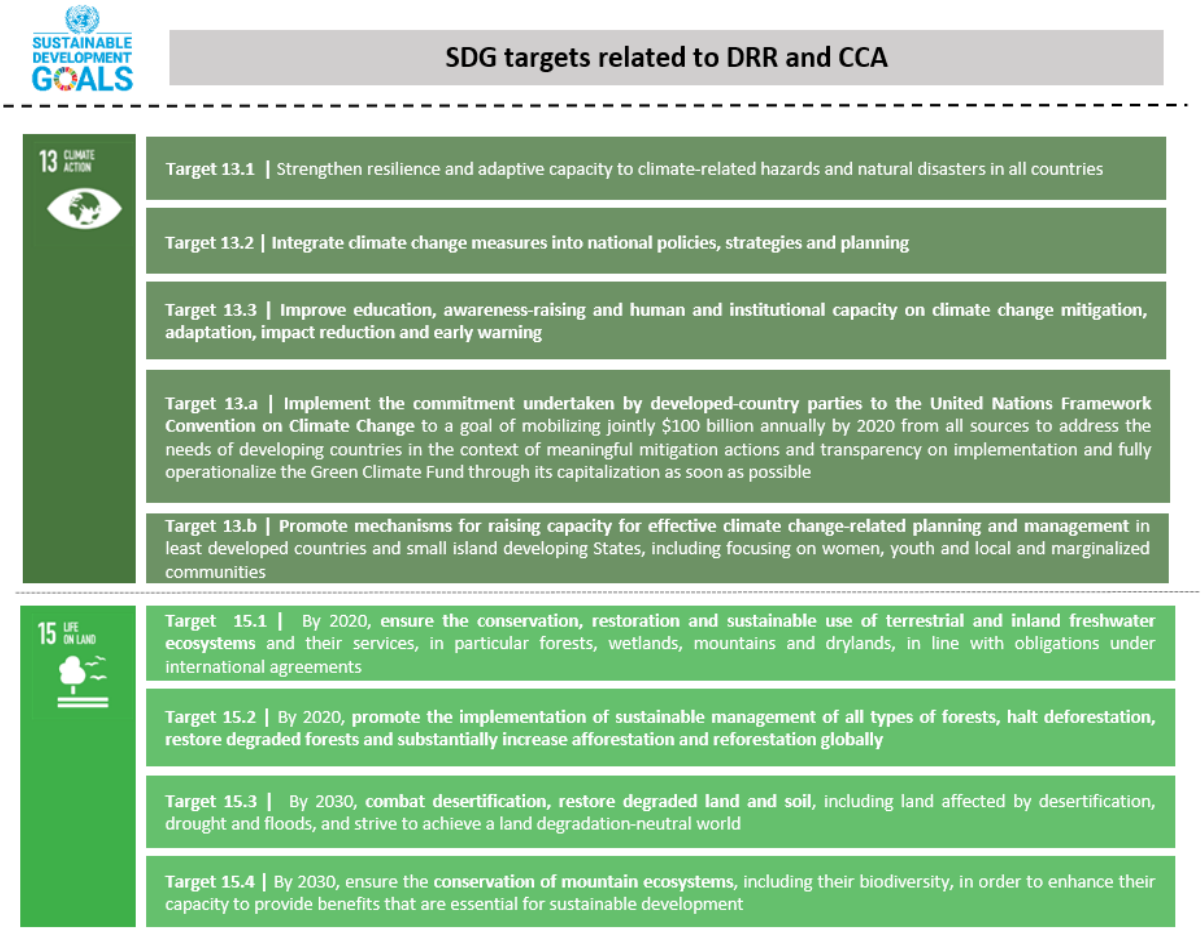
There is potential for integration of the three post-2015 agendas through the common objectives of improving livelihoods and ecosystems and enhancing their resilience. These objectives are not only stated in the PA (Art. 2 and 7) but also in several SDGs. SDG 1 (no poverty), SDG 2 (resilient agricultural practice), SDG 9 (industry, innovation, and infrastructure), SDG 11 (sustainable cities and municipalities) and SDG 13 (climate change measures) make reference to strengthening resilience. Resilience is referred to in all three post-2015 agendas that are addressed in this paper but each with different foci. The UNDRR (2021a) defines resilience as the 'ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.' This definition with its explicit focus on risk management in the light of hazards is also used in the Sendai Framework. No definition is provided in both the text of the 2030 Agenda and in the PA, but resilience is mentioned in both texts. In the PA, resilience features as an integral component of CCA and is linked to the concepts of vulnerability and adaptive capacity. The 2030 Agenda entails the broadest understanding of resilience of all three agendas, linking it to issues such as poverty reduction, human settlements and built infrastructures, agriculture as well as vulnerability to climate extremes and disasters. Resilience is hence referred to in two SDGs (2 and 9) and eight targets (in particular target 1.5 on building resilience of the poor and those living in vulnerable situations) (see also Table 2 below). Thus, how resilience is referred to in each agenda is aligned with the objectives of each agenda. Hence, the Sendai Framework considers resilience through the lens of DRR, the PA connects it to its CCA goals and the 2030 Agenda relates it to several goals and targets that cover various aspects of SD.

The 2030 Agenda further singles out climate change as a unique, crosscutting threat to the ability of all countries to achieve SD (UN, 2015c). Climate change as a major risk and driver of environmental change[2] is another common thread in all three agendas. It features prominently in the SDGs - not only in Goal 13 (Climate Action) - but climate action is also referred to in other Goals. Relevant linkages between SDG goals and related DRR targets and CCA targets are shown in Table 2 below. A table including SDG indicators is included in Appendix A. According to UNDRR (2020), including the Sendai Framework and climate change in the 2030 Agenda demonstrate that DRR and CCA are "vital strategies for achievement of the SDGs."

[2] An in-depth assessment of climate change both as a driver and cross-cutting issue in the SD context is provided in UN Environment's (UNEP) sixth Global Environment Outlook (UNEP, 2019b).

Table 2 DRR and CCA targets in SDGs

SDG targets related to DRR and CCA	
1 NO POVERTY	Target 1.5 | By 2030, **build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability** to climate-related extremes and other economic, social and environmental shocks and disasters
2 ZERO HUNGER	Target 2.4 | By 2030, **ensure sustainable food production systems and implement resilient agricultural practices** that increase productivity and production, that held maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.
3 GOOD HEALTH AND WELL BEING	Target 3d | **Strengthen the capacity** of all countries, in particular developing countries, **for early warning, risk reduction and management of national and global health risk**
4 QUALITY EDUCATION	Target 4.7 | By 2030, **ensure that all learners acquire the knowledge and skills needed to promote sustainable development including,** among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and nonviolence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development.
	Target 4.a | **Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, non-violent, inclusive and effective learning environments for all.**
6 CLEAN WATER AND SANITATION	Target 6.4 | By 2030, **substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity**
	Target 6.5 | By 2030, **implement integrated water resources management at all levels**, including through transboundary cooperation as appropriate
	Target 6.6 | By 2020, **protect and restore water-related ecosystems**, including mountains, forests, wetlands, rivers, aquifers and lakes.
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	Target 9.1 | **Develop quality, reliable, sustainable and resilient infrastructure,** including regional and transborder infrastructure, to support economic development and human well-being, with focus on affordable and equitable access for all.
	Target 9.a | **Facilitate sustainable and resilient infrastructure development in developing countries** through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island development states.
11 SUSTAINABLE CITIES AND COMMUNITIES	Target 11.1 | By 2030, **ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums**
	Target 11.3 | By 2030, **enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management** in all countries
	Target 11.5 | By 2030, **significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters,** including water-related disasters, with a focus on protecting the poor and people in vulnerable situations
	Target 11.b | By 2020, **substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels**
	Target 11.c | **Support least developed countries,** including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials



Source: Author's own figure, data source: Inter-Agency and Expert Group on SDG Indicators (2016).

2.2.1 Linkages between SDGs and CCA

Several targets in the SDGs address CCA (Table 2). First of all, this applies to the central SDG 13 to take urgent action against climate change and its impacts. This includes inter alia target 13.2 to integrate climate change measures into national policies, strategies and planning. The target is further specified by indicator 13.2.1 of the global indicator framework for SDGs to measure target 13.2 via the number of countries with NDCs, long-term strategies, NAPs and adaptation communications, as reported to the UNFCCC secretariat. The global indicator framework for SDGs was developed by the Inter-Agency and Expert Group on SDG Indicators and agreed upon at the 48th session of the United Nations Statistical Commission. The global indicator framework is regularly updated (cf the latest version A/RES/71/313; E/CN.3/2021/02). Furthermore, SDG 1 (No poverty), SDG 2 (Hunger) and SDG 11 (Cities) contain explicit references to CCA (see table above).

Climate change plays a major role in contributing to the degradation of ecosystems and biodiversity loss, and unsustainable land use in turn is one of the major drivers of climate change. In CCA discussions, ecosystem-based adaptation (EbA) has gained traction over the last years and "involves a wide range of ecosystem management activities to increase the resilience and reduce the vulnerability of people and the environment to climate change" (IUCN, 2015). In

this context, SDG 14 (Life below Water) and 15 (Life on Land) as well as Target 6.6 (Protect and restore water-related ecosystems) focus on ecosystems and call for the application of ecosystem-based solutions to prevent biodiversity loss and achieve conservation targets. Due to a strong focus on ecosystems in all three post-2015 agendas, integrative policies and planning that are ecosystem-based have great potential for reaping synergies between the three agendas.

CCA actions present opportunities to 'adapt forward' and work towards achieving the SDGs instead of regressing to the status quo before climate change (UNFCCC, 2017b). 'Adapt forward' thus embraces the transformative potential of CCA for structural changes. The high potential of a mix of CCA and mitigation options to enable rapid, systemic transitions in urban and rural areas is also mentioned in the Special Report on Global Warming of 1.5 °C (IPCC, 2018b). These approaches are believed to be most effective if implemented in a participatory and integrated manner and aligned with economic and SD, and when local and regional governments and decision makers are supported by national governments (IPCC, 2018b). At the level of objectives there are, however, also potential trade-offs between individual SDGs or targets and the goals of the PA (Brand et al., 2021). In practice, negative interactions between CCA and individual SDGs have been observed, leading to environmental-economic trade-offs if interactions are not sufficiently considered in the design of CCA measures. In Tanzania, for example, a protected marine area, the Mnazi Bay–Ruvuma Estuary Marine Park, was set up to bolster the climate change resilience of coral reefs. This limited the traditional fishing activities of local villagers, causing their dependence on energy-intensive farming with higher rates of greenhouse gas emissions and migration of fishers (Sovacool et al., 2015).

In the PA, the global goal on adaptation of the PA (Art 7.1 PA) can serve as an entry point for integrated actions, calling on "enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development" (UN, 2015b). The Adaptation Committee under the PA is mandated to "consider approaches to reviewing the overall progress made in achieving the global goal on adaptation" and to report in 2021 (CMA Decision 1(CMA.2 para 14).

2.2.2 Linkages between SDGs and the Sendai Framework

The Sendai Framework is the first international DRR framework that includes specific measurable targets (UNFCCC, 2017b). It does not directly refer to the 2030 Agenda and the PA, as it was endorsed before them (UNDRR, 2020). It, however, postulates that DRR is part of SD and that development must in turn reduce disaster risks while recognizing that unsustainable development increases risks and resulting losses from disasters (UNISDR, 2015). The guiding principle of the Sendai Framework to "build back better" embodies that DRR should go beyond addressing short-term risk to preventing the creation of disaster risk (UNISDR, 2015). This narrative introduced in the Sendai Framework sets the integration of DRR into development measures as a priority to make nations and communities resilient to disasters (UN, 2015a). Turning towards this understanding and moving away from the idea of DRR as purely operational and ad-hoc is a precondition for an effective integration.

The Sendai Framework sets up four priorities for action and seven global targets. The priorities include understanding disaster risk (priority 1), strengthening disaster risk governance to manage disaster risk (priority 2), investing in DRR for resilience (priority 3) and enhancing disaster preparedness for effective response (priority 4).

The targets are:

- to substantially reduce global disaster mortality by 2030 (global target A)

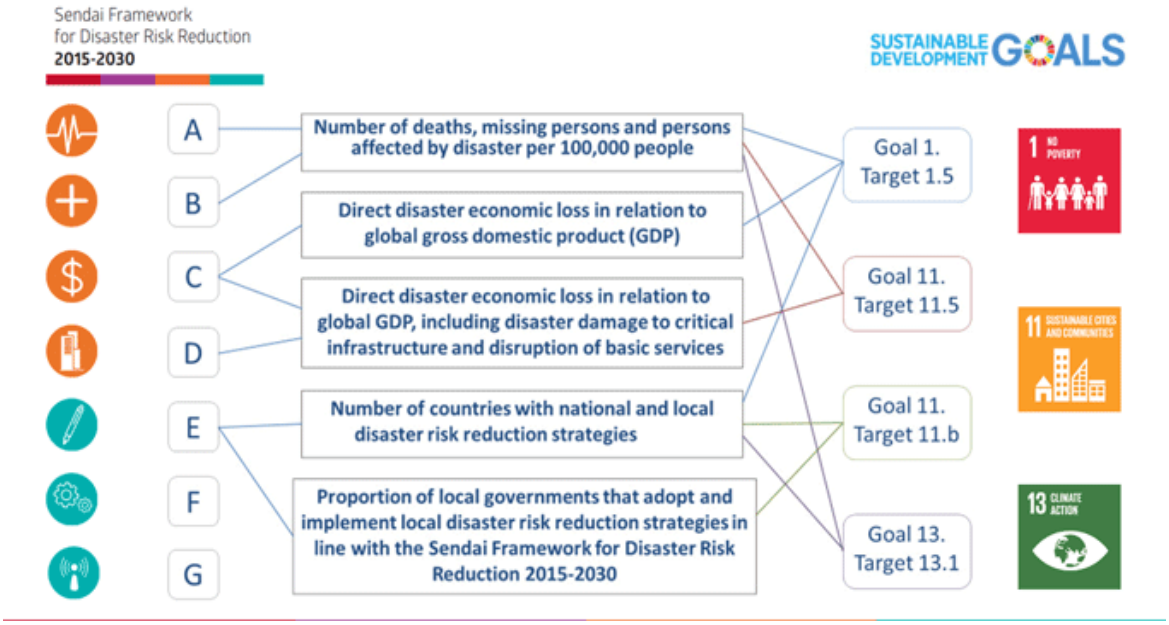
- to substantially reduce the number of affected people globally by 2030 (global target B)
- to reduce direct disaster economic loss in relation to global gross domestic product (global target C)
- to substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030 (global target D)
- to substantially increase the number of countries with national and local DRR strategies by 2020 (global target E)
- to substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of this framework by 2030 (global target F)
- to substantially increase the availability of and access to multi-hazard early warning systems (EWS) and disaster risk information and assessments to the people by 2030 (global target G)

38 indicators were identified to measure the progress of implementing the different targets (cf. Sendai Framework Indicators). The target- and indicator-based nature of the framework is therefore closely related to the SDGs (UNFCCC, 2017b). While there is no SDG that specifically addresses DRR (UNDRR, 2020), a number of SDGs make reference to strengthening resilience: SDG 1 (no poverty, target 1.5), SDG 2 (zero hunger, target 2.4), SDG 3 (good health and wellbeing, target 3.d), SDG 4 (quality education, target 4.7 and 4.d), SDG 6 (clean water and sanitation, target, target 6.6), SDG 9 (industry, innovation, and infrastructure, target 9.1 and 9.a), SDG 11 (sustainable cities and municipalities, targets 11.1, 11.3 – 11.5, 11.b, 11.c),SDG 13 (climate change measures, targets 13.1-13.3, 13.a, 13.b), SDG 14 (life below water, target 14.2) and SDG 15 (life on land, targets 15.1 – 15.4, 15.9).- This is also reflected in the Sendai Framework Monitoring for Objectives A-E.

Furthermore, monitoring of the Sendai Framework is intended to complement monitoring of 11 SDG indicators (UNDRR, 2020). Several indicators to measure the different SDG targets are identical with the indicators in the Sendai Framework. Hence, “important synergies exist between reporting on the two frameworks” (Prevention Web, n.d.).

Figure 1 shows the major interlinkages, e.g. Sendai Framework indicators A1 and B1 (Number of deaths, missing persons and persons affected by disaster per 100,000 population) are directly related to SDG 1 and its indicator 1.5.1. The Sendai Framework global target E to substantially increase the number of countries with national and local DRR strategies by 2020 is also closely related to SDG goals 1, 11 and 13 and the relevant indicators 1.5.3, 11.b.1 and 13.1.2.

Figure 1 Linkages between the Sendai Framework and SDGs

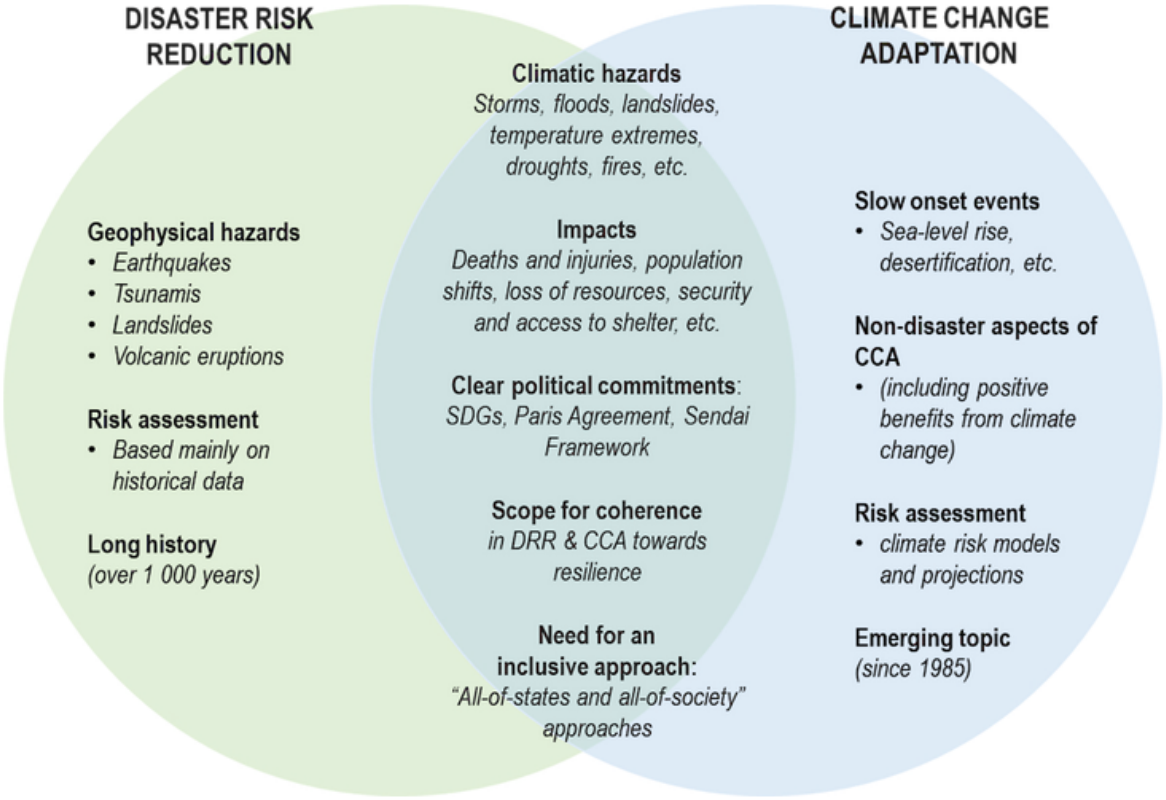


Source: UNDRR (2020)

2.2.3 Linkages between CCA and the Sendai Framework

There are significant overlaps between CCA and DRR and often they are both seen as risk reduction approaches with the overall aim to enhance SD (UNDRR, 2020). Both deal with lowering the risks of natural hazards prior to, and vulnerability reduction in the aftermath of natural hazards (Glover & Granberg, 2020). The common objective may therefore be seen in decreasing vulnerabilities against weather-related extreme events, such as floods, droughts, wild fires, storms, etc. DRR additionally covers geophysical, technological, pandemic-related etc. extreme events, e.g. volcanic eruptions and earthquakes, while CCA also targets slow onset events such as sea-level rise and desertification arising from climate change (OECD, 2020).

Figure 2 Terms and meanings in CCA and DRR: commonalities and differences.



Source: OECD (2020)

The exact relationships are, however, subject to discussions that are often held in separate communities of practice. Thus, CCA and DRR expert groups often base their work on different methodologies and funding mechanisms, and are coordinated by different ministries. This often leads to siloed approaches to managing risk (UNDRR, 2020).

Climate change is identified in the Sendai Framework as a driver of disaster risk, in conjunction with poverty and inequalities, uncontrolled urbanization, and poor land management (cf. preamble para. 6 of the Sendai Framework). Tackling these and other factors that contribute to intensification of risk is expected to lead to significant reduction of disaster risk (EEA, 2017; OECD, 2020). While there is no direct reference to the Sendai Framework in the PA, Article 7 on adaptation and Article 8 on loss and damage associated with effects of climate change are intrinsically linked to DRR (OECD, 2020; UNDRR, 2020).

2.3 Towards a procedural approach to assessing policy integration

The three post-2015 agendas are key to tackling major global challenges: adapt to climate change, foster SD and promote DRR. An integrated approach can allow countries to make better use of their available capacity, e.g. by the sharing of data between relevant actors, encouraging policy learning related to best practices and common issues, and reallocating resources from operations and maintenance to innovation and addressing complex problems (UNFCCC, 2017b). While there is political will to foster the integration of these three processes, it is often not clear what degree of integration is feasible.[3]

[3] See Teebken et. al (2021) for an extended discussion on the notion of integrated policy making in different schools and the limitations of integration.

Teebken et al. (2021) describe how policy integration in a dominant understanding aims to enhance policy coherence and integration. Integration can make strategies across policy sectors more coherent and increase policy effectiveness while reducing inefficiencies in public policymaking (Candel & Biesbroek, 2016; Teebken et al., 2021). Accordingly, policy coherence, on the one hand, refers to various components of policies and the process of designing a set of policies that can achieve a larger goal (Cejudo & Michel, 2017). Improved coordination, on the other hand, is understood as a process, in which members of different organizations (e.g. within public administrations) "define tasks, allocate responsibility and share information, in order to be more efficient when implementing the policies and programs they select to solve public problems" (Cejudo & Michel, 2017). Integration can be thus understood as an overarching way to address multidimensional policy problems by using both coordination and policy coherence (Cejudo & Michel, 2017).

Many researchers have approached the question of an optimal degree of integration following a gradual approach by Metcalfe (1994) ranging from full fragmentation to full integration characterized by strong coordination and a coherent government strategy. A challenge of Metcalfe´s approach is the assumption of a unidimensional, ordinal and cumulative scale. Such a linear approach falls short of capturing the dynamic nature of overlapping processes in different policy fields. Fully integrating all post-2015 agendas would risk losing the individual relevance of each of the three (Peters et al., 2016; Teebken et al., 2021).

The complexity of the three agendas further complicates full integration (Teebken et al., 2021). In the case of the multi-policy 2030 Agenda, which covers a broad set of policy fields, implementation in itself requires coordination and coordinated priority setting within typically 'siloed' administrations (Teebken et al., 2021). The 2030 Agenda regards its goals as "universal, indivisible, and interlinked" (para 71). It also addresses the need for governments and public institutions to work closely on implementation with regional and local authorities, sub-regional institutions, international institutions, academia and civil society (para 45). As it moves away from "one-size-fits-all"-approaches, it does, however, not provide detailed guidance on how to achieve integration at implementation level (Stafford-Smith et al., 2017)[4]. In addition, even strong policy integration in national legal frameworks does not automatically translate into strong implementation in practice, particularly when sufficient involvement of non-state actors is missing (Stafford-Smith et al., 2017; Teebken et al., 2021). In light of the difficulties of judging the feasibility of integration in terms of agenda and policy goal alignment, Teebken et al. (2021) propose a procedural definition of integrated policy-making.

In their approach, integrated policy-making means multi-sectoral, procedural cooperation of different actors, co-creation and decentralized policymaking through the inclusion of non-state actors and governmental leadership (Teebken et al., 2021). Teebken et al. (2021) also highlight the need for the prioritization of policy goals when designing integrative policies to decrease the risk of watering down concrete policy efforts. Such a prioritization requires taking into account the local political and socioeconomic context (Eriksen et al., 2015; Sandholz et al., 2020).

2.4 Summary

To identify potential synergies between the three post-2015 agendas, it is important to recognize the different understandings of SD, CCA and DRR (see chapter 2.2). The 2030 Agenda

[4] It has to be emphasized that subsequent guidance documents have, however, provided more detail on how to achieve policy integration in practice. These include the Global Sustainable Development Report (GSDR) published every four years as well as the Voluntary National Reviews. The latter aim to facilitate the sharing of member states' experiences, including successes, challenges and lessons learned, with a view of accelerating the implementation of the 2030 Agenda (Sustainable Development Knowledge Platform, 2021).

has by far the most encompassing approach embedded in its SDGs, covering the whole spectrum of SD including several aspects of CCA and DRR. It can therefore provide a common basis for coordinating the implementation of CCA and DRR, as disasters and climate change have the potential to severely affect development efforts (UNDRR, 2019). This is in line with the IPCC (2018b), which is highly confident that CCA options specific to national contexts will benefit SD and poverty reduction as well as mitigation goals, although trade-offs are possible. Thus, while effective CCA and DRR strategies could be key components of SD, they also need to be integrated into national development policy plans. Practical guidance on this will be provided in chapter 5.3.

The narratives of "adapt forward" and "build back better" in CCA and DRR, respectively, already indicate their relevance for SD. Chapter 2.3 showed that defining an 'optimal' degree of policy integration is difficult to evaluate. Instead, a procedural approach to integrative policy-making signified by multi-sectoral, procedural cooperation of different actors, co-creation and decentralized policymaking through the inclusion of non-state actors and governmental steering is a way forward (Teebken et al., 2021).

In the next chapter, we will first present existing conceptual approaches to foster integrative actions between some or all of these three processes (DRR, CCA and SD). Based on this, we will propose a novel concept of SAPs which we will then illustrate and validate using case study examples for sustainable adaptation.

3 Overview of existing pathway approaches

This chapter covers a screening of available pathway approaches regarding CCA, DRR and SD. The main objectives and characteristics of the concepts are described. A special focus is on interlinkages between different policy fields and agendas and preconditions for pathway implementation. These findings inform the concept of SAPs described in chapter 4.

3.1 Adaptation Pathways

Adaptation Pathways are described by Haasnoot et al. (2012) as an analytical method for sequencing a set of possible CCA actions, taking into account external developments over time. The authors developed the method further into Dynamic Adaptive Policy Pathways - including the concept of Adaptive Policymaking. The method enables decision-making under deep uncertainties by creating a strategic future vision, drafting short-term actions and establishing a framework to guide future actions, which allows for its dynamic adaptation over time to meet changing circumstances (Haasnoot et al., 2013). The approach has the advantage of analyzing adaptation lock-ins and path dependencies and takes into account social, political, technological, economic, and climate changes.

Box 1 | Decision-making under deep uncertainty

CCA decisions need to be made without definite certainty about future climate projections but also about future social, political, and technical conditions and even about current risk perceptions, tolerances, and social values (Siders & Pierce, 2021). These uncertainties, paired with the influence of contextual factors such as individual values, framings and risk perceptions oppose a linear and static planning and call for flexible but structured approaches allowing for iterative pathway development (Buurman & Babovic, 2016). Numerous decision-making strategies have been developed to reduce uncertainty, evaluate options under multiple future scenarios, or create decision pathways in an effort to overcome barriers (Buurman & Babovic, 2016; Siders & Pierce, 2021). Despite the existence of decision-making methods and tools, there is still a lack of research on if and how adaptation strategies are selected in practice, as well as on how decision-makers should choose which decision-making process to use (Siders & Pierce, 2021).

Haasnoot et al. (2013) are not specifically referring to the concept of transformative adaptation and issues of social inequalities. Other concepts, such as those of Butler et al. (2016), propose scenario planning as a flexible tool used to inform the design of adaptation measures in a participatory manner to leap-frog the SDGs.

Wise et al. (2014) have the aim to explore an adaptation pathway approach that draws on pathways thinking in the SD domain and accommodating a systems approach for community development planning. The approach considers the implications of path dependency, interactions between adaptation plans and settings in which societal responses to climate change are needed.

The concept of adaptation pathways by Wise et al. (2014) emphasizes five aspects of adaptation challenges which are currently not well-integrated in research and practice: (1) CCA is interlinked with a range of societal responses to change and needs to integrate in local cultural, political, economic, environmental and developmental contexts. (2) Responses need to emphasize cross-spatial scale and sectors. (3) Temporal aspects need to be taken into account. Future pathways depend on historical pathways including path dependency and lock-in effects. (4) Measuring and monitoring the trajectory is difficult within the complex social-ecological systems. (5) Societal processes are shaped by existing rules, values and knowledge cultures, and

interlinkages between them. These interdependencies need to be understood; including how they can be changed to better enable adaptation research and practice. The last dimension is also important to assess the potential of adaptation to tackle the wellbeing of disadvantaged and politically marginalized populations due to e.g. existing power relations or norms (Leach et al., 2010; Pelling, 2011).

The pathways developed by Wise et al. (2014) intend to flag integration of incremental and transformative actions (see chapter 4.4 for a discussion on incremental and transformative adaptation). Existing incremental actions should be continued in such a way that they inform and enable systemic change. Additionally, intentions and outcomes of societal change should be considered with a particular focus on the influence of existing rules and values on framing and decision-making and how to change these to more desirable pathways in the context of global change.

The adaptation pathway approach has the advantage of showing that various desirable and undesirable pathways can emerge, including mal-adaptive or unintended effects, e.g. CCA measures of building more flood defences, which can influence the risk perception of house and property owners. The pathway perspective uses an iterative approach guided by a strategic vision. Knowledge exchange and participation is mentioned as key to enhance stakeholder empowerment. An issue might be the resource intensity and needed capacities for the approach as solutions aim at altering social norms and societal values. The discussion of such underlying issues is challenging (Fischer et al., 2012).

With the re-conceptualization of adaptation pathways by Wise et al. (2014), the approach emphasizes the perspective of CCA as part of pathways of change and response, where the intent and outcome of CCA are not risk reduction per se, but rather addressing the systemic drivers of vulnerability in dynamic systems. The concept by Wise et al. (2014) increases awareness for explicitly integrating CCA activities with mitigation and development (Eriksen et al., 2011; van Vuuren et al., 2011).

3.2 Pathways to Sustainability

In 2010, researchers of the British STEPS Centre introduced the “Pathways to sustainability approach” to respond to dynamic contexts and complex social-environmental challenges (Leach et al., 2010). Since then, this approach has substantially informed the adaptation pathways literature (Turnheim et al., 2015; Wise et al., 2014)[5]. The approach originates from the observation that social-environmental systems are changing at increasing speed and challenges emerging in these systems are complex, unpredictable and unstable. Responding to complex challenges thus requires paying attention to interactions of different systems (social, ecological, technological) across multiple scales and how they play out in particular contexts.

At the same time, contemporary political institutions most often embody static understandings of policy problems, where development paths are perceived as single linear trajectories. Moreover, they observe a tendency for powerful actors and institutions to “close down” around particular framings of sustainability and SD, hence committing to pathways that promise maintaining stability and control. As a result, universalizing and generalizing approaches become dominant while alternatives are obscured or denied. Based on these observations, the authors argue that methods and practices are needed which involve flexibility, diversity,

[5] Another approach to evaluate sustainability transitions pathways has been presented by Turnheim et al. (2015), which, however, explicitly does not build on the approach by Leach et al. (2010). This approach focuses on the specific characteristics of decarbonization and thus is not sufficiently transferable to adaptation. Hence, this approach will not be discussed further in this paper.

adaptation, learning and reflexivity. They also emphasize the importance of alternative politics of sustainability that highlight and support alternative pathways. Development pathways are defined as ‘‘alternative possible trajectories for knowledge, intervention and change, which prioritise different goals, values and functions” (Leach et al., 2010, p. 5).

Concretely, they identify four major hurdles to be addressed to realize more effective approaches to sustainability and development, highlighting the importance of “dynamics”, “incomplete knowledge”, “multiple framings” and “normativity”.

The approach describes the following inertia in current policy approaches. First, ignoring dynamics is common in conventional policy approaches and most of these approaches are rooted in thinking of equilibria. This thinking favors controlling variability over adapting and responding to it. It also builds on the assumption that policy models developed for one setting will work in others. Complex, dynamic contexts, however, often undermine the neat assumptions of imported models. Emerging backlashes and feedback loops from ecological systems, social movements or politics make a widening gap between standard policy approaches and dynamic systems visible.

A second hurdle is seen in the dominant assumption that complex challenges can be calculated, controlled and managed while ambiguities are ignored and knowledge gaps are disregarded.

Connected to this is, thirdly, an insufficient consideration of alternative narratives and framings of policy problems and ways to achieve them. Instead, often, a single path to progress or development is being pursued which is based on a dominant understanding of these key concepts. Different norms and values of actors which underpin alternative framings and narratives are, however, likely to generate differing views on what is a desirable policy outcome and the ways of realizing them. Lastly, they observe that ideas of sustainability have become co-opted into managerial and bureaucratic attempts to “solve” problems, which emphasizes the need for clear conceptualization.

To avoid this conceptual blurriness, Leach et al. (2010) define sustainability as “explicit qualities of human well-being, social equity and environmental integrity, and the particular system qualities that can sustain these. All these goals of sustainability are context-specific and inevitably contested. This makes it essential to recognize the roles of public deliberation and negotiation - both of the definition of what is to be sustained and how to get there - in what must be seen as a highly political (rather than technical) process.”

They provide several examples illustrating their argumentation, one of them being water-scarce Kutch, a region of Gujarat in Western India (see in the Box below).

Box 2 | Alternative narratives to tackle water scarcity in Guajarat, India

In the Kutch region, in the state of Guajarat in Western India, technological solutions, such as large dams on the Narmada river, have been implemented to solve problems related to drastically declining water availability. While these technological and planning-based solutions address the scarcity gap, they do not consider the root causes of water scarcity and leave out the distributional side of the problem. Other than the dominant narrative present among state planners and water engineers, who perceive scarcity as a natural process attributed to low and ever-decreasing rainfall and recurring droughts, local people place emphasis on the culpability of large-scale agriculture, bad water management practices, misuse of water and circumventing legislation. In ensuring sustainability, Leach et al. (2010) argue that contexts like these require moving beyond a control-oriented engineering approach. In the Indian case, this might include building on local knowledge and techniques such as tank systems, water harvesting or strategies for crop mixes while at the same time implementing water engineering for resilience with inbuilt flexibility and ability to manage

flows in a responsive and adaptive manner. However, existing long-term climatic stresses also require longer-term shifts in land use, agricultural practices, etc., which require different technologies. Finding pathways that take into account these manifold narratives and challenges requires a certain degree of policy experimentation, the authors argue.

Source: Leach et al. (2010)

While the pathway approach does not explicitly address CCA, but rather the fields of sustainability and development, its strength lies in the transferability of its analytical framework. Still, the normative conceptualization of sustainability provides a fruitful base for exploring SAPs. Underlying goals of sustainability, the authors observe, are context-specific and inevitably contested. The authors conceptualize pathways not as singular, linear trajectories but rather as multiple and dynamic. By shedding light on the complexity and dynamic character of interactions between social, technological and ecological systems, their approach strongly opposes one-size-fits-all solutions to SD, which have been inherent to many initiatives and projects in the past. It also makes the point for taking into account alternative narratives, framings and concepts held by different actors and groups, in particular those present at the local level to identify approaches to capture underlying dynamics of interacting social, ecological and technological systems. The approach also relates to transformative adaptation literature as well as subsequent pathway approaches, which emphasize the need to transform dominant social and political conditions that produce vulnerability and perpetuate existing inequalities (Wise et al., 2014). Finally, the approach is also a call for more policy experimentation given the uncontrollability, uncertainty and ambiguity that characterize complex policy challenges.

3.3 The sustainable adaptation literature

Focusing on local vulnerabilities and adaptive capacity, one strand of literature has investigated the relationship between sustainability, CCA and development (Brown, 2011; Eriksen et al., 2011, 2015; Eriksen & Lind, 2009; Eriksen & O'Brien, 2007).

Sustainable adaptation is defined here as "adaptation that contributes to socially and environmentally sustainable development pathways, including both social justice and environmental integrity" (Eriksen et al., 2011). Sustainable adaptation is thus seen as embedded in wider SD pathways towards social justice and environmental integrity. A central argument is that, in practice, adaptation measures do not automatically contribute to these pathways (Brown, 2011; Eriksen et al., 2011). Instead, "maladaptation" may occur when adaptation decisions may fail to meet their objectives, and even increase vulnerability (Barnett & O'Neill, 2010). Grey flood protection infrastructure, such as concrete barriers to protect against sea-level rise, can produce changes in the offshore sediment balance and increase erosion in nearby coastal areas, affecting local populations lacking sufficient adaptive capacity. Also, scholars of the notion of sustainable adaptation set out to identify and address the root causes of vulnerability (Brown, 2011) similar to scholars of transformative adaptation which will be discussed in chapter 4.4. For CCA measures to be sustainable, Eriksen et al. (2011a) define four principles:

- **The context of vulnerability in which climate change is seen as one of multiple stressors**

  Identifying the direct and indirect consequences of CCA measures requires taking into account the underlying social and economic conditions (e.g. chronic poverty, spatial inequalities, existing networks) that contribute to a wider context for vulnerability.

- **Different values and interests affecting CCA outcomes**

  Identifying potential conflicts of interests and how they can impact CCA outcomes, e.g. by implementing responses that are aligned with the interests of dominant actors

- **Local knowledge and their integration with other sources of knowledge into CCA responses, e.g. in community-based CCA initiatives**

  Different approaches to CCA often reflect varying approaches to knowledge and understandings of the local context and result in different diagnoses of both problems and solutions. Integrating local knowledge based on the experience of local populations is essential for sustainable CCA.

- **Potential feedbacks between local and global processes**

  CCA measures can directly influence the vulnerability of populations, but in turn, the measure can also affect or be affected by processes on a larger scale due to economic and ecological interlinkages. Over time, this can raise questions about their sustainability, e.g. when CCA measures have significant impacts on greenhouse gas emissions or biodiversity.

Scholars of this research strand have also emphasized the importance of power and politics in responses to climate change (Eriksen et al., 2015; Eriksen & Lind, 2009). They thus conceptualize CCA as a deeply socio-political and cultural process instead of a purely technological, linear and implicitly politically neutral response to actual or expected bio-physical changes (Eriksen et al., 2015). Analyzing the case of drought adaptation in Kenya's drylands, Eriksen and Lind (2009) show how economic and political structures and processes at multiple scales affect local adaptive capacity in fundamental ways, such as through the unequal allocation of resources across regions, development policy biased against pastoralism, and competition for elected political positions.

This research strand provides valuable insights by illustrating that not every CCA measure automatically reduces vulnerability of the poor, or contributes to SD in the face of climate change. In this regard, it emphasizes the role of adaptive capacity as well as of considering the local context. It further demonstrates how including local forms of knowledge can help identify responses, which not only build on local experience but also decrease harmful effects on local populations. By pointing out what unsustainable CCA measures are and that these, in fact, often rely on grey infrastructure, they pave the way for approaches of EbA and nature-based solutions (NbS) as well as for nexus approaches. These will be discussed in greater depth in chapters 3.5 and 3.6. However, by excluding economic sustainability from their definition of SD pathways, Eriksen et al. (2011a) do not provide a concept in line with the more holistic sustainability definition of the 2030 Agenda, which also forms the basis of this paper.

3.4 Climate-resilient pathways for development

A number of interlinkages between SD, CCA and mitigation are described by Denton at al. (2014). In the following subchapters, we focus on the CCA aspects related to SD presented by the authors.

(1) Climate change responses affect SD policies in a number of sectors, e.g. agriculture, forestry, coastal zones, in which they could lead to trade-offs between the two policy fields.

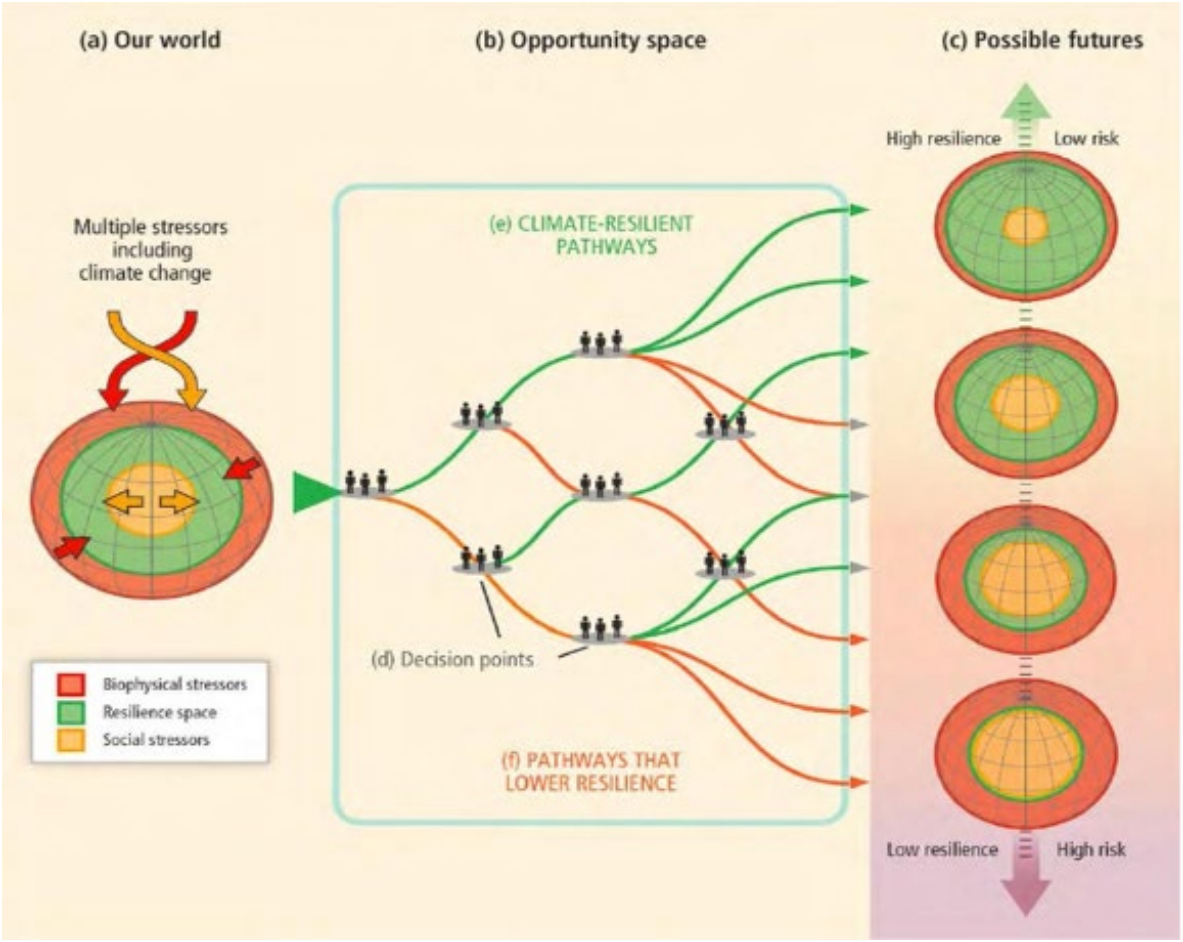
(2) CCA can enhance the ability to cope with impacts and therefore reduce negative effects of climate change on SD.

(3) The ability to adapt to CCA (adaptive capacity) depends on existing development processes and parameters (e.g. income).

(4) The goals of SD and CCA actions overlap, concerning issues such as equitable access to resources, increased livelihood and the functioning of ecosystems. A prioritization of SD could support successful CCA. Well-integrated activities have the potential to support positive feedbacks between mitigation, CCA, and SD (e.g., win-win and triple-win interventions) while minimizing potential trade-offs between them.

According to Denton et al. (2014), a "climate-resilient pathway for development is a continuing process for managing changes in the climate and other driving forces affecting development, combining flexibility, innovativeness, and participative problem solving with effectiveness in mitigating and adapting to climate change. If effects of climate change are relatively severe, this process is likely to require considerations of transformational changes in threatened systems if development is to be sustained without major disruptions."

Figure 3 Climate resilient pathways to development



Source: St. Clair (nd.)

The climate-resilient pathways are described as iterative and continually evolving processes to reduce vulnerabilities to climate change in the context of development needs and resources (see also Figure 3). Possible climate-resilient pathways target a more resilient world using elements of adaptive learning, scientific knowledge, effective CCA and mitigation actions (indicated green in Figure 3). Pathways that lower resilience can include insufficient mitigation actions and possible maladaptation (indicated red in Figure 3) (St.Clair, n.d.).

The approach takes SD as the ultimate goal. Beside CCA and mitigation actions, risk management measures are also included as essential for achieving SD. The integrating of SD and climate change policy can lead to additional benefits if "crosslinkages between poverty, the use of natural capital and environmental degradation are taken into account." (Denton et al., 2014) Especially in less-developed regions, the relationship between vulnerability to climate impacts and development is often very close and mutually dependent. The capacity of individuals, communities, and governance systems to adapt to climate impacts depends on managing developmental deficits (e.g., reduced risk for food insecurity, implementing public health programs) and improving risk management (e.g., alert systems, disaster relief) (Intergovernmental Panel on Climate Change (IPCC), 2012; Mirza, 2003; Schipper & Pelling, 2006; Warner et al., 2013).

Denton et al. (2014) mention that transformational changes are very likely to be required for climate-resilient pathways. Society will need to adapt to current climate impacts in the short term, including incremental and transformative CCA. Furthermore, mitigation responses taken in the short term will have a strong influence on climate-resilient pathways for SD and therefore influencing to which extent transformative CCA is needed in the long term. A challenge of climate-resilient pathways is that they are dependent on their local contexts. Actions need to be adjusted, taking into account the socioeconomic, cultural, biophysical, and institutional context as well as connections across geographical scales.

It is mentioned that climate-resilient pathways are in fact a process, not an outcome (Manyena, 2006), involving both incremental and transformational changes. Therefore, the pathways should be developed via iterative processes which are based on including knowledge advancements (Berkes, 2007). It includes reactive but mainly intentional and proactive measures which anticipate future change through appropriate plans and responses. In the light of long-term uncertainties, the pathways have the aim of increasing climate resilience and improve livelihoods, social and economic well-being, and environmental management (Denton et al., 2014).

3.5 Water-Energy-Food Nexus

In an influential paper for the 2011 Nexus Conference in Bonn, Hoff (2011) presented a nexus framework that integrates global trends such as climate change and fields of action such as governance. Since then, many authors have highlighted synergies and complementarities between the water, energy and food sectors and call for cross-sectoral coordination to align the post-2015 agendas (Hussey & Pittock, 2012; Leck et al., 2015; Liu et al., 2018; Rasul, 2016; Rasul & Sharma, 2016; Sachs, 2012; Weitz et al., 2014)[6]. At the same time, UN agencies such as the FAO have been applying a nexus approach to inform decision-making processes and to guide the development of "nexus-sensitive" policies, supporting countries in designing and implementing them in a participatory manner (FAO, 2019).

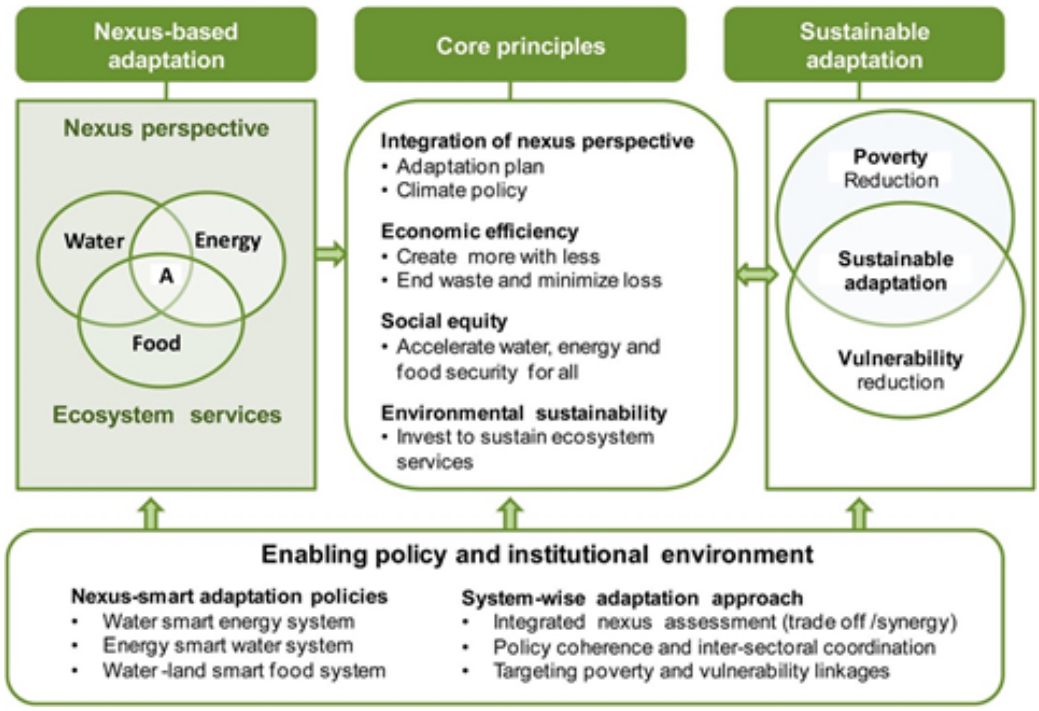
Scholars have also applied a water-energy-food (WEF) nexus lens to stress the need for intersectoral coordination in tackling CCA challenges (Pardoe et al., 2018; Rasul & Sharma, 2016). The integration of a nexus perspective into CCA plans and a CCA perspective into development planning takes into account vulnerability and adaptive capacity as crucial for effective adaptation (Rasul & Sharma, 2016). The authors observe that in NAPs and National Adaptation Programmes of Action (NAPAs) as key strategic instruments, a sectoral approach has been dominant without adequate consideration or coordination of cross-sectoral interactions

[6] It needs to be highlighted that a number of other nexus approaches apart from the WEF nexus exist. For an overview see Liu et al (2018).

among key climate-sensitive sectors (Rasul & Sharma, 2016). Ignoring these interactions can undermine vulnerability and development efforts and lead to maladaptation (Barnett & O'Neill, 2010; Rasul & Sharma, 2016).

Nexus scholars highlight the importance of local CCA actions on other scales through intersectoral linkages (Rasul & Sharma, 2016). Rasul and Sharma (2016) build their nexus approach on the concept of sustainable adaptation theorized by Eriksen et al. (2011a), (cf. chapter 3.1.3) which they embed in broader SD frameworks to increase its policy relevance. In particular, they highlight the need for interlinking efforts for poverty reduction and CCA and designing interventions in a way that strengthens the adaptive capacities of the poor and ensures long-term sustainability. In addition, they point out that CCA measures in one sector or by one community must not undermine the resilience of others. This requires a sufficient knowledge base on nexus interactions as well as an enabling environment to strengthen policy integration between nexus and CCA mechanisms across sectors at different scales and among the public, private and civil society actors, as well as adequate investment into innovative technologies and institutions (Rasul & Sharma, 2016).

Figure 4 Nexus-based adaptation framework



Source: Rasul & Sharma (2016).

Thus, these principles focus on economically rational decision-making and efficient use of water, energy and food resources in an environmentally responsible manner. Importantly, the transition to sustainability is referred to as an overarching goal, without, however, specifying what this transition will look like in detail (Rasul & Sharma, 2016). NAPs are described as key policy instruments given that they embrace cross-sectoral planning (Rasul & Sharma, 2016).

Critics argue that the WEF nexus is not a novel or innovative concept but that, instead, the term has been used to describe various approaches concerned with increasing intersectoral coordination (Wichelns, 2017). Thus, earlier approaches such as Integrated Water Resources Management (IWRM) bear resemblance to the WEF (Leck et al., 2015; Wichelns, 2017). Given the difficulties associated with managing complex nexus policy problems, a lack of capacities to coordinate intersectoral measures at system level thus remains a key challenge (Pardoe et al.,

2018). Practical examples of nexus approaches are scarce, thus complicating the evaluation of its applicability (Purwanto et al., 2021). The case of Tanzania has shown how NAPAs have successfully mainstreamed climate change into sectoral policies, but that cross-sectoral collaboration remains limited due to institutional challenges such as power imbalances, budget constraints and a lack of financial resources as well as an ingrained sectoral approach (Pardoe et al., 2018). In addition, the implementation of coordination and collaboration is associated with significant transaction costs, as related processes require significant human resources. Instead, in practice, nexus approaches have been limited to project-based interventions without overarching planning in place (Pardoe et al., 2018).

Another factor complicating putting nexus approaches into practice is that decision-making responsibilities for the related sectors are normally situated within different institutions operating at different scales (Leck et al., 2015)[7]. Nexus scholars further argue that in countries like Bangladesh or Nepal, national planning commissions which would be tasked with the implementation of such an approach primarily focus on supporting ministries to achieve planned growth and sectoral goals (Rasul & Sharma, 2016). Another open issue is the role of local stakeholders and the consideration of local knowledge in nexus approaches. In dominant conceptualizations, nexus planning is seen as a top-down approach without much room for bottom-up processes and the inclusion of local experiences, development visions and knowledge (Allouche et al., 2014; Leck et al., 2015). In addition, nexus scholars such as Rasul and Sharma conceptualize CCA decision-making in the nexus as purely technocratic decisions to maximize resource use efficiency, but leave out the importance of politics and power that shape CCA policy (Brown, 2011; Eriksen et al., 2011; Leach et al., 2010). An increasing body of literature is concerned with responding to these criticisms and filling identified knowledge gaps of this relatively young approach (Purwanto et al., 2021). Biggs et al. (2015), for example, already provide an integrated nexus-livelihoods framework to assess environmental livelihoods security by focusing on local communities. Overall, WEF nexus approaches provide valuable conceptual work on intersectoral coordination, and the extensive body of nexus literature has to be taken into account for holistic perspectives on synergies between CCA, DRR and SD.

3.6 Ecosystem-based approaches

Several approaches have been focusing on the relevance of ecosystems and their functions in finding adequate solutions for CCA and in decreasing the vulnerability of local populations to climate-related risks while enhancing SD. These approaches build on the observation that climate change and biodiversity loss are interlinked as climate change represents a major driver of biodiversity loss, while nature has a fundamental role in both mitigating climate change and enabling CCA (IPBES, 2019). The effectiveness of CCA measures is fundamentally dependent on the continued or enhanced provision of ecosystem services (Kapos et al., 2019). Additionally, nature can be harnessed to reduce climate hazards and generate multiple additional benefits (Kapos et al., 2019).

In the field of CCA, the most prominent of these approaches are termed “Ecosystem-based Adaptation” (Colls et al., 2009; Munang et al., 2013; SCBD, 2019) and “Nature-based solutions” for adaptation (Chausson et al., 2020; Davis et al., 2015; IUCN, 2020; Kabisch et al., 2016; Nesshöver et al., 2017; Seddon et al., 2020; UNEP, 2021). For DRR, ecosystem-based disaster risk-reduction (Eco-DRR) has been discussed (F. G. Renaud et al., 2016; SCBD, 2019).

[7] This particularly applies to countries in which water governance is organized at the basin scale, thus adding another scale to the already challenging intersectoral coordination.

The 2021 United Nations Environment Programme (UNEP) Adaptation Gap Report points out that Eco-DRR overlaps with EbA actions in those cases, where the ecosystem-based actions are targeted towards climate risks (UNEP, 2021). NbS is an umbrella term that has been applied to different societal challenges such mitigating and adapting to climate change, protecting biodiversity and ensuring human wellbeing (Seddon et al., 2020). Most recently, the potential of NbS has also been highlighted in light of the COVID-19 pandemic (Lieuw-Kie-Song & Pérez-Cirera, 2020). In the following paragraphs, we will focus on the concept of NbS for CCA.

Box 3 | Nature-based solutions, ecosystem-based adaptation and disaster risk reduction

Nature-based solutions (NbS) are "Actions to protect, sustainably manage and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (IUCN, 2020). NbS for adaptation restore, build on and enhance ecosystem services in order to manage climate change risks and impacts, help people (including women and marginal groups) adapt to climate change, and enhance the climate resilience of communities, assets and society (UNEP, 2021).

Ecosystem-based adaptation (EbA) describes the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change. EbA aims to maintain and increase the resilience and reduce the vulnerability of ecosystems and people in the face of the adverse effects of climate change (SCBD, 2009).

Ecosystem-based disaster risk reduction (Eco-DRR) is "sustainable management, conservation and restoration of ecosystems to reduce disaster risk, with the aim of achieving sustainable and resilient development." (Estrella & Salisma, 2013)

Source: UNEP (2021), SCBD, (2009), Estrella & Salisma, (2013).

Nbs have been praised for providing environmental, economic and social benefits to a wide range of stakeholders, including women and poor and marginalized groups, and addressing multiple climate hazards. The contributions of NbS to reaching the 2030 Agenda are most pronounced in SDGs 13 (climate action), 15 (life on land), 6 (clean water) and 14 (life below water) (UNEP, 2021). Examples of NbS and their potential contributions to the SDGs can be found in Table 7 (see Appendix B). In a meta study, Chausson et al. (2020) have found 376 studies that provide evidence on the effectiveness of nature-based interventions for CCA. The restoration of mangroves, for example, can enhance biodiversity conservation while simultaneously protecting against extreme events such as coastal storms (UNEP, 2021). NbS for CCA are often interlinked with approaches to community-based CCA which put local communities and particularly vulnerable groups of people, notably women, at the center of EbA measures (Reid, 2016; Reid et al., 2019). This is based on the perceived potential of NbS for CCA to improve the resilience and adaptive capacity of these groups (Reid et al., 2019).

NbS are being increasingly integrated into policy agendas at international level. The PA recognizes the importance of ecosystems for mitigation and CCA with a special emphasis on the role of forests (UN, 2015b). Target E of the Sendai Framework also explicitly refers to NbS (UN, 2015a). In 2019, the Secretary of the Convention for Biological Diversity (SCBD) issued voluntary guidelines for the design and effective implementation of EbA to CCA and DRR (SCBD, 2019). These guidelines are explicitly designed to facilitate integration between SD, CCA and DRR.

At national level, NbS can be found in many NDCs and NAPs. Over 60 percent of countries (104 nations) included aspects of NbS (EbA or conservation action) in the adaptation component of

their NDCs (Seddon et al., 2020). All NAPs submitted by March 2020 have included some consideration of ecosystems and their vulnerability to climate change, while most of them made explicit reference to EbA (Terton & Greenwalt, 2020).

Thus, an important characteristic of ecosystem-based approaches, which sets them apart from most of the other approaches discussed so far, is that they have gained prominence across policy cycles and are already anchored in relevant policy instruments. This creates a momentum for application as well as for intensifying efforts to evaluate their potential to enhance synergies between multiple policy fields, such as biodiversity conservation, CCA, DRR and SD. By addressing underlying broad societal goals of these policy fields, NbS provide a more systemic approach which contrasts with more narrowly defined approaches to CCA (Seddon et al., 2020). A major challenge, however, remains to fully translate NbS into evidence-based targets and action on the ground (Chausson et al., 2020). Scaling up the use of NbS for CCA along with the associated potential socioeconomic and environmental co-benefits, requires incorporating NbS in more concrete terms into relevant planning processes across both scales and sectors (UNEP, 2021). The ecosystem-based approaches presented here do not refer to distinctive adaptation pathways and no explicit conceptualization of pathways has been developed. However, NbS for CCA are directly tied to changes in land uses, which in turn might lock in particular adaptation pathways with the risk of adverse long-term effects (Nalau & Becken, 2018). Thus, when developing NbS for CCA, they need to be carefully evaluated before they are implemented, in particular if they are meant to bring about systemic, transformative change. This, however, requires sufficient financial and personal capacities of research institutions and responsible administrations to capture potential side effects of the planned interventions.

3.7 Integrated approaches on DRR and SD

The approach by Gibson et al. (2016) discusses transformation in disaster risk management embedded in development pathways. It shows the responsibility of disaster risk management to contribute to SD. DRR is often seen as protecting existing development structures, practices, goals and values (Pelling, 2011), but to a certain degree, damages of disasters can be also seen as a product of unsustainable development processes. Risk reduction policies and strategies can support transformation and SD. They emphasize the importance of multiscale processes including all relevant governance levels (local, regional, national), as well as intense interaction of actors and learning processes - such as triple-loop learning, which is a kind of societal learning referring to fundamental transitions of the established governance regime (e.g., change in regulatory frameworks, practices in risk management, dominant values) (Pahl-Wostl, 2009).

The assessment of case studies shows that transformation may be invoked, but a long-term process is necessary to achieve transformative tipping points. Disasters may be the starting point of such a process, but are not sufficient drivers of transformation. Co-responsibility of disaster risk management and development actors is highlighted as both communities need to steer transformative change (Gibson et al., 2016).

The following characteristics are used by Gibson et al. (2016) to assess the potential for transformation for their case study assessment:

- If changes can be linked to a disrupted system;
- If there was an active interaction between actors;
- If external actors were included and responsible for successful intervention;
- If changes are targeting the governance regime and not only efficiency improvements.

The following common lines of influence of disaster risk management on development have been derived by Gibson et al. (2016) based on their case studies:

- Pathway competition: At least two development models are co-evolving, e.g. in an example from New Zealand, where a "liberal" response based on Western norms and approaches and a "Māori" response based on a rather communitarian approach have developed after an earthquake. Both approaches have involved individual and structural transformations. The approaches are somehow conflictual: the liberal approach involves centralization and the introduction of public–private partnerships, while the Māori response involves collective and communitarian action. Legislation, organizational structures and social development interventions institutionalize these pathways, producing an increasingly multifaceted post-earthquake development trajectory.
- Pathway experimentation: Conditions for a controlled experimentation with social change processes are established. An example from New York shows that planned revision of public transport may include significant redesign and revision of transport management structure.
- Pathway scale effects: The case studies show the tendency of actors on the local level to carry the weight and costs of transformation. This is also highlighted by questions on flood management after storm surge events in New York, which linked risk management measures and the discussion about the gentrification of waterfront neighborhoods, illustrating close interlinkages between development pathways and risk management.
- Pathway lock-in: Existing institutional structures are designed to be resistant. The questioning of existing systems´ elements by multiple actors (local and external) is a precondition for transformation. Institutional interlock is illustrated by the example of New York and questions of waterfront development, flood protection and local stakeholder involvement.

Gibson et al. (2016) summarize that cross-scale interactions and cross-sector exchange are key for transformative potential and linked to two likely future scenarios for disaster risk: (1) First, where risk becomes more extensive, limits for risk management will be reached and forced adaptation will be necessary. Policy actors thus need to anticipate and steer forced transformation. (2) Where other socio-economic drivers (urbanization and population growth) lead to an increase of disaster risks in scale, large-scale policy responses are needed, e.g. social protection schemes. These macro-management measures also show potential for transformation.

3.8 Synthesis of existing approaches

The approaches presented build on different assumptions, originate from different research strands and have different foci: While some of them explicitly focus on CCA and its interlinkages with DRR and SD, others only touch upon the interactions with one or two of the other processes. Moreover, the term 'pathways' is used and defined in diverse ways. While some approaches explicitly conceptualize pathways (J. R. Butler et al., 2016; Denton et al., 2014; Haasnoot et al., 2013; Leach et al., 2010; Wise et al., 2014), others do not use the term but still contribute to advancing research on intersectoral interlinkages and nexus approaches (Rasul & Sharma, 2016), ecosystem-based contributions (Chausson et al., 2020; Reid et al., 2019; SCBD, 2019; Seddon et al., 2020; UNEP, 2021) and poverty-vulnerability linkages (Brown, 2011; Eriksen et al., 2011).

In sum, the approaches presented in the previous sub-chapters share several characteristics which are key for an enhanced alignment of CCR, DRR and SD. All approaches highlight (1) the importance of involving different types of stakeholders, albeit to differing degrees. Approaches focusing on local livelihoods and sustainability (Brown, 2011; Eriksen et al., 2011) and NbS (Chausson et al., 2020; Reid et al., 2019; SCBD, 2019; Seddon et al., 2020; UNEP, 2021) put local communities at the center of more holistic CCA efforts. The inclusion of local stakeholders is emphasized but less nuanced in the WEF nexus (Rasul, 2016; Rasul & Sharma, 2016).

Connected to this, (2) assessing vulnerabilities of populations and institutions in a differentiated way by acknowledging different vulnerabilities within populations and between institutions is another common observation. The majority of approaches share the assumption that strengthening adaptive capacities and resilience of the most vulnerable groups is key for enabling SD co-benefits of CCA measures.

In addition, (3) linking national and sub-national planning and action has been identified in many approaches as a key element (cf. Dazé et al., 2019). The impacts of climate change and disasters are largely felt at the local level, meaning that sub-national authorities, communities and other local organizations are essential actors in CCA and resilience building. Vertical integration of CCA and DRR across levels of development planning and implementation are critical in ensuring that local actors have the knowledge, capacity and resources to manage climate risks (Dazé, Price-Kelly, & Rass, 2016).

Furthermore, CCA, DRR and SD link to a number of other policy fields, e.g. agriculture, health and water. (4) Cross-sectoral cooperation and mainstreaming of CCA and DRR into other policies, strategies and plans, as well as using synergetic and multi-benefit measures, are key for tackling climate change in a sustainable manner.

(5) Temporal aspects have been discussed in a number of approaches. The dependence on historical pathways interlinked with path dependencies and lock-in effects was mentioned as one major challenge. It has been emphasized that iterative development and regular updates of pathways including strategies or measures are essential to integrate an advanced knowledge base (Candel & Biesbroek, 2016). Continuous learning, e.g. based on monitoring, and knowledge exchange are seen as essential to improve and further develop CCA activities. Thus, the majority of the approaches analyzed apply a procedural perspective focusing on factors that enable the integration of CCA, DRR and SD over time. Connected to this, many approaches argue that major uncertainties and the unpredictability of policy challenges require adaptive governance structures for planning under uncertainty (Buurman & Babovic, 2016; Haasnoot et al., 2013; Leach et al., 2010; Siders & Pierce, 2021).

Table 3 Overview of screened pathway approaches

Approach	Pathway Definition	Consideration of interlinkages between DRR, CCA and SD	Preconditions for pathway implementation	Added value of the approach in conceptualizing SAPs
Adaptation Pathways	Adaptation Pathways are described by Haasnoot et al. (2013) as an analytical method for sequencing a set of possible CCA actions, taking into account external developments over time.	The approach draws on pathway thinking in SD research. It considers implications of path dependencies and interactions between adaptation plans and settings in which societal responses to climate change evolve.	Consideration of - involvement of multiple stakeholders with their variety of values and knowledge; - importance of knowledge exchange and participation; - coordination of CCA actions across scales and sectors; - harmonization of implementation of incremental and transformative CCA measures; - measures resulting in benefits for any different future conditions are preferable (no regret); - adjustment to local livelihoods and local cultural, political, economic, environmental and developmental contexts necessary; - importance of temporal aspects: Future pathways depend on historical pathways including path dependency and lock-in effects.	Emphasizing interplay between transformative and incremental CCA With iterative assessment taking into account uncertainties of climate change and further socio-economic developments over time.
Pathways to sustainability	Development pathways are defined as the ‘‘alternative possible trajectories for knowledge, intervention and change, which prioritize different goals, values and functions” (Leach et al., 2010, p. 5).	Not explicitly, but focus is on dynamic interactions between policy fields and several examples are given (e.g. adaptation to water scarcity in Western India).	Consideration of: - system dynamics and context-specificity; - uncontrollability, ambiguity and uncertainty of policy problems; - alternative narrative and framings of policy problems; - political context.	Highlighting 4 major hurdles to realizing development pathways as well as the importance of power and politics

Approach	Pathway Definition	Consideration of interlinkages between DRR, CCA and SD	Preconditions for pathway implementation	Added value of the approach in conceptualizing SAPs
The sustainable adaptation literature	Sustainable adaptation is defined here as "adaptation that contributes to socially and environmentally sustainable development pathways, including both social justice and environmental integrity" (Eriksen et al., 2011).	Explicit consideration of interlinkages	Sustainable adaptation should - recognize the context of vulnerability, including multiple stressors; -acknowledge that different values and interests affect adaptation outcomes; -integrate local knowledge into adaptation responses; and -consider potential feedbacks between local and global processes.	Recognition of politics and power as well emphasizing the importance of local knowledge
WEF nexus	Nexus approaches are seen as an operational tool to enhance sustainability pathways (Liu et al., 2018)	Interlinkages between CCA and SD explicitly considered in key publications (Rasul & Sharma, 2016). Some scholars have instead focused on the nexus of DRR, CCA and Ecosystems Management (Galderisi, 2017)	Consideration of -effects of local CCA actions on other scales through intersectoral linkages (systemic approach); -vulnerability-poverty linkages across sectors	Emphasizing interrelations between water, food and energy sectors
Climate-resilient pathways for development	"A climate-resilient pathway for development is a continuing process for managing changes in the climate and other driving forces affecting development, combining flexibility, innovativeness, and participative problem solving with effectiveness in mitigating and adapting to climate change." (Denton et al., 2014)	Emphasizing the interlinkages between adaptation, mitigation and SD, partially including risk management	Emphasis on -multiscale interlinkages; -local context (socioeconomic, cultural, biophysical, and institutional) and interrelations to other regions; -iterative and collective development/update and continuous learning based on monitoring and advanced knowledge.	Approach to interlink adaptation and SD measures

Approach	Pathway Definition	Consideration of interlinkages between DRR, CCA and SD	Preconditions for pathway implementation	Added value of the approach in conceptualizing SAPs
Ecosystem-based approaches	Rather operational understanding of pathways as a stepwise approach	Explicit integration of Eco-DRR and EbA into NbS for adaptation (UNEP, 2021). Explicit reference to SD in further key publications (Reid, 2016; SCBD, 2019; Seddon et al., 2020)	UNEP (2021) highlights the need for: - diversified finance base by deploying innovative mechanisms; - effective governance and institutions to secure land tenure and access rights; - inclusion of traditional and common knowledge (youth, women, indigenous people); - equitable, transparent and participatory approaches; - integration of NbS in strategies for CCA and DRR at multiple levels.	Highlighting the importance of ecosystem health in strengthening adaptive capacity
Integrated approaches on DRR and SD	"Transforming development through disaster risk management and CCA is emerging as an alternative to treating risk as external to development — to be addressed by incremental changes that use risk management to protect existing development goals, practices and relations." (Pelling, 2011)	Discussion of interlinkages between DRR and SD	Special emphasis on: - integration of all governance levels; - intense actor interaction; - triple-loop learning; - cross-sectoral cooperation.	Interaction of disasters and risk management with development

4 Conceptualization of SAPs

In this chapter, a concept of SAPs will be developed and three categories of dynamic elements (institutional, socio-political and cultural as well as financial) will be introduced. Subsequently, the relationship of transformative CCA and SAPs will be discussed (section 4.4) and an integration of incremental and transformative CCA within the SAP concept is proposed.

The approaches discussed in the previous chapter provide fertile ground for conceptualizing SAPs. They also shed light on the different understandings of key terms like CCA, sustainable development and disaster risk reduction and of how these concepts relate to each other. In addition to these diverse understandings in research circles, stakeholders in different cultural, socio-economic and political contexts may hold different understandings of these terms. As we will demonstrate in the following paragraphs, an openness to alternative narratives and framings of relevant key terms is one of the preconditions of an inclusive and effective implementation of SAPs (see also chapter 5.3 on implementation). The concept and related definitions presented in the following are also built on specific normative assumptions and informed by taking into account diverse existing approaches in state-of-the-art research. While acknowledging the existence of alternative understandings, we aim to provide a starting point for practical implementation by defining key terms and how they relate to each other in the SAP concept. We will also synthesize a working definition for SAPs and a framework to illustrate the concept.

The concept presented explicitly takes into account the 2030 Agenda, the Sendai Framework and the PA as overarching policy frameworks to find synergies between CCA, DRR and SD at the level of practical implementation on the ground. The framework will be applied in the following chapter to selected case studies. Based on these applications, we will derive recommendations for its use in practice and identify further areas for research. The conceptualization requires defining sustainable adaptation and locating it within a broader framework of SD. We define sustainable adaptation as measures or strategies to strengthen the capacities of populations, institutions and ecosystems to adapt to climate-related risks over time, which at the same time enhance the social justice, environmental integrity and economic sustainability of socio-ecological systems.

The Venn diagram below visualizes the relationship between CCA, DRR and SD on which the concept is based (Figure 5). The diagram illustrates in a simplified way that strong functional overlaps exist between them.[8] First, strong functional relationships exist between CCA and DRR as many measures or policies aim to both increase adaptive capacities and reduce the vulnerability of societies to climate-related risks (see also chapter 2.2.3). A mainstreaming of both processes through greater linkage has gained momentum within policy circles (Glover & Granberg, 2020). Different scholars have proposed unifying DRR and CCA communities (Granberg, 2019; F. Renaud & Perez, 2010; Thomalla et al., 2006). As not all DRR measures, however, address climate-related risks, there is also a significant number of measures not overlapping with CCA policies or measures. CCA in turn also targets slow-onset climate change impacts that are not directly associated with climate-related emergencies (Glover & Granberg, 2020).

Second, functional overlaps exist between CCA and SD, again through their joint objective of decreasing vulnerabilities. Vulnerability relates directly to development metrics, such as poverty and marginalization, conflict and instability, high population growth and high rates of

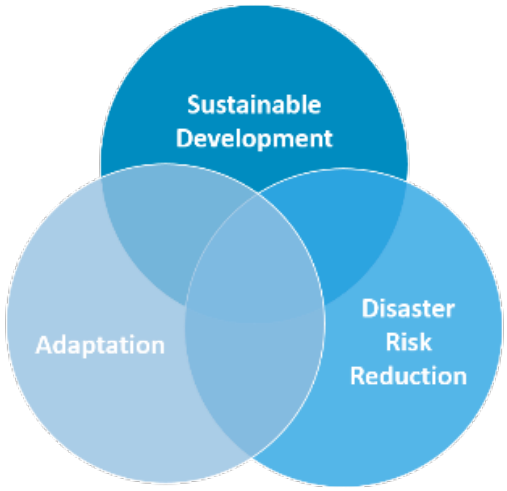
[8] The three circles in the diagram are of the same size, as the diagram does not aim to provide any information on the relevance or broadness of a particular policy field as compared to the other two.

urbanization, increased habitation of coasts and floodplains and lowering of environmental conditions (Glover & Granberg, 2020). Two causal links between vulnerability, CCA and development have been contrasted (Schipper, 2007). On the one hand, a perspective exists in which CCA impacts decreases vulnerability, which in turn fosters development. Alternatively, there is a second perspective in which measures to foster socioeconomic development, implemented to decrease vulnerability, enhance the adaptation to climate-related risks. CCA has, however, also been described as a double-edged sword, which can, depending on its design, not only reinforce, but also diminish vulnerabilities (Glover & Granberg, 2020).

Any conceptualization of the links between CCA, SD and DRR needs to remain open to these two perspectives and highlight the importance of assessing existing and future SAPs on a case-by-case basis. In fact, the case studies discussed in this paper demonstrate that both perspectives of interventions can contribute to conceptualizing SAPs. Sustainable adaptation is not limited to minimizing the adverse effects of climate change but allows to 'adapt forward' along an aspired pathway towards reaching the SDGs, instead of maintaining the status quo.

However, the discussion of existing approaches has shown that not all CCA and DRR measures automatically contribute to SD. In fact, implementing an approach which simultaneously strengthens the three dimensions of sustainability remains challenging. Thus, some CCA or DRR activities do not overlap with SD if they lack significant contributions to a holistic vision to sustainability. In some cases, trade-offs between the three dimensions of sustainability can be significant, which makes an evaluation of their overall sustainability challenging (see example on Tanzania in section 2.2.1).

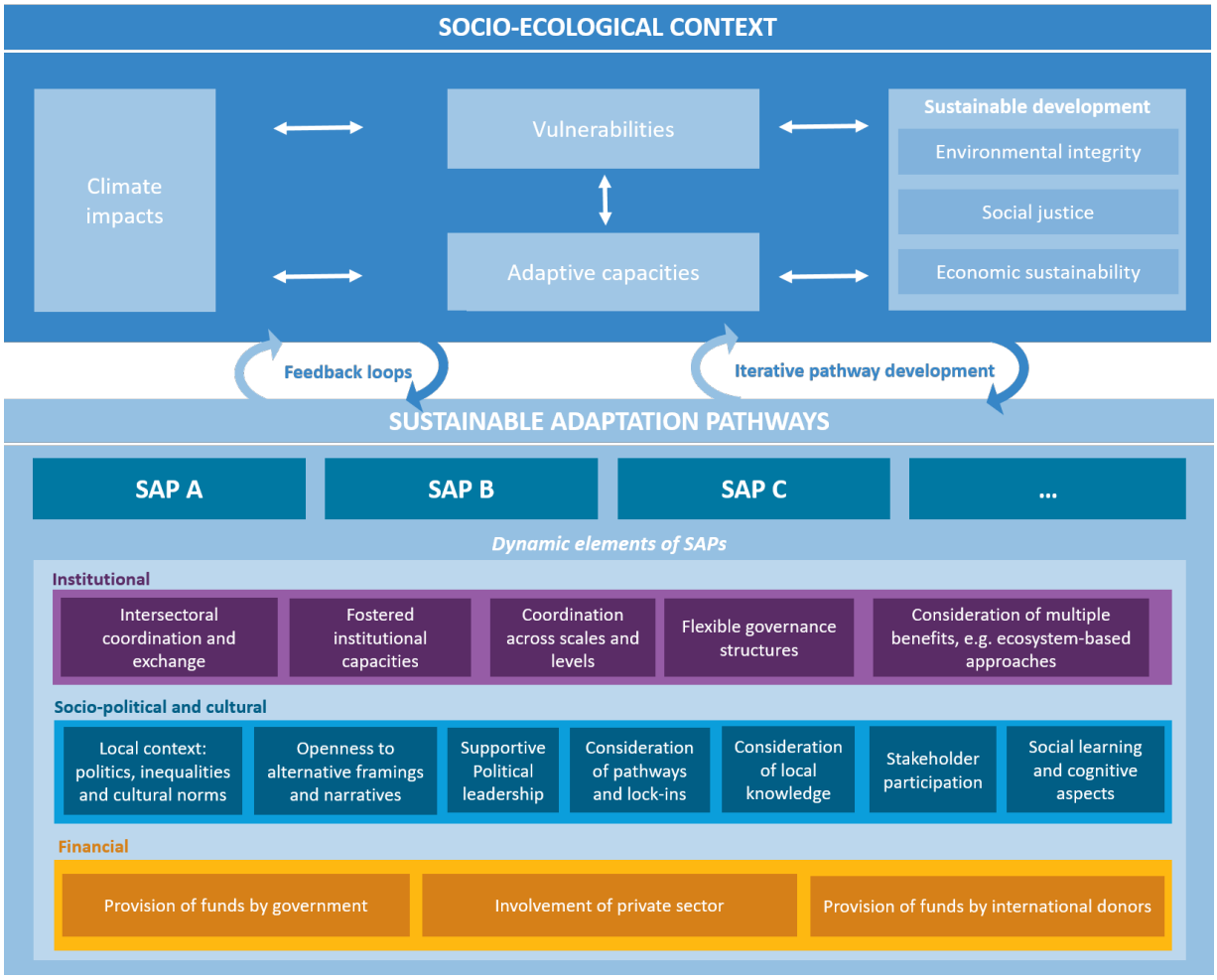
Figure 5 Relationship of CCA, DRR and SD



Source: Authors' own illustration.

Building on the definition of sustainable adaptation, SAPs, in turn, describe a coherent set of alternative adaptation strategies and procedures composed of measures and policies to strengthen the capacities of populations, institutions and ecosystems to adapt to climate-related risks over time while enhancing the social justice, environmental integrity and economic sustainability of socio-ecological systems.

Figure 6 Conceptual framework of SAPs



Source: Authors' own illustration.

SAPs aim to avoid maladaptation, i.e. the failure to deliver CCA objectives and decrease vulnerability (Barnett & O'Neill, 2010). They are characterized by a set of dynamic institutional, socio-political and cultural as well as financial elements (sections 5.1.1 to 5.1.3) which enable (and constrain) their implementation and, at the same time, interact with and depend on the socio-ecological context they are embedded in (see Figure 6). Importantly, these pathways are not static and fixed but dynamic and unfold over time through the involvement of people and institutions. The majority of the dynamic elements listed are procedural elements to enable procedures conducive to the implementation of SAPs.

The development of SAPs is contextualized as a result of complex and context-specific interactions and feedback loops, rather than a unidirectional cause-and-effect relationship (Leach et al., 2010). In addition to their context specificity, SAPs unfold against trends of the global political economy (Adger et al., 2009; Eriksen et al., 2011). Within this framework, adaptive capacity[9] is the key variable to be strengthened through implementing SAPs. Adaptive capacity describes the ability of social and natural systems to respond to the impacts of climate change (Glover & Granberg, 2020; IPCC, 2014). More specifically, it refers to the characteristics of these systems that empower social actors to respond to short and long-term impacts, either through planned measures or through allowing and encouraging creative responses from

[9] Adaptive capacities in the SAP concept presented here include capacities of both people and institutions in line with Gupta et al. (2010).

society both ex ante and ex post (Gupta et al., 2010). Adaptive capacity is one of the determinants of vulnerability, in addition to exposure and sensitivity to climate impacts (Gupta et al., 2010). Ecosystems and people's vulnerability is here understood as the extent or degree to which a system is susceptible to climate change impacts (IPCC, 2014). A decrease of vulnerability of ecosystems can lead to a decreased effect of climate impacts on the overall socio-ecological system.

If adaptation pathways are sustainable, the resulting increase in societies' adaptive capacities will not only lower the vulnerability of local populations and institutions against climate-related risks, but also enhance social justice, economic conditions and local ecosystem health. Vulnerabilities of populations and institutions are, on the one hand, influenced by the severity of climate hazards, i.e. the extent to which systems are subject to climate-related pressures. On the other hand, vulnerabilities are influenced by social, economic and ecological conditions of the respective context. Changes in these conditions can impact vulnerabilities and adaptive capacity positively or negatively (Garschagen & Solecki, 2017). Here, dynamics between different scales which influence vulnerabilities and adaptive capacities at the local level also come into play (Adger et al., 2009; Eriksen et al., 2011). Drivers of vulnerability of specific individuals and communities are connected at different scales and inseparable from large-scale processes of sociocultural change and market integration on higher scales (Adger et al., 2009). Rising inequality, for example, is a trend that manifests itself locally in different ways. However, as it is emerging in political systems across the world, inequality does not merely have local ramifications, but can also influence vulnerabilities at larger scales.

These social, economic and ecological dimensions of sustainability are again interrelated: The restoration of mangrove forests, for example, can decrease local vulnerabilities to sea level rise and flooding (see Table 5). At the same time, such restorative actions have a great potential to increase ecosystem health and local biodiversity. In addition, they can also influence social conditions positively, e.g. when fish stocks which local populations depend on for their livelihoods are preserved. This again can improve economic conditions in the localized context. This example stresses the interrelations between these three dimensions of sustainability, which is a key feature of the SAP concept. Only if a pathway brings about sustainable change in at least one dimension without negative interactions in the other two, it qualifies as a SAP according to the definition proposed in this paper. If there is a positive sustainable change in one dimension but negative change in one or two others, it does not qualify as a SAP. It has to be highlighted, however, that understandings of what sustainability in its three dimensions should entail or not entail might differ across and within stakeholder groups. This underlines the importance of openness to alternative framings and experiences to not close down around certain dominant discourses (Leach et al., 2010). Related to this is the need for institutions and procedures that allow for integrating these different framings and experiences into the development of SAPs.

The socio-ecological context also interacts with three types of dynamic elements that constitute and enable SAPs. These can be grouped into financial, socio-political and cultural as well as institutional elements, which have been synthesized from the analyzed literature. It has to be noted, that this list neither is exhaustive, nor do adaptation pathways require all of these elements to be qualified as SAPs. Rather, they are a set of enabling factors that, if present, can enhance the realization of SAPs. How the different elements play out in practice is, however, dependent on dynamic interactions between these elements in a given socio-ecological context. As the case study examples presented show, certain elements are oftentimes dominant in practice while some others might be present only to a weaker extent, not observable or entirely absent (see section 5.1).

In the following subchapter, the dynamic elements in their three categories (institutional; socio-political and cultural; financial) will be presented in more detail and illustrated by selected case studies.

4.1 Dynamic elements

4.1.1 Institutional elements

Climate change-related impacts may occur abruptly and are, to a large extent, unpredictable (Buurman & Babovic, 2016; Denton et al., 2014; Siders & Pierce, 2021). CCA planning is thus characterized by deep uncertainty (see Box 1) and complex systems dynamics shaped by thresholds and feedbacks (Buurman & Babovic, 2016; Glover & Granberg, 2020; Leach et al., 2010; Siders & Pierce, 2021). This requires an open and flexible institutional framework that allows addressing complex challenges of CCA, DRR and SD in a dynamic way, which is both a precondition and an integral element of SAPs.[10]

An open and flexible governance structure is also important to allow for implementing "no-regret" options and strategies[11] that provide multiple benefits, avoid lock-ins and address socio-ecological challenges beyond climate change. Special emphasis is placed on the importance of resilient and healthy ecosystems to decrease vulnerabilities and enhance the services they can provide when included in such no-regret options and strategies. The concept of SAPs thus highlights the relevance of NbS for sustainable adaptation, which can provide these multiple benefits. Land use changes resulting from the application of NbS, however, might lock in particular adaptation pathways with the risk of adverse long-term effects (Nalau & Becken, 2018). In addition, many ecosystems - such as coral reefs - are already in the process of critical degradation. These ecosystems are thus unlikely to be able to adapt quickly enough to provide proclaimed benefits and to support adaptive capacity in the long run (Lavorel et al., 2015; UNEP, 2021). This also decreases the cost efficiency of NbS and puts into question their overall application in certain ecosystems. Thus, in certain cases, a combination of integrating green and blue infrastructure with existing grey protection infrastructure has proven useful (Seddon et al., 2020). In any case, a comprehensive assessment of existing path dependencies is required to avoid future adaptation lock-ins, no matter whether the pathway heavily relies on NbS or grey infrastructure.

Iterative development and regular updates of pathways, including strategies or measures, are essential to integrate an advanced knowledge base (Candel & Biesbroek, 2016). This element is strongly linked to the need for openness towards alternative framings of different stakeholder groups. Sufficient institutional capacities, both financially and personally, are an important precondition to coordinate and steer holistic planning which allows for inclusive planning processes, taking into account different framing and experiences. Due to the holistic approach of SAPs, both intersectoral coordination and exchange facilitated by relevant ministries or government bodies are crucial for their implementation. Generally, SAPs can address a broad range of sectors and their interactions, but sectors with a high degree of management and control, such as agriculture, managed ecosystem services, urban settlements and coastal areas (Glover & Granberg, 2020) are considered key sectors.

[10] The institutional framework is made up of institutions understood as the norms, rules and routines that define, shape and constrain behavior and action in a specific setting (March & Olsen, 1989).

[11] No-regret adaptation options (or measures) are autonomous measures which do not worsen vulnerabilities to climate change or which increase adaptive capacities; and measures that will always have a positive impact on livelihoods and ecosystems regardless of how the climate changes (IUCN, 2014).

In practice, intersectoral coordination remains a challenge, in particular as the three domains of DRR, CCA and SD are often handled by different ministries or executive agencies operating on different geographical and time scales (Sandholz et al., 2020). When established sector or thematic approaches and rigid political hierarchy structures are dominant or disconnects between planning and implementation exist, coordination can be difficult to achieve (Sandholz et al., 2020). Also, discontinuity and rupture due to frequent turnover of staff and politicians, resulting in disruptions of workflows and an overall inclination to short-termism and disparities in available capacities and knowledge can hinder coordination (Sandholz et al., 2020). The existence of a government authority that has the competencies to lead the cross-sectoral alignment needed to realize SAPs is crucial (Ferdinand et al., 2020). Some countries have moved forward and set up national research centers or interministerial coordination bodies to enhance the integration (see e.g. the case of the Delta Governance Council in Bangladesh, case study 4). Apart from the strategic alignment of CCA, DRR and SD, stronger data sharing efforts between ministries are key to increase efficiency (Sandholz et al., 2020).

SAPs can be initiated and implemented at different scales, but need to take into account interactions of local, national and global scales and their effects on the sustainability of the CCA measures (Eriksen et al., 2011). Approaches like the WEF nexus have highlighted the importance of intersectoral coordination while at the same time stressing the complexity of putting effective coordination at national level into practice. Given the lack of capacities to steer this process at national level, lower scales can provide feasible entry points for implementing SAPs (see case study 1).

Case Study 1: Bhutan | Addressing water scarcity through NbS in Tsirang Toed

NAPA project addressing water scarcity holistically through NbS in Tsirang Toed, Bhutan

In the last decades, increasing temperatures, irregular precipitation and unsustainable land management techniques have been causing the deterioration of historical water sources in the Tsirang Toed community in southern Bhutan. Population growth and unsustainable resource use have increased local water demands. These developments have forced locals to travel increasingly long distances to access drinking water supplies or, in some cases, to migrate to urban areas.

In response to emerging concerns for water scarcity, the central government of Bhutan implemented adaptation intervention measures in the community of Tsirang Toed under the National Programme of Action (NAPA) II. The objective of the project was to strengthen adaptive capacities to climate change-induced risks and develop sustainable adaptation options for water collection, storage and distribution to ultimately reduce poverty and underlying root causes of vulnerabilities. The implementation of systemic and holistic interventions was based on a comprehensive baseline assessment of the vulnerability context and focused on the use of NbS. The project's main outcomes included the regeneration of water sources, the construction of easily accessible water points, increased human health and a decrease in outmigration. Capacities of the Tsirang Toed community were strengthened through technical training on water filtration and awareness training on issues related to climate change. As part of the project, water user associations were created to manage a newly constructed water reservoir, water harvesting tanks and a system of pipes for water distribution. Efforts to stop harmful ecological trends were made via NbS, for example by eradicating invasive plant species through the reintroduction of native varieties of trees. Strategies for adaptive water management and identification of relevant climate impacts have been integrated from the local to national level across coordinating institutions. Different stakeholder groups, including marginalized populations, were integrated in the

communities´ governance structure. Ferdinand et al. (2020) see these changes in participatory governance as a major reason for decreased outmigration.

The project results illustrate how ecosystem-based measures, combined with measures for strengthening capacities across communities can foster adaptive capacities and enhance SD at community level. Despite these positive effects, the long-term sustainability of the project's outcomes cannot yet be evaluated. In fact, some water scarcity concerns remain in the community. Due to the use of flexible multi-benefit NbS, there is, however, a potential that the benefits, also with regard to tackling systematic root cause of vulnerability, will be maintained in the long term.

Sources: Ferdinand et al. (2020), NEC and UNDP (2019)

In particular, due to the context-specificity of CCA measures, the implementation of SAPs requires a strong consideration of the local scale and of local communities. Nevertheless, SAPs can serve as a conceptual tool to integrate CCA with SD and DRR into a holistic and multi-benefit approach also at the regional, national and international level.

4.1.2 Socio-political and cultural elements

Understanding politics and its implications is vital for interpreting the forms and features of societal action (Glover & Granberg, 2020). SAPs are dependent on the socio-political and cultural, as well as the socio-ecological contexts they are embedded in. This current context is always shaped by past interventions, disturbances and responses and how this translates into both benefits and vulnerabilities (Glover & Granberg, 2020). Within this context, adaptation lock-ins occur which have to be identified and considered when developing measures and strategies within SAPs. Lock-ins refer to path dependencies which are rooted in context-specific technologies and infrastructures, institutions, power relations as well as in individual and collective behavioral patterns and practices (Oels, 2019; Siebenhüner et al., 2017). Barnett et al. (2015) among others, used the example of the Great Barrier Reef in Australia to investigate how path dependencies (historical dependencies of the fisheries and tourism sectors) hinder the implementation of CCA measures.

CCA is in fact a double-edged sword and can, depending on its design, either reinforce or diminish vulnerabilities (Glover & Granberg, 2020). The SAP approach recognizes that CCA governance is not merely a technical procedure of adapting to climatic changes, but a deeply and inherently political process (Eriksen et al., 2015; Glover & Granberg, 2020; Oels, 2019; Siebenhüner et al., 2017). We define 'politics' here as a process and practice of governing that takes place through formal and informal institutions shaping political (and other) behavior within a political system (Glover & Granberg, 2020; Leftwich, 2004). This includes activities that involve power and decision-making within a political system (Wiley, 2016). Implementing sustainable adaptation measures and strategies thus requires political will of dominant actors to prioritize the holistic policies SAPs are aiming for (Ferdinand et al., 2020; Gupta et al., 2010).

Only if socioeconomic inequalities, power relations and politics are considered jointly with ecosystem-vulnerability interactions and climate-related risks in the development of SAPs, will they be able to increase adaptive capacities of local populations and, in particular, of their most vulnerable parts. Gender considerations are an important precondition and objective of measures to enhance SD and adaptive capacities of local communities (Dazé et al., 2019). Including women in sectors relevant to CCA such as forest, water, and fishery management can provide benefits for the empowerment of women as well as for the effectiveness of CCA measures (Resurrección et al., 2019). Due to existing gender inequalities, women are particularly vulnerable to the impacts of climate change (Röhr et al., 2018). Ignoring the gender

dimension in the root causes of vulnerability can undermine CCA efforts (Resurrección et al., 2019). In contrast to developing countries, where the impacts of climate change, women's vulnerability and gender-responsive CCA programs and measures have been high on the agenda for some time, the gender aspects of CCA have been a neglected topic in industrialized countries (Röhr et al., 2018). As climate impacts are expected to become more severe, it is however important to consider gender aspects and thus make findings from development cooperation usable for CCA in the industrialized North as well (Spitzner et al., 2020).

Continuous learning based on monitoring and advanced knowledge has been highlighted as a key component of effective CCA (Denton et al., 2014; Gibson et al., 2016; Glover & Granberg, 2020; Gupta et al., 2010). Instead of adjusting decisions in reaction to errors occurred or inappropriate responses, triple-loop learning, which includes (1) reacting, (2) reframing and (3) transforming underlying rule systems of CCA (Turner et al., 2016) is an important characteristic of SAPs. It is crucial to analyze lessons (failures as well as successes) and translate these into updated and more informed decisions in the future. SD pathways are developed with the deliberative involvement of key stakeholders, who represent different values and interests as well as different forms of local knowledge. Procedures to strengthen their involvement throughout the policy-making process are at the core of SAPs. The design of SAPs takes the respective political and socio-economic contexts as well as adaptive capacities of stakeholders into account, including those of the most vulnerable groups. Scholars of political ecology have argued that participatory environmental governance at the local scale is more likely to result in desired social and ecological effects compared to activities arranged at other scales (Brown & Purcell, 2005). An instrumental, pragmatic rationale holds that enhanced participation in environmental management improves effective policy implementation (Baker & Chapin, 2018). At a practical level, this means engaging local communities in discussions about their vulnerability, in mapping their own vulnerabilities, and in designing CCA policies that will protect them (Holland, 2017).

CCA responses include different sources of knowledge, drawing on local, traditional, indigenous and scientific information that must be collected, organized, processed, analyzed, distributed and utilized (Glover & Granberg, 2020). Integrating local knowledge and experiences as well as different framings and narratives in SAPs can increase the responsiveness of the set of measures developed and thus localize them. A highly participatory approach might expose differing opinions about the sustainability of an envisaged pathway, which increases the complexity of deliberative processes, but also their legitimacy in the local context, in particular if international donors are involved (Beisheim et al., 2014). However, participatory approaches often tend to reproduce the status quo rather than changing it (Blühdorn, 2018; Oels, 2019), especially when designed without taking underlying power relations into account (Oels, 2019). This calls for bottom-up formats to co-produce SAPs which are sensitive to local power dynamics and build on existing fora of participation. Importantly, there is no blueprint for involving local stakeholders in the development and implementation of SAPs. Case Study 14 on participatory CCA planning in Santiago de Chile provides an example of empowering local populations throughout different stages of the development and implementation of sustainable adaptation measures.

4.1.3 Financial elements

The implementation of measures to simultaneously address CCA, DRR and SD can require considerable financial resources. Budgets for CCA, DRR and SD are often administered by different line ministries (Sandholz et al., 2020), complicating the financial alignment of the three processes into SAPs. In particular in countries with little national budgets heavily affected by climate-related hazards, international funding mechanisms like the Global Environment Facility,

the Adaptation Fund or the Green Climate Fund can provide substantial assistance on a project level. Dedicated climate funds, which support the provision of investment for CCA projects in developing countries, can contribute to overcoming barriers to CCA and play an important role in catalyzing a wide range of adaptation-related investments. Here, it is important to ensure that strategic and financial interests of international or bilateral donors align with national or local plans, in order to avoid their efforts undermining local policies and programs or duplicating existing efforts, driving and reinforcing incoherence (Sandholz et al., 2020). Proper measurement, tracking, and reporting systems for investments are also necessary to ensure that finance is used efficiently and targeted where it is most needed (UNEP, 2016).

The private sector plays a key role in CCA finance. Besides managing its own climate risks, private finance sources such as equity or insurance products have the potential for bridging the gap. A clear understanding of private sector financing for CCA is key to unleash this potential. A wide range of private and public actors is essential for the engagement of the private sector in financing CCA interventions including businesses and private finance institutions, e.g. major institutional investors such as pension funds and insurance companies. Relevant public actors include public institutions, e.g. development cooperation agencies and finance institutions, which source private capital and provide public revenue towards catalyzing private investment, and blend private and public finance. Barriers to private sector adaptation can be broken down by targeted financial and non-financial interventions of government agencies and development organizations. Development banks can strengthen mobilizing private sector investment. Governments can also create enabling conditions for private investment support by supportive policy and regulation, delivering businesses access to information and tools to integrative investment decisions and demonstrating approaches, in order to create a track record that helps increase market confidence (UNEP, 2016).

4.2 SAPs and transformative adaptation

In the following subchapter, it will be described how the SAP concept relates to transformative adaptation. This section provides a brief overview on the discussion around transformative CCA before outlining an integration of both transformative and incremental CCA within the SAP concept.

CCA strategies can include three types of responses[12]: incremental and transformative responses and the active decision to take no action (Park et al., 2012). Incremental CCA is seen as maintaining "the essence and integrity of a system or process at a given scale" (IPCC, 2018a) and "characterised by the decision to continue responding to the same organisational objectives and within the same governance systems" (Park et al., 2012). CCA measures rarely stand alone but rather supplement existing plans and policies, and are therefore in practice usually incremental in their effects (Glover & Granberg, 2020). In addition to incremental adaptation, the IPCC defines transformative CCA as CCA that changes the fundamental attributes of a socio-ecological system in anticipation of climate change and its impacts (IPCC, 2018a).

Examples for incremental CCA actions in the agricultural sector are building irrigation systems, shifting cultivations or reducing water use. The application of crop insurance schemes or improving weather forecasting systems are understood as incremental. Transformative CCA is understood as e.g. changing land use to agroforestry practices, reforestation of degraded land or wetland restoration. Furthermore, compensation schemes for conservation measures could be implemented. Giving up some activities such as raising livestock is a further example (Fedele et

[12] Some authors include coping measures as a fourth type. We merged them with incremental responses as done by e.g. Park et al. (2012).

al., 2019, 2020). A practical example for transformative CCA at the city level is shown in the following case study on Rotterdam.

Case Study 2: Netherlands | Rotterdam's transformative climate governance

Transformative climate governance in Rotterdam, Netherlands

In the recent past, the city's political agenda had been shaped by the perception of water as a potential threat due to rise of sea, river and groundwater levels as well as an increase in storm surges and downpours. In 2009-2010, this perception was reframed through the Rotterdam Climate Proof Programme (RCP), which considers CCA not only as a preventive and security action, but also as an opportunity to improve the city's social and economic conditions and lay the groundwork for more systemic sustainability transformations in the city. Various projects have been designed to minimize risks while creating co-benefits of CCA with greening of urban spaces, community building, and overall economic development. The RCP is based on three mutually-reinforcing pillars: action, knowledge and marketing communication.

While the city's government (through the office for sustainability and climate adaptation) is the main responsible party for the development and the implementation of the cross-cutting projects under the RCP, numerous networks and partnerships allow the active involvement of stakeholders and other actors to enable cross-boundary and cross-sectoral implementation. The office is also responsible for the coordination of actions related to climate, resilience and sustainability connecting with other departments, levels of government and water boards. To this end, knowledge schemes for information-sharing are a fundamental platform to bring together actors from different areas and government levels.

Sources: Hölscher (2019), Hölscher et al. (2019).

Both incremental and transformative CCA can be reactive and take place during and after interruptions of systems, e.g. serious climate events. Transformative adaptation is also characterized as anticipatory and proactive and as including a long-term time horizon, e.g. changes to water right systems which do not lead to short-term adjustments in land-use (Kates et al., 2012). In current examples of transformative changes, CCA actions are explicitly designed and implemented. Autonomous CCA by individuals or institutions, however, can also be implemented, as well as actions originally addressing other problems, e.g. in the case of the regreening of the Sahel (Kates et al., 2012) (see case study box below). As final objectives of transformation are difficult to define, "purposive transformation" is about noticing that a fundamental systemic change is necessary to enable major future shifts (Berkhout, 2002; Lonsdale et al., 2015)

Case Study 3: Sahel region | The Great Green Wall

The Great Green Wall of the Sahel

The Great Green Wall is an ambitious initiative, started in 2008, which aims to create an 8,000 km long wall of trees, spanning across the Sahel Region from the Red Sea to the Atlantic Ocean to halt land degradation and combat desertification. The Great Green Wall initiative is an example of applying ecosystem-based measures to decrease vulnerabilities to climate change impacts and enhance adaptive capacities at a large scale. The project addresses adverse socio-ecological developments triggered by climate change in the Sahel region by restoring the degraded landscapes. Through this, the initiative aims to ensure food and water security, empower local populations and create climate-resilient economic opportunities. The continental geographic scope of the Great

Green Wall Project means that large-scale and diffuse benefits are possible, thus creating the opportunity for a contribution in 15 of the 17 SDGs. Initially envisioned as a one-size-fits-all kind of initiative, the vision of a Great Green Wall has eventually changed into that of a mosaic of different, integrated local interventions addressing multiple challenges through good local practices in environmental management and SD. While the initiative has shown promising results, criticism has also been voiced about a gap between ambition and actions on the ground. Also, securing funding remains a challenge due to the high implementation costs.

Sources: African Union (2012); Goffner et al. (2019), Morrison (2016).

The pathway approaches summarized in chapter 3 are screened according to their understanding and integration of incremental and transformative CCA.

The screened pathway approaches consider transformation and transformative CCA very differently. Butler et al. (2016) highlight that both incremental and transformative CCA measures need to be implemented to tackle climate vulnerabilities (Butler et al., 2016). Denton et al. (2014) and Wise at al. (2014) refer to the importance of both incremental and transformative CCA activities and see them as closely interlinked. Incremental activities could be especially relevant in the short term and to improve pre-conditions for transformative CCA in the long term. The framing is interesting for the SAP approach as currently approved measures could produce synergies with actions, moving towards a fundamental shift. Gibson et al. (2016) focus their paper on transformation in disaster risk management, linking it to development pathways and developing characteristics for transformation. They point out that planned (technological and administrative) reforms can give room for transformative social and political developments. They also mention challenges of transformative changes in practice, e.g. that the local level has to carry most of the costs of transformation and that pathway lock-ins and related institutional arrangements and power relations are obstacles to moving forward with transformative actions.

Further skepticism is mentioned by Fedele et al. (2019). They observe that the understanding of what transformative CCA looks like in social-ecological systems and when it can be implemented is still limited (Fedele et al., 2019). A limited number of practice-oriented concepts have been developed; however, many concepts are more general and merely conclude with the need for a fundamental shift in development approaches (Few et al., 2017). In practice, transformative CCA is used to a limited extent as a reaction to climate change (Fedele et al., 2019; Few et al., 2017). The concept of transformative CCA is, however, defined differently within the literature, and debates on what transformative CCA should entail and how it relates to incremental CCA are ongoing (Fedele et al., 2019; Few et al., 2017; O'Brien, 2012). This emphasizes the challenge to develop a shared understanding of transformative CCA.

In the literature, a range of barriers to transformative CCA is described. Fedele et al. (2019) identify additional barriers compared to incremental CCA. High investments are a key challenge, which could also lead to less social and political support. Mandates and responsibilities of institutions might not be aligned to implement transformative CCA. Power imbalances and inequalities might be a challenge for transformative activities, especially if these activities result in a major shift of governance structures which could be blocked by dominant actors. Different future visions should first be integrated before starting with implementation. Furthermore, agreements on distributional questions, vested interests and values take time to be reached but are preconditions for transformation. Uncertainties about climate change impacts and CCA benefits are a challenge for both incremental and transformative CCA, but can especially limit

the implementation of costly and resource-intensive transformative activities (Adger et al., 2007; Dietz et al., 2007; Fedele et al., 2019; Kates et al., 2012; Lempert & Collins, 2007).

The concept of resilience is increasingly popular across policy and implementation processes at regional, national and sub-national levels (Glover & Granberg, 2020). Current discussions on how to manage pandemic situations are framing resilience and stability as objectives and also discuss its inclusion in principles of SD, e.g. in the German Sustainability Strategy (Die Bundesregierung, 2021). Scholars such as Pelling (2011) discuss the difference between resilience and transformation. They point out that resilience can be understood as the ability to maintain existing social structures and functions in the face of disturbance through changes to relevant organizations and institutions. Therefore, resilience addresses symptoms of vulnerability rather than causes, while transformative CCA has the objective of a fundamental shift and a change of governance systems and instruments (Glover & Granberg, 2020; Pelling, 2011). Other approaches also conclude that a resilient socio-ecological system changes into a new form after disturbances and therefore uses a more non-linear, complex understanding of resilience (UNISDR, 2015).

Due to the implications of climate change, many scholars have thus suggested aiming for transformative CCA (Fedele et al., 2019; Feola, 2015; Kates et al., 2012; Oels, 2019). Based on these discussions, we propose an integration of incremental and transformative CCA within the concept of SAPs. Transformative CCA is understood based on Eriksen et al. (2015) and Pelling (2011) as addressing the root causes of vulnerability instead of its symptoms. It can involve fundamental shifts of e.g. technology, physical infrastructure as well as behavior, underlying values, norms, social networks and political and institutional arrangements. Through this, transformative CCA influences societies' and individuals´ decision-making and the allocation of resources (Feola, 2015; Kates et al., 2012). SAPs include a range of activities and measures which have incremental and transformative characteristics and which lead to an increase in adaptive capacity in practice. A fluent transition can be recognized between the two types. Incremental activities can create preconditions of transformative CCA and enable systemic change, which addresses the root causes of vulnerability and strengthens adaptive capacities. Strengthening short-term incremental and transformative activities is needed to tackle current climate impacts. Additionally, the selection of CCA activities (transformative or incremental) for SAPs should take the socio-ecological context into account and has to be aligned with objectives of sustainable CCA.

5 SAPs in practice

In this chapter, implementation examples of pathways for sustainable adaptation are described using the SAP concept as framework to structure the case study analysis.[13] The case studies cover a wide range of countries, as well as sectors and actors. Based on the analysis of the case studies, a guidance on the implementation of SAPs is elaborated, including main enabling factors in practice (section 5.2) and a 10-step sequence for the implementation of SAPs (section 5.3)[14].

5.1 Case studies of SAPs

The following chapter describes selected examples for different steps of SAP design and development. The case studies were identified and selected based on a review of scientific and grey literature based on six criteria[15]. First, only case studies whose objectives were congruent with the SAP definition provided in chapter 4 were selected in this paper. Second, as one objective of the case studies is to illustrate the practical implementation of different SAPs´ dynamic elements and their combinations, case studies were sampled to ensure that specific dynamic elements across all three categories (institutional, socio-political and cultural and financial) of the SAP concept are illustrated. Third, they were selected to ensure geographical diversity. Thus, selected case studies span across different continents and countries and include, fourth, a broad range of socio-ecological challenges. Fifth, they relate to different scales (transnational, national, subnational, local) and have been designed and implemented under the lead of different actors (both state and non-state actors). Sixth, they cover cross-cutting themes, such as agriculture, nature conservation, urban planning and coastal area management.

The SAP framework is used to structure the case study analysis: For each case study, the socio-ecological context, the characteristics of the specific SAP and its dynamic elements (institutional; socio-political and cultural; financial) are illustrated. Additionally, key findings including barriers, success factors as well as the main interlinkages to the SDGs and the Sendai Priority Areas are summarized per case study. Findings on enabling elements that became apparent in the case studies' analysis are summarized in chapter 5.2. All case studies can be found in a separate document while short summaries can be found throughout the paper. The case studies presented illustrate different dynamic elements and can be broadly clustered along the three categories of dynamic elements identified - institutional, socio-political and cultural as well as financial. Importantly, these categories are non-exclusive, so typically, our analysis found that in most case studies dynamic elements of all three categories have been important in shaping the SAP. The case studies illustrate different aspects of the process, from laying the groundwork for SAPs to their implementation (see chapter 5.3 for a complete description of the different suggested stages of SAP implementation). Thus, in some case studies, pathways have already been implemented while in others implementation is still underway. The case studies presented illustrate the many ways SAPs can play out in practice. In the following chapter, findings from the case studies are summarized and enabling elements for the design and implementation of SAPs are discussed.

[13] Pathways for sustainable adaptation thus refer to specific case studies in contrast to SAPs which refer to the broader concept as such.

[14] Extended case study descriptions can be found in a separate the appendix to this document (cf. Bueb et al, 2021).

[15] Due to the conceptual framing of the SAP approach, the selection of case studies and the subsequent desk-based analysis are guided by the normative assumptions of the approach. Biases resulting from applying this framing as well as from the researcher's subjective lens thus cannot be ruled out.

5.1.1 Institutional dynamic elements

The case studies illustrating the institutional dimension cover all five dynamic elements listed under this category. In all case studies in this category, a clear emphasis on cross-sectoral coordination and exchange was present. The case study of the Delta Plan 2100 below provides an example of how a government-led strategy can act to integrate sector plans and policies into a coherent long-term strategy that integrates CCA, DRR and SD goals. In many cases, different ministries have been involved (see case study 15 on policy integration in Ghana). In other case studies, cross-sectoral coordination was made possible by political will and leadership to force coherence, which highlights interlinkages between different dynamic elements across categories. At the same time, flexible governance structures which provide sufficient leeway can enable the provision of ad-hoc support, which is crucial in the light of uncertainties and the limits of policy planning. In the case of the Danish NAP (case study 16), a mobile team has been set up to provide direct support to municipalities in the implementation of their plans. A task force coordinated the overall implementation, which was key to translating national planning to lower levels of government. Such actors are thus key to couple different governance scales and allow for an interaction across scales. In the Danish case, the task force was thus responsible for both fostering both cross-sectoral and cross-scale alignment of CCA policies. In many cases, intersectoral coordination was accompanied by a strengthening of institutional capacities, especially in those case studies with little experience in cross-sectoral integration. A number of case studies put forward ecosystem-based approaches, e.g. restoration of coral reefs, reforestation or nature-based flood protection. The Gambian government, with their Programme for Adaptation launched in 2017, even targets a natural and ecosystem-based economy (case study 13). In some case studies, international donors played an important role in providing funding or technical support (see case study 11 on the Colombian NDC). The Bangladesh Delta Plan, presented below, has also been designed based on financial support from the World Bank and technical support from a Dutch consultancy firm. The communication of clear benefits for the private sector was important for private sector involvement.

Case Study 4: Bangladesh | The Delta Plan 2100

Managing water and disaster risk in the world's largest delta. The Bangladesh Delta Plan 2100

The Ganges–Brahmaputra–Meghna Delta area covers most of the territory of Bangladesh and is one of the most densely populated deltas in the world. The region is particularly exposed to climate change impacts and water-related natural disasters, such as recurring floods and tropical cyclones. Vulnerabilities are further exacerbated by deep social inequalities among the population. In addition to climate change, several human activities that exert pressures on the delta ecosystem – irrigation, fisheries, transport, construction of industrial infrastructure etc. – are rapidly expanding due to economic development and demographic change.

In 2018, Bangladesh launched an integrated, long-term plan, the Bangladesh Delta Plan 2100 (BDP 2100), which combines water resource management, disaster risk management and CCA in the Ganges–Brahmaputra–Meghna Delta to enhance SD. The Plan was developed by a consortium of companies and governmental institutions from the Netherlands and Bangladesh, led by Dutch consultancy firm Twynstra Gudde. A major funding partner was the World Bank. The program seeks to implement numerous medium-small scale "no-regret" interventions, phased over time, instead of a large-scale and irreversible single project. The intent of this strategy is to maximize the efficiency of the timing of investments through adapting solutions to changing ecosystem and socioeconomic settings over time and in coherence with previously implemented projects. For each intervention, opportunities to align implementations and to reap social and environmental benefits are

considered. The BDP 2100 program integrates existing development policies and sectoral strategies into a multi-sectoral effort that mainstreams CCA, biodiversity, sustainable land and water management. An intersectoral character is at the core of the program, with a specific focus on coordination and interaction among different areas of intervention such as flood risk management, fresh water, sustainable spatial planning and land use, food security, agriculture, sustainable livelihoods, water resource management, land and water transport and renewable energy. The governance structure of the BDP 2100 includes the Delta Governance Council for strategic directives comprising eight ministries, the Project Selection Committee for the selection of programs to be implemented and the Delta Commission for the management of annual spending plans. The long life span of the strategy, as well as the size of the aggregate investment, pose a number of challenges to its successful outcome. Sustained commitment to management and alignment of interconnected projects and financing activities is essential, and represents a challenge given the unpredictability of long-term climate changes and socioeconomic trends.

Sources: Global Center on Adaptation (2021), Government of Bangladesh (2020).

5.1.2 Socio-political and cultural dynamic elements

Case studies illustrating especially socio-political and cultural dynamic elements range from local actions to enhance grassroots flood resilience building in Gorakhpur (case study 9) or participatory CCA planning in Santiago de Chile (case study 10) to transnational examples like the Great Green Wall of the Sahel (see case study 3, chapter 4.4). Community-based approaches and realigning to local knowledge can be found e.g. in a food project in the Colombia-Ecuador border area (case study 5). Two-way communication between communities and governments and a citizen monitoring committee is set up for a project on flood protection and EWSs in the Kelani river basin in Sri Lanka (case study 7). With shared learning meetings, another interesting approach to stakeholder involvement is used in Gorakhpur, India (case study 9). In this case, the lack of operational and financial capacities of the city government was overcome by the engagement of a civil society organization. For the CCA planning in Santiago de Chile, a novel approach for the city was used which not only integrated public authorities in the discussion but opened the process to a broad range of stakeholders, including private actors, and their multitude of perspectives. All case studies in this category are also characterized by a strong institutional foundation which highlights the interconnectedness of the different categories. This is also illustrated by the case study below on local food and nutrition security and peacebuilding actions in the Colombia-Ecuador border area aimed at building adaptive capacity of marginalized populations. The entire project cycle is built around the close involvement of local communities. Coordination across scales and a constitutional framework in both Ecuador and Colombia are, however, important enabling factors that support project implementation, showing interlinkages between the socio-political and cultural as well as institutional dynamic elements.

Case Study 5: Colombia and Ecuador | Building local adaptive capacity through food security measures

Building adaptive capacity through food and nutrition security measures and peacebuilding actions in the border region of Ecuador and Colombia

The Mira river basin in the Ecuador-Colombia border area is one of the most climate-sensitive and food-insecure regions in Latin America. The main environmental and climate-related risks are extreme precipitation events leading to landslides and infrastructure damages. Drought events have resulted in forest fires, reduced water access and lower crop yields, reducing local incomes.

The basin is primarily inhabited by historically marginalized Afro-Colombian communities as well as indigenous communities of the Awá. The region is impacted by recurring violent conflicts and by problematic social conditions such as chronic malnutrition and a high mortality rate among children. In 2018, Columbia and Ecuador, with support from the World Food Programme, started a binational community-based food security project in the Mira river basin to develop local village adaptation plans in a comprehensive participatory co-development process. The village adaptation plans contain a list of innovative adaptation solutions, taking into account traditional knowledge to reduce vulnerabilities of the local populations, e.g. using forest species that retain soil on riverbanks prone to erosion and landslides. Additionally, communities are equipped with basic instruments to collect precipitation and temperature data in their villages and trained in their usage. The project objective to empower marginalized groups is supported by constitutional provisions on citizen participation and multiculturalism, including ethnic minorities' right to self-governance, present in both Ecuador and Colombia.

The project demonstrates that finding ways to combine local knowledge and scientific findings can lead to innovative and effective sustainable adaptation activities. While the project is still ongoing, early evaluations have shown that stakeholders valued the participatory process as beneficial to achieving sustainable project outcomes. A key factor for the community participation was seen in effective trust building. Due to the enhanced involvement of stakeholders throughout the project, the project progressed slower, but in a more robust way.

Sources: Adaptation Fund (2021), Global Center on Adaptation (2021).

5.1.3 Financial dynamic elements

Four case studies focus on the financial dimension of SAPs. Two case studies explain the important role insurance companies can play in decreasing the impact of climate-related disasters: case study 6 on pro-poor microinsurance in Haiti (see box below) provide an example of innovative involvement of the insurance sector. Case study 14 describes a national program using an innovative approach to halt deforestation through financial incentives for local communities in Ecuador. Case study 20 describes Peru's public investment policy invierte.pe, which simplifies the process of accessing funds and focusses on citizen-centered service delivery. In addition to these four case studies, the other case studies show that a sufficient finance base is an integral enabling factor of any SAP.

Case Study 6: Haiti | Pro-poor catastrophe insurance

Pro-poor catastrophe insurance in Haiti

Haiti is among the countries most vulnerable to multiple natural disasters, suffering regularly from floods and landslides, droughts, earthquakes and hurricanes. Due to widespread poverty, survivors of natural catastrophes are often confronted with serious problems of food insecurity, access to drinking water and sanitation. Fonkoze is an NGO and the largest microfinance provider in Haiti, committed to decreasing poverty by empowering Haitians through financial inclusion and development services. Recently, the institution began offering disaster insurance loans to clients in order to decrease the impacts of natural disaster events. Since a series of hurricanes struck the island in 2008, Fonkoze set up affordable insurance against natural disasters for its microfinance clients. The result was Kore W, a program for natural catastrophe coverage whose affordability is granted by the institution and international donors' subsidies to the premiums paid by participants. The program covers small entrepreneurs from earthquakes, storm and hurricane events, and is mandatory for every loan client. By regularly paying a small fee, participants are covered for most

of the losses; furthermore, they have the right of cancellation of their loan, with the possibility to take a new loan as soon as they deem it necessary. This affordable insurance addresses food insecurity caused by natural disasters and allows for a swift recovery. Under such conditions, small entrepreneurs are more confident when making investment decisions without having to worry about climate-induced losses.

Fonkoze included an educational initiative as part of Kore W, in order to raise awareness of the benefits of the product to clients. The involvement of international donors allowed Fonkoze to subsidize the premium paid by clients, lowering it from 8% of the loan to just 3%. Affordable rates are fundamental to guarantee diffused insurance coverage across communities. One of the main challenges to the sustainability of micro-insurance in Haiti is the capacity to maintain substantial capital in order to afford to fulfil clients' claims for particularly destructive or recurring natural disasters. A complicating variable is the management of thousands of claims that accumulate in the wake of a large-scale disaster. Visiting claimants, verifying damages, filling out, submitting and approving forms are processes that end up extending payout times if these processes are not carried out efficiently. Corrective measures include the adaptation of the team capacities according to seasonal increased risks or the use of technological solutions such as smartphone apps to support damage assessments.

Sources: Cubas et al. (2020), Impact Insurance Facility (ILO) (2014), Kolbe et al. (2012).

5.2 Enabling factors of SAPs

The case studies presented in this paper provide a few initial examples of how to use the SAP concept when analyzing integrated policy processes aimed at CCA, DRR and SD goals. In each case study, a specific socio-ecological context influences specific vulnerabilities and evokes different degrees of adaptive capacities. The case studies presented are thus highly heterogeneous, which allows only for a limited comparative assessment.

Due to their explicit focus on CCA, a common thread in all case studies is their contribution to SDG 13. While not all of them implicitly aim to address CCA, DRR and SD, all case studies presented pursue CCA goals while contributing to selected SDGs. Some of them, e.g. case study 11 on inclusive flood protection and EWSs in Sri Lanka, have a clear focus on DRR.

The case studies have also shown that implementing SAPs in practice is associated with a number of difficulties, most of them resulting from context-specific lock-in effects. This emphasizes the importance of conceiving the design and implementation of SAPs as an iterative process open to readjustments and flexible enough to react to unforeseen dynamics. Based on these case study findings, we have grouped the individual dynamic elements and linked them to specific case studies to shed light on the relevance of specific enabling factors. Chapter 4.3 builds on these findings and provides guidance on the implementation of SAPs in practice using a stepwise approach. Summaries of selected case studies illustrate the different steps of the stepwise approach.

Table 4 Major dynamic elements enabling SAPs

Enabling factor	Description	Specific aspect. Illustrated in Case Study Examples
Planning and development of **SAPs** taking into account relevant **socio-ecological contextual factors that go beyond climate and environmental change**	In addition to environmental and climate change, individuals, groups or regions are exposed to other stressors (e.g. economic, social, political-cultural factors) that need to be taken into account when designing SAPs.	**5 |** Building adaptive capacity through food and nutrition security and peacebuilding actions in the Colombia-Ecuador border area **7 |** Inclusive Flood Protection and EWSs in Sri Lanka
Inclusion of stakeholders, their local knowledge, alternative problem perceptions and networks	Existing shared knowledge of actors in specific locations leads to different problem perceptions and preferences for different sustainable adaptation pathways and concrete measures (e.g. different issue prioritization in discourses; different shared value orientations, environment- and climate-related world views). Diverging goals on CCA measures and development priorities between actors can be negotiated through joint learning and knowledge co-production. Existing networks and related power structures, especially at the local level, should be taken into account when planning Sustainable Adaptation Pathways. Failure to take them into account can, for example, reduce the effectiveness of measures or increase social inequalities.	**16 |** Strengthen governance by supporting adaptation planning and action at municipal level through knowledge and consultancy in Denmark **10 |** Participatory CCA planning in Santiago de Chile
Coordination of policies, programs, processes and measures for SD, CCA and DRR at different decision-making scales and across sectors	Coordination between different policy fields and across different decision-making levels and administrative boundaries is necessary to plan and effectively implement complex pathways. This also includes a coherent division of responsibilities. NAPs, for example, are an instrument to bundle intersectoral activities at the national level and to increase policy coherence. When established sectors/thematic approaches and rigid political hierarchy structures are dominant or disconnects between planning and implementation exist, coordination can be difficult to achieve.	**11 |** Integrating adaptation with 2030 Agenda and Sendai Framework in the Colombian NDC **15 |** Approaches to increased coherence between CCA and DRR in Ghana
Consideration of **path dependencies and lock-in effects**	The selection and success of future SAPs is influenced by lock-in effects and historical development paths.	**9 |** Grassroot flood resilience building in Gorakhpur, India
Flexible multi-benefit governance structures	Flexible multi-benefit governance structures allow responding to uncertainties in the planning of SAPs.	**2 |**Rotterdam's transformative climate governance **16 |** Strengthen governance by supporting adaptation planning and action at municipal level through knowledge and consultancy in Denmark

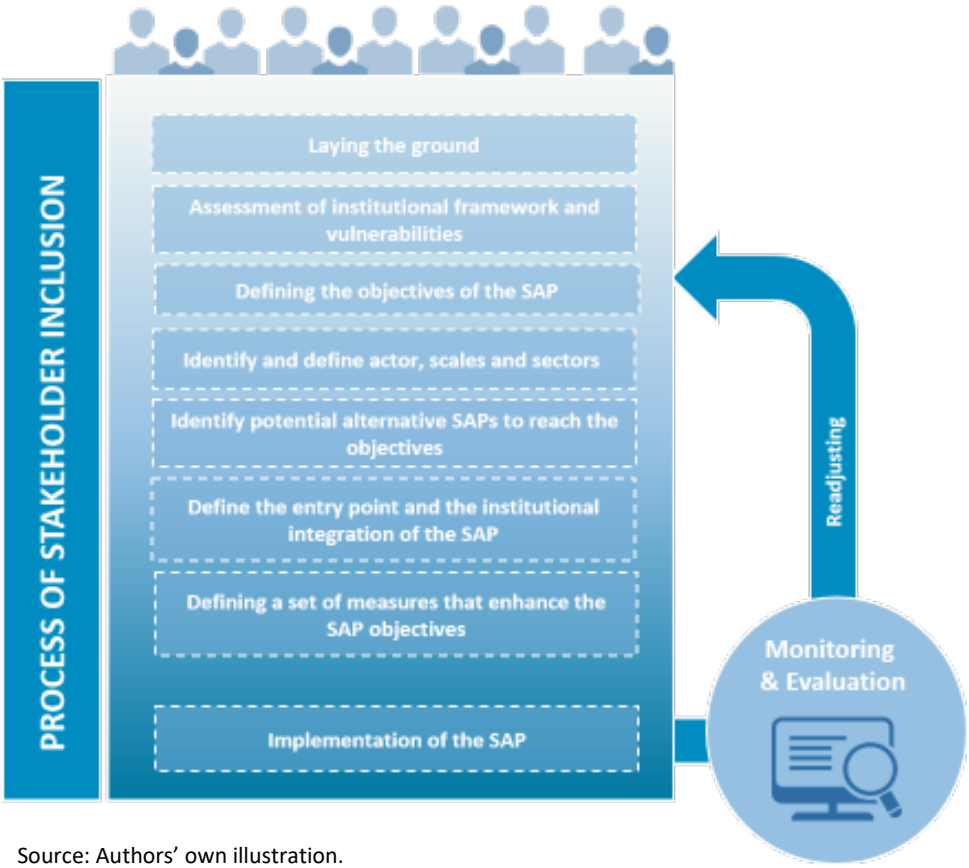
Enabling factor	Description	Specific aspect. Illustrated in Case Study Examples
Access to funding for appropriate measures	Both access to financial services for stakeholders and communities at the local level and sufficient funding for national/regional plans are necessary for successful planning and implementation of adaptation measures. This includes the possibility of accessing international funding mechanisms, such as the UN Adaptation Fund (AF), to pursue innovative pathways.	**14 |** The Socio Bosque Program to protect forest ecosystems and decrease poverty through monetary incentives in Ecuador

5.3 From groundwork to implementation of SAPs

The case studies presented in Chapter 5.1 have illustrated how the SAP concept framework can be used to analyze linkages between CCA, SD, and DRR. Based on these applications of the SAP concept to different case studies, we will present entry points and recommendations for implementing SAPs in practice. In the following chapter, a sequence of 10 steps is proposed to provide guidance when implementing SAPs. It is important to note that this sequence should not be seen as fixed; instead, certain steps might be added, omitted or swapped to fit the respective local context.

SAPs can be initiated by different actors associated with different sectors that are operating at different scales. The range of actors to start the process include international donors, national and subnational government agencies, local community groups, non-governmental organizations (NGOs) as well as private actors.

Figure 7 SAP implementation process



Source: Authors' own illustration.

As shown in Figure 7, a key feature of SAP development and implementation should be the inclusion of relevant stakeholders. There is, however, no blueprint for their involvement in the process. Instead, their involvement should be facilitated by taking existing participatory fora, as well as political power relations and inequalities that influence access to these fora, into account. Depending on the context, the involvement can be stretched across the full 10 suggested steps or can be focused on a number of selected activities.

In the following subchapters, the 10 suggested steps for implementation of SAPs are described.

5.3.1 STEP 1 | Lay the ground

As a first step, an initial assessment of the socio-ecological context is required. This includes taking stock of relevant institutional, socio-political and cultural and financial dynamic elements which are present in the respective context. This should include exploring stakeholder perceptions of SAP, taking into account different cultural understandings, ambitions and preferences for SAPs and their objectives in the specific local context. The SAP definition presented here can provide a first starting point, but it may be required to break it down to ensure accessibility and inclusiveness from early on. Obtaining political support of key actors is crucial at this early stage to guarantee that sufficient political leadership is available throughout the development and implementation of the SAPs.

Identifying to what extent key enabling factors (Table 6) are present in the specific context is another important step at this early stage. Available initial information, e.g. on existing climate-related risks and vulnerabilities, is collected. If available, existing responses to adapting to and reducing climate-related risks are screened and evaluated with regard to their contribution towards sustainable adaptation. In some cases, SAPs have been initiated by external actors such as international development organizations, but with close involvement of local populations (see case study 5 on Colombia/Ecuador in chapter 5.1.2). In these cases, identifying synergies with current or past interventions should be examined to ensure coherence.

5.3.2 STEP 2 | Assess the institutional framework and vulnerabilities

In a second step, a more in-depth analysis of the institutional framework and vulnerabilities of both populations and institutions in the specific socio-ecological context is conducted. Here, a systematic assessment of vulnerabilities of populations, ecosystems and institutions is key. Engaging local communities in discussions about their vulnerability or in mapping their own vulnerabilities can be important to ensure their buy-in at an early stage (Holland, 2017). Measures like participatory rural appraisal and community-based risk assessments have great potential to capture opinions and knowledge present at local level (van Aalst et al., 2008).

Vulnerability can be assessed along three criteria (Donatti et al., 2018):

- Exposure of the considered population to climate change
- Sensitivity to climate change of the livelihood systems/ecosystem services that target population relies on
- Adaptive capacity of the target population

It should be ensured that voices of marginalized members of communities are included in the assessment of vulnerability and adaptive capacity to empower them by CCA actions and to avoid that power and gender inequalities undermine CCA efforts if underlying root causes of vulnerability are not adequately addressed (Resurrección et al., 2019). Identifying most vulnerable populations to design differentiated responses that take inequalities into account is key (see case study 7 on inclusive flood protection and EWSs in Sri Lanka).

Case Study 7: Sri Lanka | Inclusive Flood Protection

Inclusive Flood Protection and EWSs in Sri Lanka

Sri Lanka is particularly vulnerable to different types of large-scale natural disasters. In recent history, the most dramatic example is surely the 2004 Tsunami, which caused more than 30,000 casualties in the country. Increased flood risk due to climate change threatens to directly affect a large portion of the population, but to differing degrees due to different sensitivity and exposure to climate impacts. The history of natural disasters in Sri Lanka led to the development of policy frameworks for disaster risk management. During this process, one of the priorities of policy-making was to incorporate provisions for vulnerable group inclusion in disaster risk management plans; yet, one gap that emerged was that policies were addressing these concerns in a rather generalized fashion, grouping all the vulnerable into a single category.

The Climate Resilience Multi-Phase Programmatic Approach Project in Sri Lanka aims to close that gap and commits to an inclusive approach to disaster risk management by deploying multiple communicative and participative measures to ensure the inclusion of marginalized and vulnerable groups in the early warning system. One of the fundamental challenges of an inclusive approach is

the identification of vulnerable categories or individuals and the definition of related indicators. The vulnerability assessment strategy pursued in this case study was based on community empowerment, with the establishment of citizens´ committees that are representative of local diversities.

Issues of exclusion concerning the EWS emerge as different groups have different means to receive early warning messages and to consequently take action. In order to increase the outreach of the EWS to socially excluded groups/individuals, warning messages are delivered through a range of communication means (television, radio, social media, SMS, etc.) with appropriate measures to address different visual and hearing needs. In addition, community early warning committees are established with such a composition as to represent the variety of components of each community. The capacity of local communities to understand and use EWS is enhanced through dedicated capacity-building training programs.

Among the most challenging socio-economic issues, in relation to flood management infrastructure development, is that often, the most vulnerable households tend to reside in areas most exposed to natural disasters. The project made these areas priority areas for intervention and constructed embankments to mitigate flood risks. The project further established a resettlement assistance plan, cash transfer schemes and awareness raising campaigns, among several safeguards to minimize the negative impacts to project-affected groups and individuals.

Sources: World Bank (2019, 2021).

An important aspect is also the analysis of existing path dependencies and adaptation lock-ins and additional enabling factors of SAPs (see Table 6). Another important aspect is the assessment of institutional and financial capacities of implementing actors as they determine the set of measures that can be implemented to achieve the objectives to be defined in the next step. Both access to financial services for stakeholders and communities at the local level and sufficient funding for national/regional plans are necessary for successful planning and implementation of CCA measures.

One outcome of this step can be a map illustrating areas of low, medium and high vulnerability, and an indication of what impacts of climate change and extreme weather events they are vulnerable to (see Figure 8 for an example) (Donatti et al., 2018). The assessment of vulnerabilities also needs to be conducted in the light of a high degree of uncertainty about how future climate impacts will play out (Buurman & Babovic, 2016; Leach et al., 2010; Siders & Pierce, 2021). We propose a strong consideration of socioeconomic factors in the assessment of vulnerability and adaptive capacity (Holland, 2017). Understanding interlinkages between climate impacts and vulnerability, but also between these socioeconomic conditions and vulnerability, is key in designing measures that enhance not only adaptive capacities of local populations and institutions, but also SD on a wider scale. Relevant indicators of the 2030 Agenda and the Sendai Framework (see chapter 2.2.1) can provide a starting point for a baseline assessment aligned with the overarching post-2015 agendas. Agreements on the sharing of data between different government agencies or platforms can facilitate assessing relevant indicators (see case study 8 below).

Case Study 8: Brazil | National Platform for data-sharing on adaptation

AdaptaClima - A National Platform for data-sharing on adaptation

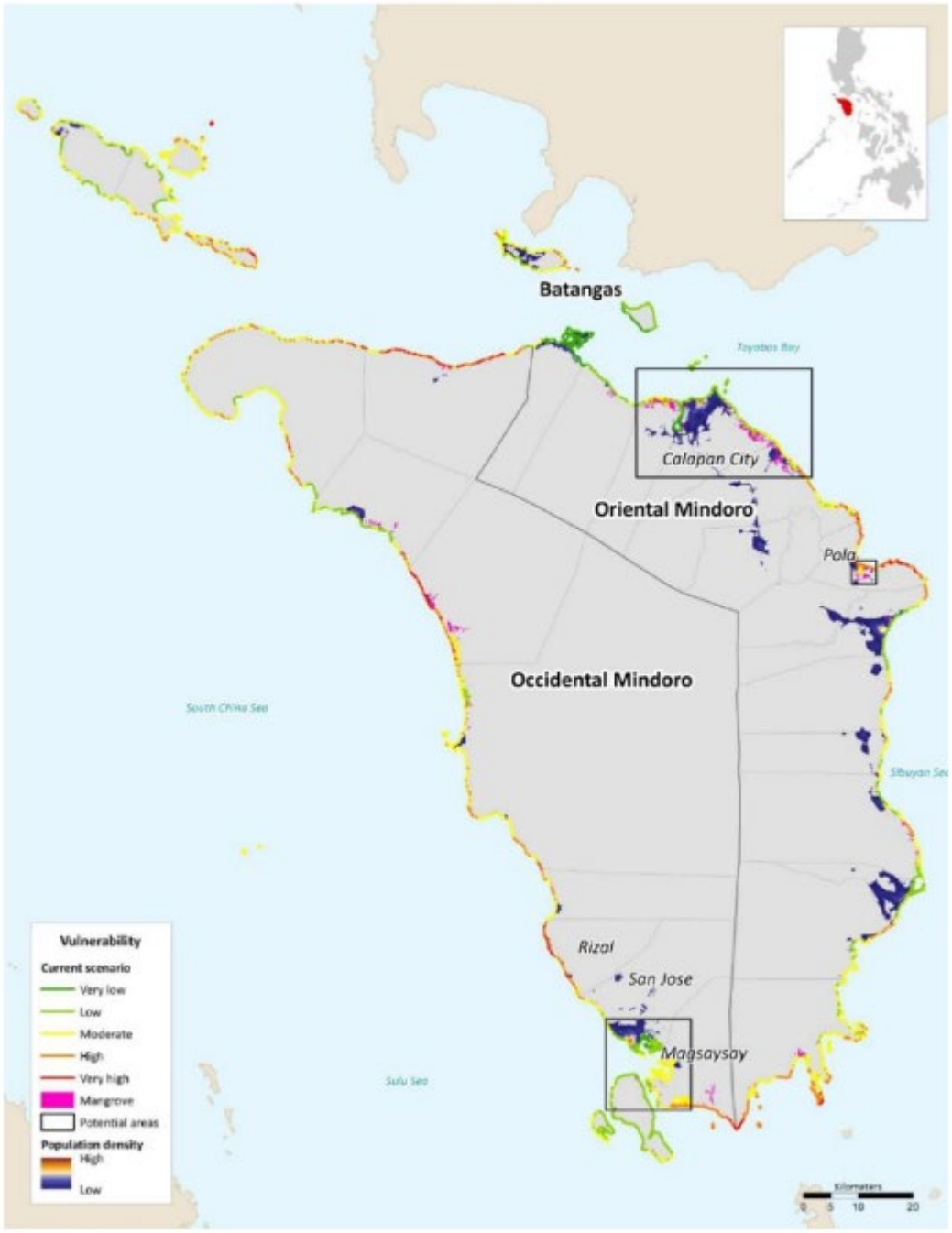
Knowledge is an essential resource for people and organizations that take decisions on adaptation strategies and actions. The quality and reliability of available information directly affects the

outcomes of implemented projects. Launched in 2017 with the support of European partners, AdaptaClima is a Brazilian platform for sharing data on CCA. It was developed to enable free access to practical information on adaptation and avoid knowledge gaps, thus achieving the first objective of the Brazilian NAP, which requires the development and delivery to society of an online platform for management of knowledge on adaptation. The platform provides information through multiple services, including scientific publications, interactive data interfaces, systematic guidance tools for the development of strategies and networking tools. Acknowledging the involvement of a diverse range of stakeholders in the adaptation agenda, the platform was developed through an inclusive and participatory process, which saw contributions from more than 60 Brazilian organizations and several experienced foreign partners. Since its publication, the AdaptaClima platform has been coordinated and operated by the Ministry of Environment, which holds responsibilities for the effective management of the platform.

AdaptaClima connects decision makers on adaptation across Brazil, bridging both regional and sectoral differences and enabling common understanding over mutual challenges and emerging ones. The participatory development process underlines the importance of stakeholder inclusion to ensure that the design of the platform matches the needs and expectations of potential users and is actually being used in policy practice. AdaptaClima is also part of the Knowledge Exchange Between Climate Adaptation Knowledge Platforms (KE4CAP) network for knowledge exchange between CCA platforms, an international forum where developers and operators of similar projects compare their approaches and learn from each other on how to address common and emerging challenges.

Sources: Barrott (2018, 2019), Ministry of Environment (BRA) (2016).

Figure 8 Map of vulnerability to coastal erosion for the Mindoro area in the Philippines



Source: Cogswell et al., 2016.

5.3.3 STEP 3 | Define the objectives of the SAP

Once the institutional framework as well as vulnerabilities in the target context have been analyzed, the main objectives of the SAP have to be defined. The objectives should build on analyzed risks and vulnerabilities as well as the assessment of institutional arrangements. Their definition should be based on an openness to alternative framings as well as to diverging interests which can be assessed through stakeholder consultations. The definition of SAPs as a coherent set of alternative CCA strategies and procedures composed of measures and policies to strengthen adaptive capacities while enhancing the three pillars of SD can provide orientation in elaborating pathway objectives.

This step also includes defining the underlying logic of intervention regarding SD. How will the SAP enhance SD? Are there aspects of SD which should be focused on?

Furthermore, the objectives can be developed iteratively for different timeframes, e.g. as priorities for activities in the short term, mid term and long term. Furthermore, first steps or preparatory work for long-term developments can be integrated in decisions today - these considerations can keep open possibilities for CCA activities within later iterations of the SAP if better knowledge on climate impacts is available and predictability is higher. Land-use restrictions within urban planning processes, for example, can lead to more mid-/long-term flexibilities for flood management.

5.3.4 STEP 4 | Identify and define actors, scales and sectors

Regardless of who initiates the SAP, an important step is the mapping of relevant stakeholders to be affected by the SAPs planned. A participatory process can be valuable to increase the legitimacy of the SAPs under discussion and provide information on the individual effects of the different SAPs. Which actors, sectors and scales have to be involved is to a large extent determined by the objectives defined. As SAPs are about aligning different policy fields (CCA, DRR and SD), collaboration among the different actors involved in leading and supporting the different policy processes is required (Dazé et al., 2019). Alignment efforts are most likely to be effective if there is a shared goal among the relevant actors, which facilitates sharing of information, joint stakeholder engagement and the flexibility required for alignment to occur (Dazé et al., 2019). A certain degree of leadership is a precondition to coordinate the different stakeholders and sectors involved (Gupta et al., 2010) (see box 9 on grassroot flood resilience building in Gorakhpur).

Case Study 9: India | Grassroot flood resilience building

Grassroot flood resilience building in Gorakhpur, India

High population growth in the city of Gorakhpur, India has been posing enormous challenges to urban planning. This fact, coupled with a diminished capacity of the local government to provide water supply, sanitation and drainage, as well as endemic issues of flooding and waterlogging, are likely to increase local climate change impacts. As a response, the civil society organization Gorakhpur Environmental Action Group (GEAG) decided to become active by planning ecosystem-based adaptation measures that could address multiple goals through community efforts. The group, in collaboration with local stakeholders, identified opportunities for interventions to achieve overarching objectives like food security, climate resilience and sustainability of agricultural practices in peri-urban areas.

While the activation of bottom-up initiatives brought incremental improvements to the agricultural income of farmers, local public authorities lacked operational and financial capacity to make and implement decisions regarding basic services. Acknowledging these facts, GEAG collaborated with the city's agencies in order to establish regulatory and incentive frameworks for a managed expansion of the urban area. Shared learning meetings with relevant stakeholders such as the Municipal Corporation of Gorakhpur, the Fisheries Department, Gorakhpur Development Authority, informed citizens, academics of the city (and many others) were organized to discuss approaches and future scenarios of urban growth.

The grassroots-led flood resilience strategy adopted by GEAG managed to increase the city's capacity to deal with climate change hazards, while at the same time increasing the agricultural income of local farmers and avoiding their displacement. These encouraging results are likely

transferable to other similar urban contexts and have the potential to be scaled up. Tapping the potential of ecosystem-based measures to enhance adaptive capacities of vulnerable communities in the light of climate change as well as socio-economic risks is a crucial element of realizing SAPs in cities.

Sources: Du (2019), Global Center on Adaptation (2019), Gorakhpur Environmental Action Group (2013).

Case Study 10: Chile | Participatory CCA planning in Santiago de Chile

Participatory CCA planning in Santiago de Chile

In the Metropolitan Region of Santiago de Chile (MRS), as in other parts of the country, urban planning and governance schemes have been typically sectoral and non-participatory. Projected impacts of climate change in the region include rising temperatures and prolonged heatwaves, with decreases of annual precipitation volumes and general water availability. These expected developments would amount to harsher trans-sectoral conflicts over the use of water as a major challenge for the future of the region.

The transversal nature of climate change and the documented effectiveness of integrated adaptation responses forced local policy-makers to introduce participatory mechanisms and more open models of governance for the development of the Regional CCA Plan. A series of roundtables was organized to attract a range of relevant stakeholders to discuss specific issues. A number of key stakeholders attended regularly throughout the entire process, while others participated in single sittings in which specific issues addressed. Each session was introduced by a detailed and up-to-date set of scientific information on current issues and expected developments, which enabled meaningful discussions to identify priority areas for action, as well as barriers and opportunities for the implementation of adaptation measures, with consideration for the different interests and needs of the various categories represented.

The final product of the process was a plan proposal that could achieve high levels of political and social acceptance, in contrast with past non-participatory policies which often sparked opposition. Moreover, participants improved their awareness on climate change impacts and a solid common understanding of adaptation requirements developed across sectors and social parties.

Sources: Barton et al. (2015), Krellenberg et al. (2014).

The integration in practice is facilitated through the common cross-sectoral approach of all three processes (CCA, DRR and SD) which unanimously call for integrative actions that benefit more than one sector or policy field (UNFCCC, 2017b). Synergies between CCA, DRR and SD are normally most pronounced in specific sectors, e.g. urban planning, agriculture, energy, forestry or water management. Thus, the identification of key sectors and their interlinkages at national and/or local level is crucial in order to reach cross-sectoral alignment for SD, DRR and CCA. National governments, however, tend to mandate different departments to deal with the CCA, DRR and SD processes separately, which can hinder effective cross-sectoral alignment. DRR is often assigned to national disaster management agencies, civil protection and response while climate change tends to be coordinated through ministries of the environment, in close coordination with finance and planning ministries (OECD, 2020; UNDRR, 2019). Also, sectoral policies are still developed and implemented in a siloed manner and without taking interlinkages with other sectors into account. When implementing measures that are not directly linked to CCA or DRR, such as social protection, climate proofing of these measures can ensure alignment. This by no means implies that a full integration of the three post-2015 agendas is always feasible. Rather, analyzing synergies can help to make national efforts more effective, even if the choice has been made to establish a separate legal or institutional framework to deal with climate change holistically (UNDRR, 2020). Potentially, redefining the objectives may be needed once an overview of actors, scales and sectors affected has been compiled.

5.3.5 STEP 5 | Identify potential alternative SAPs to reach the objectives

In any given context, multiple pathways exist to reach a specified set of sustainable adaptation objectives. In this step, good practice examples can be collected and their fit to the specific context can be assessed. Stakeholder consultations can support the development of SAP pathways and ensure that local experience and knowledge as well as different perceptions and narratives of SAPs are taken into account in the pathway development. This also allows assessing and integrating the general acceptance and priorities of different stakeholder groups for particular pathways and interventions.

5.3.6 STEP 6 | Define the entry point and the institutional integration of the SAP

SAPs are developed and implemented in iterative processes to take into account feedback loops and uncertainty in policy development and planning. Still, their implementation requires a specific entry point for integrating the overarching 2030 Agenda, Sendai Framework and CCA provisions under the UNFCCC to align CCA, DRR and SD goals within SAPs at national and sub-national level. While the post-2015 agendas are multi-scalar in nature and stress linking national and sub-national planning (UNFCCC, 2017b), three entry points are to be found at national level: national development visions; national commitments to international agendas and operational vehicles, such as the NAPs (Dazé et al., 2019). At the national level, the three agendas are, however, often implemented through separate mechanisms, which stresses the importance of a sound institutional analysis to assess existing responsibilities and competencies across relevant governance actors. Based on the assessment of vulnerabilities and institutions as well as of actors and scales involved, potential interactions between the three policy processes should be carefully examined to identify positive and avoid negative interactions. At the planning level, this can include relating the CCA objectives to related goals of the 2030 Agenda and Sendai Framework (see example on Colombian NDCs for an application). In many contexts, focusing on a limited number of policy processes where clear synergies exist may thus be more feasible than aligning multiple processes at once (Dazé et al., 2019). Analyzing synergies can help to make national efforts more effective, even if the choice has been made to establish a separate legal or

institutional framework to deal with climate change holistically (UNDRR, 2019). At the national level a likely starting point is informal alignment through information sharing and ad hoc coordination between administrations (Dazé et al., 2019). Once leadership is defined, institutional integration can happen more strategically, either at national (e.g. NAP), regional or subnational level.

Case Study 11: Colombia | Integrating CCA with 2030 Agenda and Sendai Framework in the NDC

Integrating CCA with 2030 Agenda and Sendai Framework in Colombia's updated NDC

In early 2021, Colombia published its updated NDC under the UNFCCC for the period of 2020-2030 and used an integrated approach aiming at synergies between the 2030 Agenda, the PA and the Sendai Framework. It describes actions to mainstream climate change considerations into national and local development plans. The NDC identifies water resources, protection of terrestrial and coastal marine ecosystems, restoration of protected areas, infrastructure and agriculture as target areas for adaptation actions. The adaptation priorities are aligned with areas of risk and vulnerability identified as priorities for the country, to be congruent with the SDGs and the Sendai Framework. The NDC builds on key policies such as the country's 2010-2014 National Development Plan, which established a National Climate Change System to improve coordination among the institutions.

Through more robust technical modelling and stakeholder engagement, Colombia has stepped up its NDC's CCA components by better aligning its 30 sector-specific NDC goals with the Sendai Framework and the SDGs. With its NDC, Colombia sets out to address climate and economic challenges in a coherent way and thus to work towards SD in its three dimensions, as promised in the NDC. As countries continue to submit enhanced NDCs, Colombia's NDC can provide an example for an integrated strategy for other nations. A key challenge remains the implementation of this ambitious framework. This will largely depend on an adequate political environment that continues to prioritize holistic development and adaptation policies, also in the light of the COVID-19 pandemic and associated socioeconomic challenges.

Sources: Government of Colombia (2020), Vergara et al. (2021).

NAPs and NDCs are central instruments of the UNFCCC to communicate and operationalize adaptation-related commitments at country level. In countries where CCA information is included in NDCs, NDCs communicate the goals and targets that are envisioned for CCA. Links between national climate action and the SDGs are abundant in the NDCs. A comparison at global scale has shown that the SDGs most frequently connected to NDCs are Affordable and Clean Energy (SDG 7), Life on Land (SDG 15) and No Hunger (SDG 2) (German Development Institute & Stockholm Environment Institute, 2018). In developing countries, NAPs are an additional instrument to elaborate how CCA will be planned, implemented and monitored (Dazé et al., 2019). As of 22 March 2021, 21 NAPs have been submitted to the UNFCCC. In particular, NAPs are a major operational vehicle for integrated actions with the potential to contribute to all three post-2015 agendas by explicitly aiming to integrate CCA in development processes across sectors and levels (see case study 12 on the Sri Lankan NAP). This may involve alignment across agendas (e.g. by aligning NAP processes with DRR strategies) or within a particular agenda (e.g. by aligning NAP processes with the adaptation components of NDCs) (Dazé et al., 2019).

Initially, DRR has not been mentioned in NAP guidelines published by the UNFCCC Least Developed Countries Expert Group despite addressing climate-related hazards, such as severe storms, droughts, sea-level rise and floods (UNFCCC, 2012). More recently, supplement documents and technical reports have aimed to bring in a disaster risk perspective to promote

synergies with DRR in NAPs (UNDRR, 2019). Synergies have also been identified in the NDCs under the PA with more than 50 countries referring to DRM or DRR as part of their NDC (UNDRR, 2019).

Case Study 12: Sri Lanka| Integrated approach to CCA in the NAP

Integrated approach to CCA in the Sri Lankan NAP

In recent decades, the island country of Sri Lanka has been witnessing a number of ongoing transformations of its climate that could put its developing economy in peril. Warmer temperatures, rising sea levels and increasingly irregular patterns of precipitation are the phenomena that are most likely to affect agriculture, tourism, energy and other crucial sectors. Moreover, frequent episodes of extreme weather disasters pose a tangible threat to the life and livelihoods of many citizens.

To address these emerging issues, Sri Lanka adopted its NAP on Climate Change in 2016, joining the UNFCCC NAP process. The main objective of the plan is to increase the resilience of the country's economic sectors and natural ecosystems against emerging impacts of climate change. The priority for adaptation is assigned to a selection of sectors that are crucial for the country's economy and those that are particularly exposed to climate change. Cross-sectoral dimensions are also included in the document to address transversal adaptation needs.

The policy design idea at the base of the plan is one that understands adaptation as a process of adjustment of Sri Lanka's path of development to the emerging pressures of climate change. Thus, adaptation action is considered meaningful when it contributes to an SD. The result is an integrated approach to CCA, where priority areas of action in each sector and practical measures are selected based on their potential to support multiple policy agendas. A number of SDGs in areas that are relevant to climate change are actively pursued, with the identification of policy targets and practical adaptation measures. Integration and synergies are also pursued in relation to past national policies and plans on climate change and global climate commitments. In early 2021, Colombia published its updated NDC under the UNFCCC for the period of 2020-2030 and used an integrated approach aimed at synergies between the 2030 Agenda, the PA and the Sendai Framework. It describes actions to mainstream climate change considerations into national and local development plans. The NDC identifies water resources, protection of terrestrial and coastal marine ecosystems, restoration of protected areas, infrastructure and agriculture as target areas for adaptation actions. The adaptation priorities are aligned with areas of risk and vulnerability identified as priorities for the country, to be congruent with the SDGs and the Sendai Framework. The NDC builds on key policies such as the country's 2010-2014 National Development Plan, which established a National Climate Change System to improve coordination among the institutions.

Sources: Ministry of Mahaweli Development and Environment Sri Lanka (2016), UNFCCC (2017).

As the NAP process is iterative and explicitly aims to integrate CCA in development processes across sectors and levels, it provides important opportunities to advance sustainable adaptation and development, thereby contributing to objectives under multiple agendas (Dazé et al., 2019). Furthermore, high-income countries have approved national and subnational CCA strategies and plans, which can also be instruments to support integration between policy processes.

Regardless of the scale defined, interactions across scales need to be carefully evaluated to reduce the risk of negative feedback loops that hinder reaching the SAP objectives. Alignment

should be done in a flexible manner allowing for adjustments over time, if needed (Dazé et al., 2019). Context-specific issues need to be considered when defining the entry points for such an alignment (Dazé et al., 2019). These include taking stock of existing capacities and capacity development needs within involved institutions, financing needs as well as institutional arrangements and the role of relevant coordinating actors and stakeholders. Here, Step 4 is particularly relevant to make sure that the stakeholder arrangement is taken into account when planning the institutional integration. With regards to the underlying international post-2015 agendas, states have agreed to different elements in terms of reporting, funding and other mechanisms for their implementation. In addition, different streams of international financing can reinforce silos at national level due to different funding criteria and compliance requirements (UNDRR, 2019).

5.3.7 STEP 7 | Define a set of measures that enhance the SAP objectives

Once alternative SAPs have been carefully evaluated and entry points for the institutional integration defined, a set of measures that enhance the SAP objectives can be developed. Measures implemented within SAPs can take different forms. We follow the typology of the European Environment Agency (Leitner et al., 2020), which contains the following key types of adaptation measures:

- Governance and Institutional
- Economic and Finance
- Physical and Technological
- NbS and Ecosystem-based Approaches
- Knowledge and Behavioural Change

Examples of measures for each of these categories and how they relate to reaching the SDGs and Sendai Goals are shown in Table 7 (in Appendix B). SAPs usually contain more than one measure from more than one category. Governance and institutional measures such as a strategy to guide the implementation of efforts under different policy fields can, for example, provide an overarching framework under which technological or ecosystem-based measures can be integrated. In practice, this is often already done in NAPs, NDCs as well as national or regional DRR strategies and development plans. Measures should be selected by evaluating their contribution to reach the objectives defined in Step 3 and the underlying policy processes of CCA, DRR and SD. Particularly promising is the strong consideration of ecosystem-based measures (see case study 13 on Gambia). Such multi-benefit NbS can be implemented in NAPs and CCA components of NDCs, and numerous countries have already included CCA in NDCs (UNEP, 2021). Not all measures within each of these categories fulfil the criteria for sustainable adaptation introduced in this paper by default and might thus lead to maladaptation (Barnett & O'Neill, 2010)). However, this can only be assessed on a case-by-case basis. This also includes the assessment of negative interactions between potential measures while ensuring aspects such as non-discriminatory access to, and use of, land resources as well as equitable participation in decision-making processes (CDKN, 2021). Potential trade-offs at the level of objectives between individual SDGs and the goals of the PA have to be carefully considered (Brand et al., 2021). A simplified structure to assess potential synergies and trade-offs is provided in Table 5.

Case Study 13: Gambia| Developing a climate-resilient economy

Developing a climate-resilient, natural resource-based economy in Gambia

The government of Gambia, in collaboration with UNEP, launched its most comprehensive project for CCA, with the aim of developing a natural and ecosystem-based economy.

The program for adaptation, launched in 2017 by the government, is centered on EbA. This provides a cost-effective and low-risk approach to CCA that reduces adverse impacts of climate change while improving and safeguarding ecosystem services and nature. More than one hundred natural resource-based businesses have been established, thus stimulating economic activities and decent work opportunities for poor communities. The project strategy is to anchor adaptation culture by focusing on mainstreaming its principles and practices in four strategic sectoral policies: transhumance, migration, agriculture and energy. In these areas, adaptation actions are integrated into the respective annual plans with dedicated budget and monitoring systems. The implementation of the proposed ecosystem-based adaptation measures is facilitated by the government policy that promotes the decentralization of natural resource management to dedicated community-based committees.

Sources: UNEP (2016, 2019).

Financial instruments like green bonds or innovative funding concepts to provide co-benefits between CCA, mitigation and SD (see case study 14 on Ecuador) can attract financing for CCA action and the involvement of financing partners.

Case Study 14: Ecuador| The Socio Bosque Program

The Socio Bosque Program to protect forest ecosystems and decrease poverty through monetary incentives in Ecuador

The deforestation rate in Ecuador is one of the highest in South America, with territories covered by forests steadily decreasing since the 1990s due to the expansion of human activities such as agriculture, oil exploration, logging and mining. Deforestation and environmental degradation have severe effects on many ecosystem services and resources essential to the country's biodiversity and economy, and which are especially important for the livelihood of rural communities, which are often closely intertwined with forest ecosystems. The removal of forests and their ecosystem services – carbon storage, regulation of the water cycle, provision of habitat for biodiversity etc. – furthermore increases vulnerabilities of populations, ecosystems and institutions to climate change.

As a response, the government of Ecuador launched the Socio Bosque Program, a national conservation agreement scheme based on incentive-driven voluntary actions that aims to protect vast forest areas from deforestation. The environmental target of forest conservation is integrated with socioeconomic ones, specifically poverty alleviation, as the scheme was designed to support the poorest rural landowners and indigenous communities in the country.

Socio Bosque offers economic incentives to individuals or communities who own land property rights in native forest areas to guarantee the protection of the ecosystem and its services. The amount of monetary incentive received by individual landowners is calculated through a regressive formula that guarantees higher relative remuneration to smallholders. By restoring and maintaining fundamental services of the forest ecosystem, the program contributes to climate change mitigation thanks to the forests' function of carbon sequestration and storage, and

develops climate change adaptation and improved disaster risk management and resilience by containing run-offs, limiting flood risks and increasing infiltration and water storage.

The combination of environmental protection and poverty alleviation goals is the distinctive feature of the Socio Bosque program. This requires balancing efforts between environmental and economic efficiency as well as social equity, as trade-offs might arise in relation to issues such as access to the program and the inclusive distribution of incentives. One of the major barriers that has been identified within the program is the issue of land distribution. Direct involvement of the poorest is often undermined by informal or missing land rights, which are a precondition to project participation. The Government of Ecuador is committed to regularize land ownership and is currently planning an ambitious land titling program to improve the land tenure situation.

Socio-ecological research has mainly depicted Socio Bosque as a positive incentive program for forest conservation that complementarily supports other policy efforts of reforestation, control of illegal logging and sustainable forest management. The policy experiment provided by the Socio Bosque program holds great potential for replicability, as its main design features are not specific to the Ecuadorian context.

Sources: De Konig et al. (2011), Fehse (2012).

Table 5 Exemplary assessment of interactions across the post-2015 agendas between CCA, SD and DRR within an SAP[16]

SAP: Restoring tropical coastal ecosystems to enhance adaptive capacities to sea level rise and coastal storms and surges, ecosystem services provision and biodiversity						
SAP Objectives	**Potential positive interactions with CCA objectives as defined in relevant national/subnational strategies**	**Potential negative interactions with CCA objectives as defined in relevant national/subnational strategies**	**Potential positive interactions with SDGs**	**Potential negative interactions with SDGs**	**Potential positive interactions with Sendai Targets**	**Potential negative interactions with Sendai Targets**
Social, e.g. decreased vulnerability of populations to climate change impacts	- Enhancing adaptive capacity of local populations to sea level rise and coastal storms and surges	- Potential lock-in effects resulting from major land use change	- Make communities more resilient (SDG 11)		Targets: A, B, C, D	
Ecological, e.g. enhanced biodiversity and ecosystem services provision of tropical coastal ecosystems	- Strengthening of adaptive capacities of ecosystems - Enhanced provision of flood protection services by ecosystems		- Improved fish stocks, improved water quality (SDG 14) - Biodiversity conservation (SDG 14, 15) - Carbon sequestration and storage (SDG 13) - Sediment accretion (SDG 13)			

[16] The table describes a hypothetical example developed by the authors of this report to illustrate the assessment of interactions between the post-2015 agendas. Interactions depicted are based on the authors' own reasoning and are informed by the SAP concept.

SAP: Restoring tropical coastal ecosystems to enhance adaptive capacities to sea level rise and coastal storms and surges, ecosystem services provision and biodiversity						
Economic, e.g. increased sustainability of local ecosystem-based economic activities			- Tourism and recreation and associated employment (SDG 1, 8) - Livelihoods based on local fisheries (SDG 1, 2, 8)	- Potential negative short-term effects on employment (SDG 8) - Potential land use conflicts with other economic activities, e.g. harbors is limited (SDG 8)	Target: C	
Measures						
Mangrove protection and restoration	Decreased climate impacts from coastal storms	- Positive effects take time to unfold	- Improved fish stocks (SDG 1, 2, 14) - Biodiversity conservation (SDG 14, 15) - Carbon sequestration and storage (SDG 13) - Sediment accretion (SDG 13) - Make communities more resilient (SDG 11)		Targets A, B, C, D	
Capacity building of local tourism boards	Increased adaptive capacities for climate impacts		- Tourism and recreation and associated employment (SDG 1, 8) - Make communities more resilient (SDG 11)	- Negative interactions of unsustainable tourism activities (SDG 13, 14) - Potential for increase of inequalities if local context is not adequately considered (SDG 10)		

5.3.8 STEP 8 | Implement the SAP

Implementation can be guided by a dedicated strategy and/or an action plan (Climate-ADAPT, 2019). The adaptation strategy and action plan should be developed in an inclusive process and should define roles and responsibilities, timelines and resources to implement the selected CCA measures, and, with this, reach the objectives of the SAP. Mainstreaming CCA into current planning processes and existing budgets is also a possible option.

Case Study 15: Ghana| Approaches to increased coherence between CCA and DRR

Institutional approaches to increased coherence between CCA and DRR in Ghana

Due to the expected severe impacts of climate change on Ghana, the country has focused on coherent CCA and DRR in addition to its mitigation efforts.

Ghana has a decentralized governance system. At the national level, different ministries are responsible for the policy development of CCA. The Ministry of Environment, Science, Technology and Innovation and the Environmental Protection Agency (EPA), as well as the National Development Planning Commission, are mainly responsible for integrating CCA, and to some extent DRR, into the country's development agenda. The National Disaster Management Organisation (NADMO), which operates under the Ministry of Interior, is responsible for the management of disaster risks and similar emergencies, as well as for rehabilitation after disasters. The responsibility for implementing CCA and DRR lies with local authorities.

In order to react to these challenges, Ghana has made institutional arrangements to enhance policy coherence between CCA and DRR. An examples is the close coordination between EPA and NADMO. The coordination between EPA and NADMO led to the Ghana Plan of Action on DRR and CCA and Ghana's National Climate Change policy. The latter is the main policy document with regard to climate change in Ghana and includes program areas that are explicitly linked to disaster risk management. One of the NAP's key elements is the development of integrated priority policy responses including EWSs.

Sources: OECD (2020).

Some measures might also require setting up new projects that involve different types of actors and new sources of funding. National strategies or NAPs, for example, require breaking them down into concrete action plans at the subnational level (see case study 16 on Denmark). When implementing measures that are not directly linked to CCA or DRR, such as social protection measures, linking them with innovative financial instruments can ensure alignment (see case study 6 on Haiti).

Case Study 16: Denmark| Supporting adaptation planning and action at municipal level

Strengthen governance by supporting adaptation planning and action at municipal level through knowledge and consultancy in Denmark

In 2012, Denmark adopted an NAP to ensure the country's resilience towards climate change in the future. Since then, accompanying measures have been implemented across different scales to put a place-based approach to adaptation into practice. In light of the uncertainties and geographically different climate change impacts expected, the Danish NAP understands CCA to be a locally-based and iterative effort. Local authorities, companies and other stakeholders are perceived as being the most familiar with local conditions and as best-equipped to make decisions

on adaptation. At the same time, strategic responsibilities for adaptation are also allocated at the national level to provide a sound legal and regulatory framework for local initiatives, as well as support through coordination and information sharing. Thus, the NAP required municipalities to create their own strategies for CCA following guidelines provided by the government.

In this context, the Ministry of Environment has established a task force to ensure the availability of updated knowledge and data to municipal governments and other local stakeholders involved in adaptation efforts. In order to facilitate these functions, a web-based platform (Klimatilpasning.dk) was created. The portal provides the most recent information from research and development in the area of CCA worldwide, with the inclusion of databases for case studies and instruments. Within the national task force on CCA, a mobile unit was established soon after the adaptation of the NAP. The mobile unit provides direct support to municipalities in the implementation of their plans. The team can be summoned free of charge and provides guidance, facilitates the involvement of stakeholders and organizes workshops and meetings with various actors.

While adaptation measures are to be identified mainly at a local/regional level - as climate change risks and vulnerabilities are often determined by local circumstances - the national level promotes initiatives, develops common guidelines and a framework for collaboration, in order to avoid gaps and a piece-meal type of adaptation. The NAP stresses the importance of knowledge sharing and the empowerment of local institutions as crucial areas where the central government can provide functional frameworks for multilevel coordination.

Sources: EEA (2014), Government of Denmark (2012).

A precondition for the implementation of measures is the access to sufficient funding with financial limitations frequently mentioned as a barrier to initiating and implementing CCA actions on the local level (Climate-ADAPT, 2019). The type of funding suitable for certain measures can vary and funding decisions should be made while taking the institutional context into account, in particular with regard to existing budgets of government authorities and/or the involvement of non-state actors and international donors. While a number of relevant mechanisms, such as the Adaptation Fund, Green Climate Fund or the Global Environment Facility have committed to provide funding for holistic actions in line with achieving the SDGs, practical coordination for international reporting is in the early stages. Thus, states need to be aware of distinct reporting requirements and funding streams for CCA and DRR. An “SDG-proofing” mechanism can ensure alignment and avoid contradictions that undermine the contributions to each of the agendas as well as negative interactions between the SDGs.

5.3.9 STEP 9 | Monitoring & Evaluation

The M&E framework aims to assess whether the objectives defined are being achieved. Clear and specific objectives made measurable through indicators are thus crucial for meaningful M&E. Setting up an M&E framework requires robust indicators, knowledge management and active and sustained engagement of stakeholders (Climate-ADAPT, 2019). Involvement of concerned stakeholders early on in the process will ensure continuous monitoring of the CCA activities throughout the implementation phase.

If SAPs have been integrated in NAPs, an indicator-based vulnerability M&E framework that assesses implementation progress of the pathways can supplement the M&E of the NAP process. Measuring progress of indicators evaluated in the baseline assessment conducted in Step 2 can provide information on the extent to which the SAPs contribute to specific aspects of each policy agenda, as well as to the alignment of DRR, SD and CCA embodied in the SAP concept.

5.3.10 STEP 10 | Readjust the process

SAPs should be developed in an open and iterative way to allow readjusting measures and objectives defined throughout the implementation process. The M&E of the SAP process and results should lead to an assessment and, if necessary, an adjustment of the selected set of measures and implementation of these measures in order to reach the defined SAP objectives. Furthermore, the defined objectives can be critically discussed and might need to be adjusted to ensure effective implementation. Also, a re-definition of objectives according to new political foci or new available knowledge can be suitable. Additionally, other steps within the SAP implementation process should be revisited if envisioned objectives are challenging to reach, e.g. are the relevant stakeholder actors and groups included in the SAPs? Are the relevant scales covered? Is the potential for institutional integration between CCA, DRR and SD used?

This stepwise approach to structure the implementation of SAPs highlights the processual understanding of SAPs. SAPs are developed in an iterative way, taking feedback loops and uncertainty into account. Sound M&E enables potential for readjustments over time.

6 Conclusion

The objective of this paper is to introduce and discuss the concept of “Sustainable Adaptation Pathways" (SAPs), which is based on the academic pathway literature and the synergetic implementation of the three post-2015 agendas: the 2030 Agenda, the PA and the Sendai Framework. The 2030 Agenda aims at various overarching goals of SD while the Sendai Framework and the PA tackle specific objectives related to DRR and CCA respectively. Despite these differences, there is a clear overlap of thematic foci. The concepts of “adapt forward” in CCA and “build back better” in DRR, respectively, already indicate their relevance for SD. “Adapt forward” embraces the transformative potential of CCA for structural changes. “Build back better”, introduced in the Sendai Framework, establishes the integration of DRR into development measures as a priority to make nations and communities resilient to disasters. Potential for interlinkages between the agendas exists both at the level of objectives and at the level of operational and policy instruments (e.g. NAPs or development plans). A number of SDGs and their targets link to CCA and DRR, e.g. SDG 1, SDG 2, etc. A challenge, however, remains to put integrative approaches into practice.

In particular, the complexity of each of the three agendas challenges full integration. At the same time, fully integrating all agendas would risk losing the individual relevance of each three of them. Connected to this are differences between DRR and its operational character on the one hand, and CCA and SD with a predominant long-term approach on the other hand. The current trend in DRR policy and research to move away from the idea of DRR as purely operational and ad-hoc is a precondition for effective integration.

A number of pathway approaches linking CCA, DRR and SD, albeit to different degrees, have been already developed. The reference to ‘pathways’ is, however, used and defined in diverse ways. While some approaches explicitly conceptualize pathways, others do not use the term but still contribute to advancing research on intersectoral interlinkages, ecosystem-based contributions and poverty-vulnerability linkages. Based on the literature, a number of enabling factors for interlinking CCA, DRR and SD can be identified, e.g. the involvement of different types of stakeholders, the focus on vulnerable groups and communities, linking national and sub-national planning activities and enabling cross-sectoral coordination. Dynamic elements identified in these existing approaches were clustered and integrated in the concept of Sustainable Adaptation Pathways (SAPs). We define SAPs as a coherent set of alternative adaptation strategies and procedures composed of measures and policies to strengthen the capacities of populations, institutions and ecosystems to adapt to climate-related risks over time while enhancing the social justice, environmental integrity and economic sustainability of socio-ecological systems. SAPs are explicitly context-specific and interlinked with a dynamic set of institutional, socio-political and cultural as well as financial elements, which both enable and characterize SAPs. The development of SAPs is conceptualized as a result of complex and context-specific interactions and feedback loops. Deep uncertainties regarding aspects such as climate impacts or the effectiveness of CCA measures lead to an understanding of SAPs as iterative processes, which are in need of regular re-adjustments.

Dynamic elements are identified as important characteristics of SAPs, but certain elements are dominant in practice while some others might be present only to a weaker extent, not observable or entirely absent based on the specific socio-ecological context. Institutional elements include the coordination across scales and levels, flexible and adjustable governance structures, the consideration of multi-benefit approaches such as ecosystem-based approaches to enable no-regret measures with multiple benefits for diverse socio-ecological challenges. Funding streams should take an integrative view and prioritize projects targeting multiple socio-

ecological challenges. Important socio-political and cultural elements are e.g. consideration of local context, integration of social learning processes, political leadership embracing sustainable adaptation and the consideration of path dependencies and lock-ins, among others. The third group - financial elements - includes aspects such as provision of funding by governments or internal donors and the involvement of private sectors. A stronger alignment of different sources of funding, such as public and private funding, can also foster cross-sectoral benefits.

We propose an integration of incremental and transformative CCA within the concept of SAPs. A fluent transition and mutual dependency can be recognized between the two types. Incremental activities can create preconditions of transformative CCA. Strengthening both incremental and transformative activities can be thus needed to tackle current climate impacts.

The presented case studies provide good practice examples illustrating specific aspects of the SAP concept. They demonstrate possibilities for implementing SAPs, the relevance of particular dynamic elements, as well as challenges and lock-ins that complicate this process. The long versions of the case study descriptions can be found in a separate appendix document (Bueb et al., 2021).

Based on the case studies, a sequence of 10 steps has been suggested to provide guidance when implementing SAPs. The sequence of steps provides a clear but flexible structure adjustable to the respective context and unforeseen changes and feedback loops. These steps cover (1) the assessment of the socio-ecological context and a screening of dynamic elements present in this context. Furthermore, (2) institutional framework and climate vulnerabilities should be assessed to build the basis for (3) identifying objectives of the SAP and (4) relevant actors, scales and sectors to be focused on. An important step is (5) to ensure openness to potential alternative pathways to reach the objectives. It is further relevant (6) to screen and define potential entry points for institutional integration of the SAP, e.g. via national adaptation frameworks, NAPs, national and subnational development plans, disaster risk reduction strategies, as well as territorial planning instruments. Once entry points have been defined, (7) measures to enhance SAP objectives should be selected. Local or national adaptation action plans or strategies can help to define roles, responsibilities, timeline and resources for the (8) implementation of the SAP. Any SAP should contain a (9) M&E framework, including a set of robust indicators. In light of the iterative character of the SAP, (10) regular readjustments should be considered. Updated available knowledge and outcomes of learning processes can be incorporated, followed by an adjustment of measures or even SAP objectives. Enhanced data sharing between key actors can enable holistic vulnerability assessments, help to identify potential for stronger alignment and increase efficiency within relevant institutions.

A participatory approach to pathway design and implementation open to diverse forms of knowledge, as well as to different narratives of sustainable adaptation, can increase the buy-in of stakeholders from early on. It can also enhance the effectiveness of measures planned, address gender inequalities and ensure the consideration of vulnerable groups. An inclusive approach that considers vulnerabilities of different groups in a differentiated way is also key to putting the central narrative of the SDGs, “Leave no one behind”, into practice. Importantly, political leadership and stakeholder involvement should not be seen as opposing, but as mutually-reinforcing elements, both crucial for effective SAPs. However, in practice, participatory approaches often tend to reproduce the status quo rather than changing it (Blühdorn, 2018; Oels, 2019) and if designed without taking underlying power relations into account the processes can be challenged by low acceptance (Oels, 2019). This calls for bottom-up formats to co-produce SAPs which are sensitive to local settings as well as power constellations and build on existing fora of participation. Most importantly, there is no blueprint for involving local stakeholders in the development and implementation of SAPs.

A number of open questions and potential future research topics remain which were out of scope for this study and are described in the following.

Implementation in practice: A number of interesting implementation examples exist at the local, regional and national level, but practical implementation of synergetic activities still seems limited. We developed a framework which can support enhancing harmonized implementation of agendas. The application of the stepwise approach needs to be tested in practice and the concept could be supported with development of specific tools. An "SDG-proofing" methodology, adjustable to the specific socio-ecological context, could be based on the conceptual groundwork on SAPs done in this paper and help to explore potential co-benefits across sectors. Key for the uptake of such tools is, again, a participatory development process that takes the needs of relevant actors regarding their design and functionality into account. Further challenges remain to operationalize SAPs and dynamic elements for different sectors or local decision-making contexts, taking into account the socio-ecological context. Another relevant field for future research is how to build on current activities and projects, intensifying the discussion of suitable entry points. In addition, systematic cross-case comparisons can provide more in-depth insights on the applicability of the SAP concept in practice.

Integration of ecosystem-based approaches: The multi-benefit approaches of NbS show a high potential for sustainable adaptation, but how can ecosystem-based approaches be further integrated and operationalized in sustainable adaptation discussions? The analysis of interlinkages with and entry points to biodiversity policies remains an open field for future research.

Interlinking to recovery activities: In the light of the current pandemic situation, a strengthening of "Building back better" and "Adapt forward" principles needs to be analyzed. An assessment of potential contributions of SAPs to mid- and long-term recovery can provide insights about this debate.

7 Glossary of key technical terms

Adaptive capacity describes the ability of social and natural systems to respond to the impacts of climate change (Glover & Granberg, 2020; IPCC, 2014).

Climate Change Adaptation (CCA), according to the IPCC, is the process of adjustment to actual or expected climate change and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects (IPCC, 2014).

Climate vulnerability is a wide-ranging term usually describing the extent or degree to which an (ecological or social) system is susceptible to climate change impacts. Vulnerability is influenced by a combination of the system characteristics and the impact characteristics (Glover & Granberg, 2020; IPCC, 2014).

Disaster risk reduction (DRR) is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of SD. According to this definition, DRR is the policy objective of disaster risk management, and its goals and objectives are defined in DRR strategies and plans (UNDRR, 2021a).

Incremental adaptation is understood in this report, in line with the IPCC, as adaptation that maintains the essence and integrity of a system or process at a given scale. The IPCC refers to the definition of Park et al. (2012) (IPCC, 2018b)

Institutions are the norms, rules and routines that define, shape and constrain behavior and action in a specific setting (March & Olsen, 1989).

Learning according to Pahl-Wostl (2009):

> **Single-loop learning** refers to a refinement of actions to improve performance without changing guiding assumptions and calling into question established routines. Incremental changes in established practice and action aim at improving the achievement of goals. This kind of learning might also include a first improvement of the capacity to make and implement collective decisions.
>
> **Double-loop learning** refers to a change in the frame of reference and the calling into question of guiding assumptions. 'Reframing' implies a reflection on goals and problems (for example by resetting priorities, including new aspects and changing boundaries of system analysis) and assumptions on how goals and solutions can be achieved. Such reframing occurs within structural constraints. Therefore, social learning processes are an essential part of double-loop learning, which might lead to changes in the actor network characterizing the governance system. Improvement is achieved by experimenting with innovative approaches and new kinds of measures.
>
> **Triple-loop learning** refers to a transformation of the structural context and factors that determine the frame of reference. This kind of societal learning refers to transitions of the whole regime (e.g. change in regulatory frameworks, practices in risk management, dominant value structure). Transforming requires recognition that paradigms and structural constraints impede an effective reframing of resource governance and management practices. Learning processes involve actors that go far beyond the established governance system. Transformation implies a change in paradigm and, in the end, of underlying norms and values. The structural change will

lead to a transition of actor networks where new actors come into play, boundaries and power structures are changed and new regulatory frameworks are introduced.

Resilience: the 'ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.' (UNDRR, 2021a)**.** Resilient outcomes feature 'social systems' with 'functional persistence', 'self-organization' and 'social learning' (Pelling, 2011).

Sustainable development (SD) has been defined in many ways, but the Brundtland Report provides a frequently used definition that is also in line with the understanding of the term in the 2030 Agenda: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."(WCED, 1987). At the core of the 2030 Agenda and its SDGs is a three-dimensional concept of SD (social, economic, and environmental sustainability). Measures and strategies aimed towards SD always require a consideration of "the dynamic interactions between social, technological and ecological processes" (Leach et al., 2010).

Sustainable adaptation refers to measures or strategies to strengthen the capacities of populations, institutions and ecosystems to adapt to climate-related risks over time, which at the same time enhance the social justice, environmental integrity and economic sustainability of socio-ecological systems.

Sustainable Adaptation Pathways describe a coherent set of alternative adaptation strategies and procedures composed of measures and policies to strengthen the capacities of local populations, institutions and ecosystems to adapt to climate-related risks over time while enhancing the social justice, environmental integrity and economic sustainability of socio-ecological systems.

Transformative adaptation is understood in this report as defined by the IPCC. It refers to adaptation that changes the fundamental attributes of a socio-ecological system in anticipation of climate change and its impacts (IPCC, 2018a). Transformative adaptation addresses root causes of vulnerability and leads to fundamental systems' changes (Fedele et al., 2019).

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A Appendix

Table 6 DRR and CCA in SDG targets and indicators

SDG Goals	SDG targets and indicators related to DRR	SDG targets and indicators related to adaptation
Goal 1: End poverty in all its forms everywhere	Target 1.5: By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extremes and other economic, social and environmental shocks and disasters	
	Indicator 1.5.1: Number of deaths, missing persons and persons affected by disaster per 100,000 population (this matches indicator A1 and B1 of the Sendai Framework indicators)	
	Indicator 1.5.2: Direct disaster economic loss in relation to global gross domestic product (GDP) (this matches indicator C1 of the Sendai Framework indicators)	
	Indicator 1.5.3: Number of countries with national and local DRR strategies in line with the Sendai Framework (this matches indicator E1 of the Sendai Framework indicators)	
	Indicator 1.5.4: Proportion of local governments that adopt and implement local DRR strategies in line with national DRR strategies (this matches indicator E2 of the Sendai Framework indicators)	
Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Target 2.4: By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that held maintain ecosystems, that strengthen capacity for CCA, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.	
	Indicator 2.4.1: Proportion of agricultural area under productive and sustainable agriculture	
Goal 3: Ensure healthy lives and promote well-being for all at all ages	Target 3.d: Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks.	
Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	Target 4.7: By 2030, ensure that all learners acquire the knowledge and skills needed to promote SD including, among others, through education for SD and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and nonviolence, global citizenship and appreciation of cultural diversity and of culture's contribution to SD.	

	Target 4.a: Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, non-violent, inclusive and effective learning environments for all.	
Goal 6: Ensure availability and sustainable management of water and sanitation for all.	Target 6.4: By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.	
	Target 6.5: By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.	
	Target 6.6: By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.	
Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	Target 9.1: Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with focus on affordable and equitable access for all.	
	Target 9.a: Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island development states.	
Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable	Target 11.1.: By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums	
	Target 11.3.: By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries	
	Target 11.5.: By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations	
	Indicator 11.5.1: Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population (this matches indicator A1 and B1 of the Sendai Framework indicators)	

	Indicator 11.5.2: Direct economic loss in relation to global GDP, damage to critical infrastructure and number of disruptions to basic services, attributed to disasters (this matches indicator C1, D1 and D5 of the Sendai Framework indicators)	
	Target 11.b.: By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and CCA, resilience to disasters, and develop and implement, in line with the Sendai Framework, holistic disaster risk management at all levels	
	Indicator 11.b.1: Number of countries that adopt and implement national DRR strategies in line with the Sendai Framework (this matches indicator E1 of the Sendai Framework indicators)	
	Indicator 11.b.2: Proportion of local governments that adopt and implement local DRR strategies in line with national DRR strategies (this matches indicator E2 of the Sendai Framework indicators)	
	Target 11.c.: Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials	
Goal 13: Take urgent action to combat climate change and its impacts	Target 13.1.: Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	
	Indicator 13.1.1: Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population (this matches indicator A1 and B1 of the Sendai Framework indicators)	
	Indicator 13.1.2: Number of countries that adopt and implement national DRR strategies in line with the Sendai Framework (this matches indicator E1 of the Sendai Framework indicators)	
	Indicator 13.1.3: Proportion of local governments that adopt and implement local DRR strategies in line with national DRR strategies (this matches indicator E2 of the Sendai Framework indicators)	
	Target 13.2.: Integrate climate change measures into national policies, strategies and planning	

		Indicator 13.2.1: Number of countries with NDCs, long-term strategies, NAPs and adaptation communications, as reported to the secretariat of the UNFCCC
	Target 13.3.: Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	
	Indicator 13.3.1: Extent to which (i) global citizenship education and (ii) education for SD are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment	
		Target 13.a: Implement the commitment undertaken by developed-country parties to the UNFCCC to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible
	Target 13.b Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities	
		Indicator 13.b.1 Number of least developed countries and small island developing States with NDCs, long-term strategies, NAPs and adaptation communications, as reported to the secretariat of the UNFCCC
Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	Target 15.1: By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements	
	Target 15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally	
	Target 15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	

	Target 15.4: By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for SD

Source: Author's own elaboration, data source: Inter-Agency and Expert Group on SDG Indicators (2016).

B Appendix

Table 7 Examples for potential synergies between CCA, DRR measures and SDG targets

Examples of adaptation and DRR measures	Description	Hazards based on Buth et al. (2015)	Potential synergies with SDGs	Sources
Economic and financial instruments				
Insurance against natural disasters	Insurance schemes are the most common instrument for risk sharing and transfer. By transferring risks from individuals and companies to an insurer, financial damages do not turn into long-term economic damages if critical damages can be compensated for. Insurance against natural disasters can cover domestic, business or agricultural properties.	Multi-Hazard	Transfer of individual risks (SDG 1, 17) Resilient cities and human settlements (SDG 11)	Bräuninger et al. (2011)
Natural disaster microinsurance	Natural disaster microinsurance consist in the protection of low-income households against specific perils in exchange for regular monetary payments (premiums) proportionate to the likelihood and cost of the risk involved. Schemes of microinsurance typically cover damages to crops and livestock due to floods, droughts, hurricanes, wildfires etc. in exchange of modest regular monetary payments.	Multi-Hazard	Improved financial security of low income population (SDG 1, 3) Transfer of individual risks to the community or inter-community level (SDG 11, 17) Reduce inequalities within and between countries (SDG 10)	ISDR (2007)
Direct payments, grants and other subsidies for CCA	Subsidies, direct payments or grants to adapt individual decisions to collective goals. As such, these policy instruments can be used to mobilize investment that would otherwise be unattractive to the recipient, e.g. climate-adapted infrastructures (without generating revenues), or high levels of compliance with existing land use or resource management laws and regulations.	Multi-Hazard	Indirectly affects SDGs through other measures and depending on the nature of the financial support provided	UNISDR (2015)

Habitat Banking	Habitat banking consists in markets where actions with beneficial outcomes to the ecosystem and biodiversity attribute credits to those who carried them out to offset debits that occur when ecosystems are being compromised. Habitat banking adheres to the polluter pays principles and it is usually referred as a no-net-loss policy, as the goal is to maintain a certain threshold for ecosystem services or biodiversity	Multi-Hazard	Increased resilience of ecosystems (SDG 6, 14, 15) Provision of ecosystem services (SDG 2, 11, 13)	Bräuninger et al. (2011)
Payments for ecosystem services	Payments for ecosystem services are transactions where a properly defined environmental service is being bought in order to secure the provision of the service. The payment received by the ecosystem managers essentially adds up to the benefits of conservation in order to avoid a conversion of the ecosystem which would be otherwise more cost effective.	Multi-Hazard	Provision of ecosystem services (SDG 2, 11, 13)	Bräuninger et al. (2011)
Governance and institutional				
NAP	NAPs are processes of strategic planning to identify medium- and long-term priorities of a country for the CCA. The plan can include identifiable national/subnational vulnerabilities and design measures to minimize them. The plans can be designed to make adaptation an integral component of a country's plan for social and economic development	Multi-Hazard	Employment in rural areas (SDG 1, 8) Promotion of sustainable agriculture (SDG 2, 8, 11, 12) Support of services such as soil production and stabilization of water supplies (SDG 2) Climate action (SDG 11, 13) Biodiversity conservation (SDG 14, 15)	UNFCCC (2017b)
Sectoral resilient planning	The concept of resilience can be put at the core of sectoral planning in order to implement solutions that contribute, at the same time, to long-term economic and SD, DRR and CCA.	Multi-Hazard	Develop quality, reliable, sustainable and resilient infrastructure (SDG 9) Employments and well-being (SDG 3, 8) Water and land use management (SDG 14, 15) Make communities more resilient (SDG 11)	UNFCCC (2017b)

Early Warning System	Early Warning systems are crucial scientific-technical instruments for DRR and CCA as they forecast climate hazards and issue alerts. Moreover, they provide accessible and scientifically credible knowledge from a constant monitoring activity.	Multi-Hazard	Make communities more resilient (SDG 11)	IPCC (2018b)
Adaptation & DRR council of representatives of civil society	Participation brings a solid foundation for building resilience and preparedness to disasters. Civil involvement in DRR and adaptation policy making reduce the probability of economic and social inequalities within processes of reconstruction and recovery.	Multi-Hazard	Reduction of inequality (SDG 1, 10) Fair distribution of access to basic services (SDG 3, 4, 6, 11)	UN-Habitat (2015)
Social safety net for DRR	The development of social safety nets linked with livelihood enhancement programs towards the resilience of individuals and communities to natural disasters is an essential measure to prevent disaster events from pushing more people into poverty and to facilitate a swift recovery.	Multi-Hazard	Reduction of Poverty and inequalities (SDG 1, 10) Improve institutional capacity on CCA, impact reduction and early warning (SDG 13)	UNISDR (2015b)
Vulnerability and risk assessment / mapping	Identifying and evaluating risks is the first step towards their reduction. Comprehensive frameworks for risk assessment not only indicate the extent and likelihood of potential impacts but also provide information about the causes of those impacts, as well as their further implications. Once developed, risk assessment provides a solid foundation for policy making in the area of DRR, adaptation and development.	Multi-Hazard	Reduce poverty (SDG 1) Reduce inequalities (SDG 10) Make communities more resilient (SDG 11) Climate action (SDG 13)	UNDP (2020)
Scenario planning in adaptive development decision making processes	Workshops for scenario planning for adaptation pathways are a novel participatory approach that creates opportunity for stakeholder engagement and the coordination between top-down policy making and grassroots initiatives. This approach facilitates the tailoring of centralized policies of adaptation to local livelihood needs, avoiding or readdressing potentially mal-adaptive development outcomes.	Multi-Hazard	Reduce poverty (SDG 1) Reduce inequalities (SDG 10) Make communities more resilient (SDG 11)	Butler et al. (2016)

Knowledge and Behavioral Change				
Capacity building on CCA	Within the scope of CCA, capacity building typically targets organizations operating in specific regions to build resilience to relevant climate threats and with a sectoral focus, but it can also take the shape of a multi-sector and multi-threat perspective program. Programs for capacity building include activities such as training, specific coaching, technical assistance, workshops, sharing platforms and other networking events.	Air temperature; Heatwaves	Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters (SDG 13) Improve education and awareness-raising on CCA (SDG 4, 13)	ECBI (2018)
Disaster risk & Adaptation education	Promoting disaster risk and adaptation knowledge for all levels of education, including professional education and training, have the potential of triggering behavioral change in how to react to disaster events and climate impacts. It is a crucial strategy to reduce vulnerabilities and consolidate resilience to disaster risk. Awareness campaigns, social media and mobilization are also effective means to promote awareness in risk reduction. Videogames can be a stimulating mean for awareness-raising campaigns.	Multi-Hazard	Enhance CCA and DRR knowledge and awareness (SDG 4, 13)	UNISDR (2015)
Mobilizing campaigns for disaster prevention	The participation of civil society, local communities, indigenous peoples and migrants in disaster risk management is an effective way to strengthen public awareness and education, promote a culture of disaster prevention, resilience and responsible citizenship. These campaigns can empower local governments´ efforts as they can work and coordinate more efficiently with a civil society that understand disaster risks and the value of resilience.	Multi-Hazard	Strengthen education on disaster prevention (SDG 4) Resilient urban development (SDG 11) Reduce inequality within and among countries (SDG 10) Enhance CCA and DRR knowledge and awareness (SDG 4, 13)	UNISDR (2015)
Information sharing	Platforms for the collection and exchange of information and experiences aim to develop a common knowledge base to support governments and organizations in the implementation of CCA strategies and actions.	Multi-Hazard	Contribution to intergovernmental coordination (SDG 17) Enhance CCA and DRR knowledge and awareness (SDG 13)	EEA (2018)

Promotion of ecologically sustainable businesses	The promotion of sustainable practices and business models reduces the impact of human activities on the environment and the ecosystem's biodiversity. It enhances the resilience of local communities and businesses to climate change. At the same time, ecologically sustainable businesses can attract investments and make use of previously untapped ecosystem services.	Multi-Hazard	Stimulate economic activity (SDG 1, 8) Diversify food and income sources (SDG 1, 2, 12) Foster sustainable communities (SDG 11, 13)	UNEP (2021)
NbS and EbA				
Ecosystem-based coastal protection	Enhanced and restored coastal ecosystems can improve resilience towards the rise of sea levels, coastal storms and surges. Moreover, they are habitats to a variety of animal and plant species. Measures include, e.g. mangrove, coral reef, seagrass protection and restoration as well restoration of coastal marshes and dunes.	Sea Level Rise;(Coastal) Storm surge	Improved fish stocks (SDG 1, 2, 14) Biodiversity conservation (SDG 14, 15) Carbon sequestration and storage (SDG 13) Sediment accretion (SDG 13) Tourism and recreation and associated Employment (SDG 1, 8) Resilient Infrastructures (SDG 9)	UNEP (2021)
Urban green spaces	The management, creation and extension of green spaces within urban environments contributes to the resilience and sustainability of cities and local communities. Parks, urban forests, open countryside and gardens lower maximum surface temperatures and reduce surface runoffs, thus helping local communities to deal with both increasing temperatures and increasing precipitations.	Air temperature; Precipitation, Heatwaves; Drought	Reduction of surface runoffs, recharge of groundwater (SDG 6, 11) Reduction of demand for air conditioning in buildings (SDG 13) Increased biodiversity (SDG 14, 15) Reduction of air pollution (SDG 3)	Gill et al. (2007)
Green Roofs	Green roofs are roofs that are partially or entirely covered by vegetation. Adding green roofs to the buildings of a city can have an effect on surface temperatures, especially areas with high-density of population and heat-island effects. Green roofs also limit run-offs and sustain biodiversity in the urban environment.	Air temperature; Precipitation; Heatwaves	Reduction of surface runoffs (SDG 6, 11) Reduction of demand for air conditioning in buildings (SDG 13) Increased biodiversity (SDG 15) Reduction of air pollution (SDG 3)	Gill et al. (2007)

Management and restoration of watershed vegetation	The management of watershed vegetation can improve infiltration, reduce run-offs, peak flows and stabilize slopes. The management of water retention by watershed vegetation should be closely evaluated on a case-by-case basis according to local ecological and hydrological conditions.	Precipitation; Flash floods; River floods	Increased availability of wild-sourced food and other products (SDG 2) Carbon sequestration and storage (SDG 13) Improved soil fertility (SDG 2) Biodiversity conservation (SDG 14, 15) Improved water quality (SDG 6) Strengthen resilience and adaptive capacity to climate-related hazards (SDG 13)	UNEP (2021)
Urban watercourse restoration and "re-naturing"	Historically, rivers have been modified to serve one dominant function (navigation, industrial production etc.). Today, a great variety of measures are taken to restore the natural functions. Restoration not only produces benefits for the ecological functioning and the conservation of the ecosystem, but also contributes to flood risk reduction, water quality improvement, groundwater recharge and the opportunity of recreational activities for local communities.	Precipitation; Flash floods; River floods; Drought	Carbon sequestration and storage (SDG 13) Improved soil fertility (SDG 2) Biodiversity conservation (SDG 14, 15) Improved water quality (SDG 6) Improved physical and mental health among urban populations (SDG 11) Tourism and recreation (SDG 1, 8)	UNEP (2021)
Agroecology	Agroecology is a scientific discipline that applies ecological principles to agricultural production systems in a synergetic way, towards the implementation of socially and environmentally sustainable systems for food production. Agroecology can offer an important vehicle to reduce poverty, hunger and inequality by contributing to decent work in rural areas.	Air temperature; Precipitation; Heatwaves; Flash floods; Drought	Reduction of Poverty (SDG 1) Extend access to food (SDG 2) Reduction of inequality (SDG 10) Opportunities for decent work (SDG 8) Promotion of sustainable agriculture (SDG 2, 8, 11, 12) Strengthen resilience and adaptive capacity to climate-related hazards (SDG 13) Biodiversity conservation (SDG 14, 15)	Amiri-Talesh et al. (2018)

Agroforestry	Agroforestry is a land use management system in which trees are planted next to farmed crops. This farming diversification enhances canopy cover and provide shade, thus increasing the resilience of agricultural production against climate change and rising temperatures in particular. Furthermore, agroforestry increases the efficiency of farming, diversify production (trees can provide fruits and other products), biodiversity.	Air temperature; Precipitation; Heatwaves; Flash floods; Drought	Decrease poverty (SDG 1) Carbon sequestration and storage (SDG 13) Strengthen resilience and adaptive capacity to climate-related hazards (SDG 13) Improved soil fertility (SDG 2) Diversify agricultural production (SDG 2) Biodiversity conservation (SDG 14, 15) Improve crop production (SDG 12)	UNEP (2021)
Establishment of protected areas	A protected area is a precisely defined geographical space which is safeguarded and managed to achieve the long-term conservation of its environmental features, its ecosystem services and biodiversity. Protected areas are an important support for local people's livelihood and play an important role in mitigating the effects of climate change.	Multi-Hazard	Increased tourism (SDG 1) Employment in rural areas (SDG 1, 8) Promotion of sustinable agriculture (SDG 2, 8, 11, 12) Support of services such as soil production and stabilisation of water supplies (SDG 2) Opportunity for education on basics of ecosystem functioning (SDG 4) Climate change buffers (SDG 11, 13) Biodiversity conservation (SDG 14, 15)	Dudley et al. (2017)
Physical and Technological				
Wastewater reuse	Wastewater reuse is an important option for water supply that refers to the process of readdressing used water for further uses. Domestic and industrial-grade waste water can be treated to eliminate pollutants and contaminants in order to mitigate its environmental impact, and it could even be reused in certain processes.	Precipitation; Heatwaves; Drought	Increased supply of water (SDG 6) Increased food security (SDG 2) Reduction of fertilizers (SDG 12)	UNFCCC (2017a)

Rainwater harvesting	Rainwater harvesting is the practice of collecting rainwater for later use from roofs and other artificial surfaces. Rainwater harvesting has been a common practice for centuries.	Precipitation; Flash Floods; River floods	Reduction of surface runoffs (SDG 6, 11) Reduction of water demand (SDG 11) Decentralized water supply (SDG 1, 2)	Conservation International (2019)
Flood protection barriers	Flood barriers represent a robust form of flood protection that raise the height of a riverbank. These physical infrastructures can be designed to support various recreational activities when deployed in an urban environment.	Precipitation; Flash floods; River floods	Support public art (SDG 4) Support sport activity (SDG 11) Develop quality, reliable, sustainable and resilient infrastructure (SDG 9) Strengthen resilience and adaptive capacity to climate-related hazards (SDG 13)	UN-Habitat (2015)
Crop diversification / Crop Shifts	Practices of crop diversification or crop shift to adjust to new patterns of temperature and precipitation, including the use of drought and flood-tolerant crop varieties.	Air temperature; Precipitation; Heatwaves; Drought	Decrease poverty (SDG 1) Increased food security (SDG 2) Improve crop production (SDG 12)	UNISDR (2015)
Implementation of new livestock breeding practices	Switching to alternative livestock breeds, class and species so as to obtain higher heat, drought and parasite tolerance.	Precipitation; Heatwaves; Drought	Decrease poverty (SDG 1) Increased food security (SDG 2) Improve livestock production (SDG 12) Strengthen resilience and adaptive capacity to climate-related hazards (SDG 13)	UNISDR (2015)
Shifting grazing patterns	Opting for conservative stocking rates, seasonal rotation of grazing, herd size and composition optimization, identifying reserve forage, strategic distribution of water and proactive management of vegetation are all options of management practices to help livestock producers adapt to the negative impacts of climate change.	Precipitation; Heatwaves; Flash floods, Drought	Decrease poverty (SDG 1) Increased food security (SDG 2) Improve livestock production (SDG 12) Strengthen resilience and adaptive capacity to climate-related hazards (SDG 13)	UNISDR (2015), Joyce et al. (2013)

Water and soil moisture conservation measures	Technologies of harvesting water and conserving soil moisture (for example crop residue retention) can help to minimize harvest losses under dry conditions	Precipitation; Drought	Increased food security (SDG 2) Improve crop/livestock production (SDG 12)	UNISDR (2015)
Multipurpose stormwater retention	In cities with a limited capacity of stormwater infiltration and/or evapotraspiration, solutions for stormwater retention can mitigate damages from urban and downstream floods. Since the flooding of the urban retention basins and ponds is temporally circumscribed, these infrastructures can serve a variety of purposes in the everyday life, e.g. sport courts, parking sites and playgrounds.	Precipitation; Flash Floods, River floods	Maximization of urban land use (SDG 9) Sustainable cities and communities (SDG 11) Strengthen resilience and adaptive capacity to climate-related hazards (SDG 13)	WMO, GWP (2008)
Diversification of tourism offers	Depending on their current characteristics, target groups and flexibility, tourism destinations will be affected differently by climate change. To keep competitive, it will be important to diversify tourist offers and services and to develop sustainable tourism structure.	Multi-hazard	Stable tourism economic activities (SDG 1, 8) Reduced ecological impacts of tourism (SDG 14, 15)	Hjerp et al. (2012)
Increasing robustness of energy networks	Design standards for energy network and power stations should be adapted. Transmission grids are especially affected by extreme storm events. Because of their outstanding importance for population and industries, grids have to be adapted to a higher intensity of storms. Further electricity storage facilities should be installed. Thermal power plants should target advanced flood protection and adapted water-cooling systems.	Wind	Increased energy security (SDG 7, 13) Decreased impacts on economic activities (SDG 8, 9)	UNISDR (2015b)
Adaptation of rail, road infrastructure	Retrofitting of transport infrastructure to climate impacts.	Precipitation; Heatwaves; Flash floods; River floods	Decreased impacts on infrastructure, supply chains and linked economic activities (SDG 9, 8)	Hjerp et al. (2012)
Forest fire protection	This option can include several specific measures, reaching from information systems on forest fires, to improved firefighting services and disaster prevention planning.	Heatwaves; Drought	Decreased fire risk for ecosystems and human settlements (SDG 3, 15) Strengthen resilience and adaptive capacity to climate-related hazards (SDG 13)	Hjerp et al. (2012)