Policy Brief

Transboundary adaptation to climate change

Governing flows of water, energy, food, and people

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Key Messages

Climate change alters transboundary flows that are essential for people and nature, including flows of water, people, energy, and food.

Transboundary adaptation can reduce risks by focusing interventions at the origin or source of the climate change impact, along transmission channels, and in destination country or region.

Anticipating, planning for, and managing flows across geographic and sectoral boundaries builds resilience across interconnected systems and populations.

Transboundary adaptation is strengthened and more effective when using a nexus approach, which considers how interconnected flows such as hydropower changes affect irrigation and/or energy needs.

Greater recognition of governance of transboundary flows within adaptation planning can better identify and manage systemic vulnerabilities that escalate climate change risk.

Strengthening governance frameworks to improve cross-border cooperation must be done in conjunction with addressing critical dimensions of vulnerability and promoting the integrated management of shared resources.

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About this publication

This policy brief responds to the need for greater clarity on transboundary adaptation. It builds on the existing body of work at ODI Global on anticipating cross-border effects of climate change and climate action and how to best manage transboundary climate risks with particular focus on adaptation and development planning in Africa.

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Contents

Boxes and tables

Boxes

Figures

Acronyms

ECOWAS	Economic Community of West African States
IGAD	Intergovernmental Authority on Development
IPCC	Intergovernmental Panel on Climate Change
SADC	Southern African Development Community
SAPP	Southern African Power Pool

1 Introduction

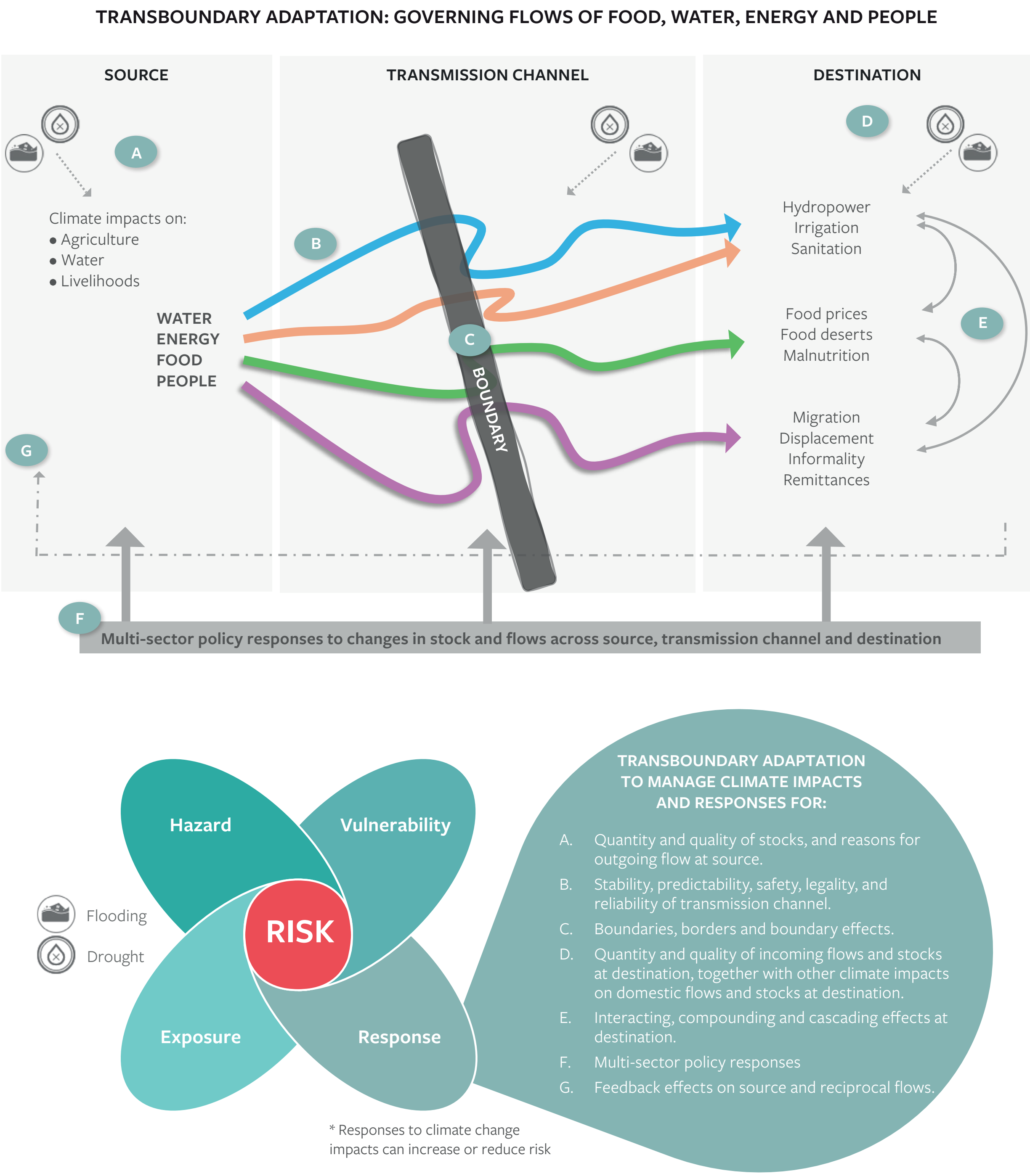
Transboundary adaptation includes actions taken to avoid or reduce the impacts of climate change. It requires managing climate risks that cross geographic, temporal and sectoral boundaries through planning and investing in feasible interventions that can operate effectively at scales appropriate to how the impacts of climate change manifest across boundaries (Opitz-Stapleton et al., 2023a). This is important because the impacts of climate change in one country or sector can cascade into another (Challinor et al., 2017; Challinor et al., 2018; Carter et al., 2021). For instance, global supply chains of semiconductors, global investments in manufacturing, major food crops like wheat, maize and soybean, and transboundary fish stocks are all affected by climate impacts in one part of the world, with cascading effects in other countries (O'Neill et al., 2022; Opitz-Stapleton et al., 2023b). Moreover, flows of trade, finance, people and shared ecosystems can transmit climate change risks (Harris et al., 2023; Bednar-Friedl et al., 2022; Munene, 2023). If managed well, however, transboundary flows can also reduce risk (Gualandris et al., 2024).

Importantly, both the physical impacts and climate mitigation and adaptation response taken in one or more countries can trigger risks to neighbouring countries. This highlights the importance of also understanding how responses to climate change can themselves affect risk or transmit it across boundaries (Simpson et al., 2021), and the need for transboundary adaptation (O'Neill et al., 2022; Trisos et al., 2022).

Climate impacts on the flows of key goods and stocks can directly affect one or more of water, food or energy sectors (Hejnowicz et al., 2022). These impacts have transboundary and cascading implications for people and nature at source, destination and along transmission processes (Figure 1). An excess stock (e.g., water resulting in flooding) or insufficient flows (e.g., low river levels, depleted groundwater or poor harvest) can exacerbate climate change risks (Grey and Sadoff, 2007).

Further, longstanding assumptions of risk landscapes are shifting under climate change (Müller-Mahn et al., 2018; Simpson, 2020; Mutongwizo et al., 2019). This has led to the need to recalibrate governance boundaries beyond conventional scopes of geography, sector or polity. For example, evidence shows vector-borne diseases (e.g., malaria, dengue) are shifting geographic distributions to higher altitudes and latitudes under warmer conditions (Mordecai et al., 2020; Ryan et al., 2020; Carlson et al., 2022; Semenza and Paz, 2021). Marine wildlife have shifted into new territories at a rate averaging 70 kilometres per decade, and these shifts are expected to continue or accelerate under continued warming (Pinsky et al., 2018; Cheung et al., 2016). The consequences of these two redistributions for human health and fisheries will demand novel governance solutions commensurate to their new geography of climate change impacts.

Figure 1 Conceptualising adaptation to transboundary risk



Note: Transboundary adaptation needs to account for the range of potential effects of climate impacts from source (A) to destination (D) and understand how risk is transmitted across boundaries (B & C) and with what interacting and feedback effects (E, F & G). Climate impacts in one country or sector, in this case impacts on agriculture, water and livelihoods from flooding following a prolonged drought, can affect flows of food (green), water (blue), electricity (orange) and people (purple) across borders or boundaries with diverse and interacting effects in other regions and sectors. The figure is structured spatially, but cross-sectoral and temporal risks are implied through how impacts on each of the four sectors affect each other at source and

destination. In this case, climate impacts on agriculture and actions taken in response to manage those impacts can affect flows of food and can have effects on food prices, access to food in (peri-)urban areas (food deserts) and malnutrition. Climate impacts water flows, with negative impacts on hydropower production, ecosystems, irrigation and sanitation. Climate impacts livelihoods, and the decision to move or stay can increase or decrease the movement people within and across borders, as well as informality growth rates and international or internal remittances. Such cross-border effects interact with each other, e.g., changes in food prices affect the wider economy, or reduced crop revenues from reduced irrigation affect food prices. Cross-border effects moreover have feedback effects, e.g., on trade. The figure does not show the substantial effects on flows of food, water and people within countries which could be greater than those crossing borders.
Source: The author's and elaborated with inspiration from New et al. (2022) and Carter et al. (2021)

Seven entry points where transboundary adaptation can reduce risks are outlined in Figure 1. Transboundary adaptation involves understanding and managing both the direct within-border impacts of climate change and the transmitted cross-border effects that lead to secondary impacts (Mason et al., 2023). These transmitted effects can be foreign or domestic. Understanding individual flows and how they interact with or compound each other is also important in accounting for cascading interactions and feedback loops (Simpson et al., 2023; Simpson et al., 2021; Mora et al., 2018). Adaptation planning should be incorporated into broader development and infrastructural planning, such as in development corridors, fisheries governance and power pooling initiatives (Juffe-Bignoli et al., 2021; AFDB, 2018; GCF, 2018; Zambezi Watercourse Commission, 2021; Pinsky et al., 2018; Juffe Bignoli et al., 2024). The coordinated governance of these numerous flows is especially important for climate change and development planning policymakers. It necessitates shifting away from unilateral and sectoral approaches and towards multilateral cooperation across various sectors, levels and governance mechanisms. This approach can more effectively address the transboundary challenges posed by climate change (Zeitoun et al., 2013; Munene, 2023).

This policy brief focuses on transboundary adaptation in Africa. While a handful of transboundary approaches to adaptation exist in Africa, such as the Intergovernmental Authority on Development's Adaptation Strategy (IGAD, 2023), these are still nascent, not widely adopted, and not yet aligned with national and sub-national adaptation planning processes. This addresses an important gap in adaptation conceptualisation and implementation because most African governments face significant barriers in developing transboundary adaptation at regional to continental scales (Opitz-Stapleton et al., 2023b).

Despite mounting evidence of how climate risk 'flows' across boundaries, this challenge has not been equaled by appropriate conceptualisation of and planning for transboundary adaptation (Climate Action Tracker, 2021; Sapiains et al., 2021; Petzold et al., 2023). Only a handful of countries globally have integrated inter-regional aspects into their climate change risks assessments and adaptation is still framed predominantly as a national or local issue (O'Neill et al., 2022). The

Intergovernmental Panel on Climate Change (IPCC) acknowledges that while our understanding of transboundary risk has improved in the past 10 years, we still face major gaps on how to manage transboundary adaptation (O'Neill et al., 2022; New et al., 2022).

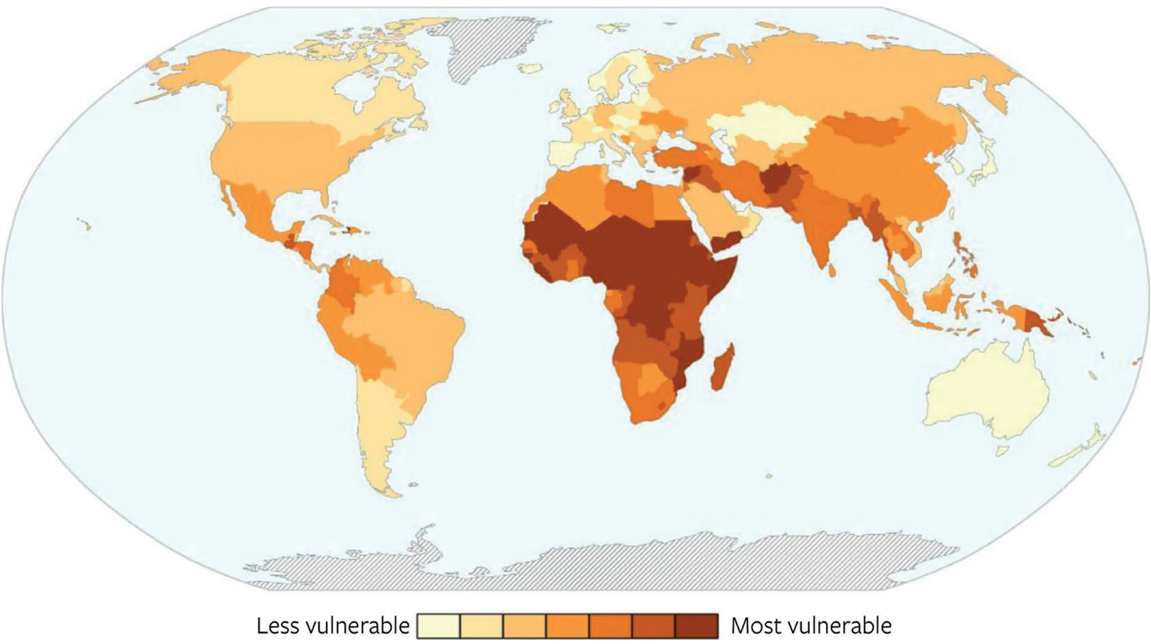
In the following sections, this policy brief uses examples of observed and projected climate impacts on the flows of water, energy, food and people. Transboundary vulnerability is recognised as an important cross-cutting dimension for transboundary adaptation. It then highlights how a nexus approach is critical for transboundary adaptation (Hejnowicz et al., 2022). The brief identifies transboundary adaptation options that show promise in reducing climate change impacts at source, at destination, and along transmission lines and concludes with three recommendations towards scaled up implementation.

2 Adaptation and transboundary vulnerability

Vulnerability is the propensity or predisposition to be adversely affected (IPCC, 2022). It includes sensitivity or susceptibility to harm and is also determined by capacity to adapt to climate change and its effects to moderate harm (Ara Begum et al., 2022; Pörtner et al., 2022). In the African context, climate vulnerability crosses geopolitical divides as regional clusters of fragile and high vulnerability countries exist (Trisos et al., 2022), showing the need for transboundary adaptation to climate change (Birkmann et al., 2021).

Vulnerability is a product of structural inequality and is often systemic in nature (Birkmann et al., 2021). It is also highly uneven across Africa with highly variable socioeconomic development, governance, ecosystem management and capacities within and between countries (Trisos et al., 2022; Ayanlade et al., 2023; Adelekan et al., 2022). Spatial analyses reveal an emerging pattern of climate vulnerability within regional clusters and shows that vulnerability is a transboundary issue, crossing political, sectoral and geographical borders and impacting shared resources (Figure 2).

Figure 2 Transboundary clusters of vulnerability



Note: The vulnerability index used integrates the best available metrics of poverty, income inequality, lack of human development and human capital, gender inequality, governance, health and health infrastructure, food security, malnutrition in children under 5 years, sanitation, preparedness, and forced migration and up-rooting (mainly from the WorldRiskIndex and INFORM Index).
Source: Birkmann et al. (2021)

Spatial hotspot analysis of vulnerability underscores high vulnerability, state fragility, low biodiversity protection or forced migration emerging in multi-country clusters across Africa (Birkmann et al., 2021). This aspect has often been overlooked and work on transboundary risk rarely considers this view on transboundary vulnerability and is therefore not helpful in informing transboundary adaptation planning for Africa (Munene, 2023), including both hard and soft infrastructure.

Adaptation is not just about transforming systems to manage or reduce a specific climate-related hazard (e.g. drought, flood or extreme heat) but, more fundamentally, is also about reducing vulnerability of populations and the systems they depend on, including for example improving social protection systems (Birkmann et al., 2021). It is also about ensuring climate impacts do not exacerbate vulnerability through transboundary effects (including effects both from one system to a neighbouring one, as well as from one system to a distant one) (O'Neill et al., 2022). Given the development deficit facing many regions of Africa, transboundary vulnerability reduction needs to be integrated with approaches to transboundary adaptation to better account for the durability and feasibility of adaptation interventions. The 'temporal' dimension of transboundary adaptation is therefore critical, cutting across boundaries of time or when climate risk is deferred to a later date. Vulnerability is usually dynamic over time and space, almost never static, making it an important determinant of the transmission system for transboundary risks. It is therefore critical both that transboundary adaptation includes a vulnerability lens, and that its measures of success include indicators that reduce transboundary vulnerability.

3 Transboundary adaptation options for water, energy, food and people

3.1 Nexus of water, energy and food

A nexus approach is vital in transboundary adaptation, recognising the interconnectedness of water, energy and food systems. Integrated strategies can optimise resources, reduce trade-offs, and enhance resilience, leading to more sustainable and effective outcomes across all sectors and regions. Implementing strategies that consider the interlinkages between water, energy and food sectors can lead to more sustainable resource management (Mehrabi et al., 2022). By addressing the nexus between these sectors, countries can enhance flows of water and food while ensuring energy security (Keskinen et al., 2016; De Strasser et al., 2016) (Box 1).

Box 1 Water-energy-food nexus

The water-energy-food (WEF) nexus explicitly recognises the strong interdependencies of these three sectors – including at transboundary levels – and their high levels of exposure to climate change. The WEF nexus highlights the need to better understand the conditions under which nexus coordination may occur at the transboundary level. A case in point is how hydropower investments on shared rivers can impact the provision of energy, water and food security across borders (Avery and Tebbs, 2018). Beyond interdependencies of water, energy and food, risks can be transmitted from one WEF sector to the other two, with cascading risks to human health, cities and infrastructure. However, implementation of nexus approaches has lagged compared to theoretical development (Taguta et al., 2022; Müller-Mahn et al., 2018).

Sources: Zografos **et al.** (2014); Dottori **et al.** (2018); Trisos **et al.** (2022); Dombrowsky and Hensengerth (2018); Conway **et al.** (2015); England **et al.** (2018b); England **et al.** (2018a)

Understanding of WEF nexus interlinkages can help characterise risks and identify entry points and the relevant institutional levels for cross-sectoral climate change adaptation actions. An integrated response can be enhanced through the inclusion of community-based organisations, such as water resource user associations and the wide range of other multi-sectoral actors involved in and affected by development decisions. The following sections will elaborate how this plays out across flows of water, food, energy and people.

3.2 Water

Up to 90% of all Africa's surface freshwater resources are located in river basins and lakes that are shared between two or more countries (Bhaduri et al., 2011; Goulden and Conway, 2009). Transboundary water management is more complex than national water management due to upstream access to and control over water flows for downstream users, as well as power asymmetries and dependencies on predictable flows across the drainage basin. Additionally, climate impacts will exacerbate longstanding challenges such as water resource capture (Zeitoun and Warner, 2006; Goulden and Conway, 2009; Yibeltal, 2024). Water management regimes usually differ more between countries than within countries, making alignment complex and difficult. Further, in many parts of the world, there remains a shortfall in institutionalised cooperation mechanisms for transboundary dams (Schmeier, 2024) even though many countries have histories of cooperation over shared water resources (Ho, 2017; De Stefano et al., 2010; Rosenblum and Schmeier, 2023).

Transboundary adaptation for water therefore needs to draw on existing approaches and develop new ways to collaborate effectively among stakeholders in neighbouring countries to enhance efficiency and share benefits (Yu et al., 2019). Several states have developed legal and governance mechanisms to address potential conflicts, ranging from international water law principles, to basin management plans, to environmental impact assessments, to ensuring basin treaties incorporate dam-specific provisions (Schmeier, 2024). For example, both the Southern African Development Community (SADC) Climate Change Strategy and the SADC Shared Watercourses Protocol emphasise the importance of incorporating observed and projected climate change impacts to water as well as coordinated regional, river basin and local-level adaptation planning (Mgquba and Majozi, 2018).

Cooperation in transboundary river basins can make water resources systems more efficient and benefit the diversity of stakeholders involved. Implementing integrated transboundary water management can lead to significant sharing of socio-economic benefits for nations (Taraky et al., 2021; Whitley, 2024). The Volta River Basin highlights how hydro diplomacy strategies to solve challenging water conflicts can facilitate sustainable transboundary water sharing (Box 2).

Box 2 Transboundary adaptation in the Volta Basin

The Volta River Basin is a critical transboundary water resource in West Africa spanning six countries: Ghana, Burkina Faso, Togo, Benin, Côte d'Ivoire, and Mali. The basin covers an area of about 400,000km^2 and supports the livelihoods of over 24 million people. Climate change exacerbates water-related challenges. Water is used in the region for hydropower generation, agricultural production, sanitation, and maintenance of riparian ecosystems. Despite perceived increasing competition and conflict over shared water resources, governance and cooperation is essential in water management across borders, regional stability, and resilience. Through this cooperation, Ghana (downstream) has increased its water abstraction for agriculture and hydropower exports by cooperating with Burkina Faso (upstream). Although progress is nascent and water-sharing agreements have been criticised for existing more 'on paper' than in implementation, lessons for Africa can be elicited on how to develop framework water-sharing agreements and economically sustainable action plans.

Sources: Bhaduri et al. (2011); Baah-Kumi and Ward (2022); Dembélé et al. (2023); Lautze et al. (2008); Milman et al. (2013); Mul et al. (2015)

There is growing evidence that strengthening cooperation and promoting water markets in regions with unevenly distributed water resources can play a vital role in mitigating water scarcity challenges and fostering regional integration through coordinated transboundary water transfers (Matchaya et al., 2019). For instance, countries like Malawi and Mozambique could explore the establishment of water markets to address water scarcity issues, although the adaptation feasibility of water markets in the region is contingent on multiple factors including new build of water infrastructure (George-Williams et al., 2024; Pittock et al., 2021). Cooperation between Mozambique and Zimbabwe on the Buzi River Basin, and between Botswana, Namibia and South Africa on the Stampriet Transboundary Aquifer, highlights that sometimes countries can take relatively straightforward steps to trigger cooperation and accelerate progress towards ensuring that operational arrangements cover all of their transboundary basins (UNESCO, 2021; Kileshye Onema et al., 2020). This can also be applied to drainage basins that are adjacent but for which the impacts of climate change on water resources are not correlated (Cervigni et al., 2015; Cervigni et al., 2017; Conway et al., 2017) (see Figure 3 below).

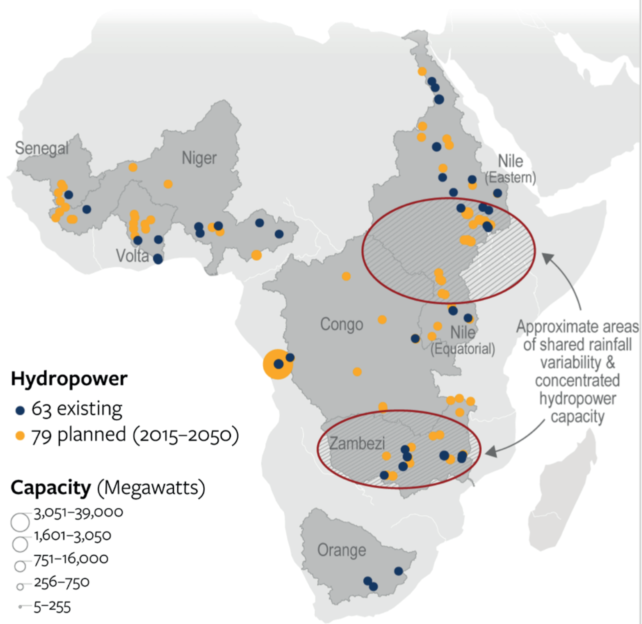
3.3 Energy

Transboundary adaptation challenge for energy in Africa is compounded by current energy deficits and the need for substantial infrastructure investment to enable access to reliable energy sources and cross-border energy trade. For example, estimates to achieve universal electricity access in Africa by 2030 show that power generation capacity needs to increase by between 211–302 GW (Pappis, 2022), with distribution capacity scaled up commensurately (Mabhaudhi et al., 2016). Moreover, many energy systems are linked across borders. For example, SADC's hydropower for Zambia and Zimbabwe is generated from the flow of the Zambezi River through the Kariba Dam (Mabhaudhi et al., 2016).

Figure 3 Flows of water and transboundary adaptation for energy in Africa

Climate risks to hydropower and irrigation in Africa

(A) Distribution of hydropower plants within 7 major river basins



(B) Correlation of historical annual river flows

negative | weak | strong

	Nile (Equatorial)	Zambezi	Congo	Niger	Senegal
Nile (Eastern)	−0.28	0.29	0.25	0.34	0.52
Nile (Equatorial)		0.03	0.43	−0.18	−0.25
Zambezi			0.46	0.52	0.38
Congo				0.43	0.31
Niger					0.74

Hydropower plants clustered within the same areas, are likely to experience similar rainfall and run-off patterns, increasing the risk that neighbouring states will experience concurrent drought-induced hydropower shortages.

When historical annual river flows are weakly or negatively correlated, power trade between basins will be more effective in managing the risk of shortages than power trade between those experiencing similar patterns.

Note: In panel (a), the map shows the location and size of existing (blue) and planned (orange) hydropower plants in African governments' infrastructure expansion plans, 2015–2050. In panel (b), the matrix shows historical correlations in annual river flows between some of the major river basins indicating risk of hydropower shortages where correlations are higher. The expected increase in hydropower and irrigation revenues as new hydropower and irrigation infrastructure is added based on planned infrastructure development (the African Union's Programme for Infrastructure Development along with other national energy plans jointly referred to as PIDA+) in a scenario without climate change. Used with permission from Figure Box 9.5.1, Climate risks to hydropower and irrigation in Africa in IPCC Working Group II Report Chapter 9: Africa.
Source: Trisos et al. (2022)

Enhancing regional integration and cooperation in the energy sector can facilitate sharing of energy resources, technologies, and expertise, as well as develop interconnected energy grids and promote renewable energy sources (Mabhaudhi et al., 2016). For example, feasible power transmission highways from the Grand Inga in Democratic Republic of the Congo and the Grand Renaissance Dam in Ethiopia to other regions on the continent create the possibility of a pan-African electricity grid (Rose and Perez-Arriaga, 2022). Establishing power pools that are able to trade between different regions and drainage basins could be a game changer for energy for Africa (Rose and Perez-Arriaga, 2022) (Figure 3). Implementing such power pools will require a dedicated regulatory authority for co-optimisation of generation and transmission and identifying rules for shared reserves. Cooperation and integration of common power grids and markets among some SADC countries enables cross-border electricity trade, particularly between hydropower-rich countries like Zambia and fossil fuel-dependent nations like South Africa, known as the Southern African Power Pool (SAPP) (Box 3).

Box 3 Ensuring energy security through shared hydropower generation

The Southern African Power Pool (SAPP) is a regional electricity network that connects the power grids of 12 Southern African countries, enabling cross-border energy trade. SAPP's 12 member countries include Angola, Botswana, Democratic Republic of Congo, Lesotho, Malawi, Mozambique, Namibia, South Africa, Eswatini, Tanzania, Zambia, and Zimbabwe. SAPP has been working on enhancing the resilience of its energy infrastructure to climate impacts by improving the management of shared water resources for hydropower and promoting the integration of renewable energy sources to diversify the energy mix. SAPP enables members to coordinate and cooperate in the planning, development and operation of regional generation and transmission facilities for their mutual benefit.

The Eastern and Southern Africa Power Pools possess renewable energy potential from hydropower many times their projected electricity demand growth of 5% and 3.4% per year till 2040 (IRENA, 2021), yet their cross-border energy dependencies face correlated rainfall variability, increasing the risk of concurrent climate-related electricity supply disruption in each region.

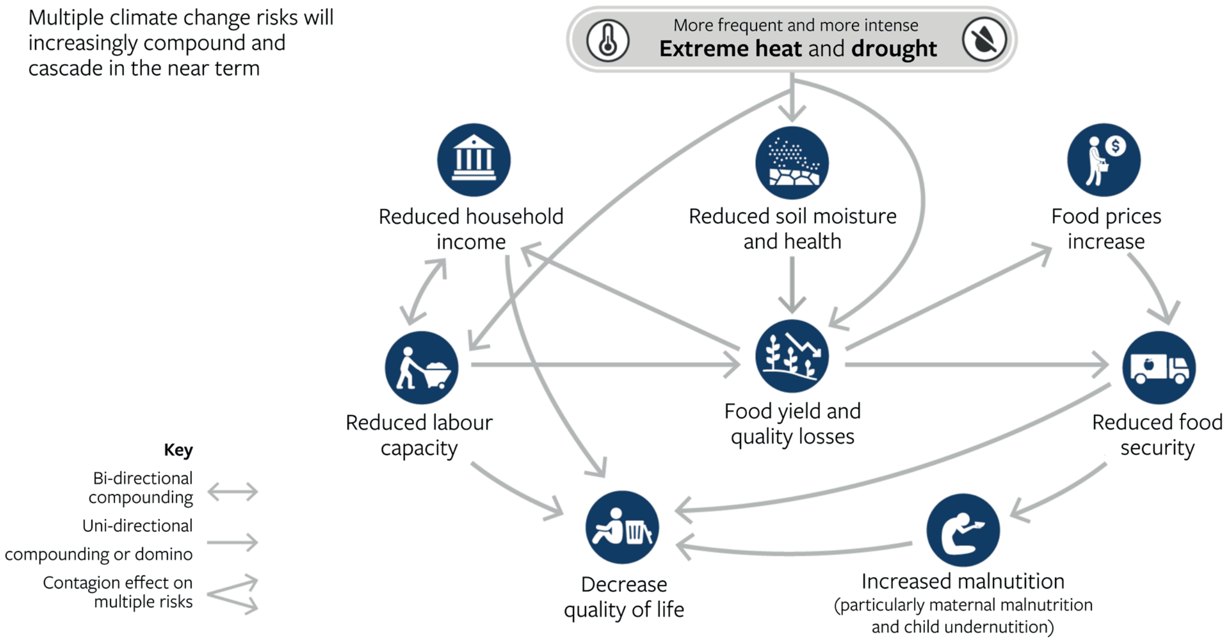
Source: SAPP (2017); SAPP (2021); Conway et al. (2017)

3.4 Food

Climate change impacts the agricultural and livestock sectors throughout the food supply chain – from farm production through food distribution to human consumption (Godde et al., 2021). Climate change impacts on agriculture necessitate collaborative efforts to address issues like food security and price shocks (Harris et al., 2022). Responses by individual countries to adapt ripple through formal and informal supply chains and trade networks in other countries. For example, the Southern African drought of 2015–2016 had policies leading to spillover effects in neighbouring countries, with lifting of import restrictions leading to an increase in maize prices and imports (Bren D'Amour et al., 2016; Casella and de Melo, 2022).

Climate variability explains at least 30% of year-to-year fluctuations in agricultural yield (Gaupp et al., 2020). The global trade system transmits but also buffers against climate change shocks from one country to others affecting food availability across borders especially where food prices have increased globally in the wake of climate-related disasters affecting major producers (Gaupp et al., 2020). If more than one global 'breadbasket' experiences climate impacts, global food security can be threatened (Gaupp et al., 2019; Gaupp et al., 2017; Bednar-Friedl et al., 2022) (Figure 4). Recent studies have shown increasing risk of simultaneous failure of wheat, maize and soybean crops across globally significant breadbaskets (Gaupp et al., 2020; Bednar-Friedl et al., 2022). Flows of food are also projected to be particularly constrained under increasing risks of multiple breadbasket failure at 1.5 and 2 °C global warming (Hasegawa et al., 2022; Trisos et al., 2022). For example, projected wheat, maize and soybean yield losses in the global breadbaskets increase disproportionately between 1.5 and 2 °C global warming (Gaupp et al., 2019). Such events will require effective policy coordination to increase countries' resilience to shocks and avoid negative spillovers.

Figure 4 Impacts from climate change have cascading effects on food, nutrition, livelihoods and wellbeing



Note: Climate hazards can initiate risk cascades that affect multiple sectors and propagate across regions and borders following complex natural and societal connections. This example of a compound heat wave and a drought event striking an agricultural region shows how multiple risks are interconnected and lead to cascading biophysical, economic, and societal impacts even in distant regions, with vulnerable groups such as smallholder farmers, children and pregnant women particularly impacted (used with permission from Figure 4.3, Panel C: Every region faces more severe or frequent compound and/or cascading climate risks in the near term in IPCC Sixth Assessment Synthesis Report).
Source: IPCC (2023).

A combination of strategies are needed in addition to the transboundary water cooperation stated above (Anghileri et al., 2024; Goulden and Conway, 2009), including adaptive management of agricultural landscapes, collaborative river basin management and grazing lands management

(Waalewijn et al., 2005; Midgley et al., 2021), stable and predictable trade regimes (Hepburn et al., 2021; Baldos and Hertel, 2015), and incorporating Indigenous knowledge systems and technologies into adaptation design and policy (Mabhaudhi et al., 2019; Zvobgo et al., 2022; Leal Filho et al., 2023).

Managing trade-offs in climate adaptation requires careful planning and decentralisation. National governments often intervene with policies and regulations that, while intended to address climate impacts, can unintentionally create negative consequences. For example, interventions like price controls, subsidies and trade regulations may strain budgets, inflate food prices, and reduce competition, leading to lower crop yields. Overuse of subsidised fertilisers can also suppress crop diversification. To effectively manage these trade-offs, governments must focus on decentralising decision-making. Localised planning allows for more context-specific solutions, helping to balance short-term interventions with long-term sustainability. Decentralisation enables local authorities to address unique regional challenges while ensuring that national policies support, not hinder, adaptation efforts. A well-designed decentralisation approach can improve resilience by encouraging crop diversification, promoting efficient resource use, and tailoring social protection to local needs. In this way, managing trade-offs through decentralised governance and targeted interventions helps mitigate the unintended consequences of national policies, fostering a more adaptive and resilient agricultural system (Kemoe et al., 2022; Damania et al., 2023).

Regional and national collaboration with regional economic communities such as the Economic Community of West African States (ECOWAS), IGAD and SADC as well as the African Union in food policy planning and decision making could play a critical role in agricultural resources management and governance. Involving subnational governments in climate change adaptation policies has been crucial when managing food price shocks and subsequent transboundary adaptation food trade (Aall et al., 2023).

At a continental level, the African Continental Free Trade Area has been shown to have positive effect at a transboundary level on agri-food sectors and for food security in Africa. Although there will be some winners and losers, on aggregate it could potentially lift a million people out of risk of hunger while increasing national incomes (Simola et al., 2022).

3.5 People: migration, displacement and transhumance

Direct impacts of climate change may increase or decrease movements of human populations through climate mobility and displacement (Amakrane et al., 2023). Sometimes migration is used as a form of adaptation and can affect remittance flows (Simpson et al., 2024; Thorn et al., 2022). In the worst case, climate hazards in destination and transit countries can be fatal to migrants, especially those forced into unsafe journeys or work (Mason et al., 2023; Cissé et al., 2022; Wrathall et al., 2022). Projections of climate change may lead to significant population shifts, including in mobility hotspots within Ethiopia, within and between Malawi and Mozambique, and across the Niger–Nigeria border (Amakrane et al., 2023) (Figure 5), among other regions (Thorn et al., 2022).

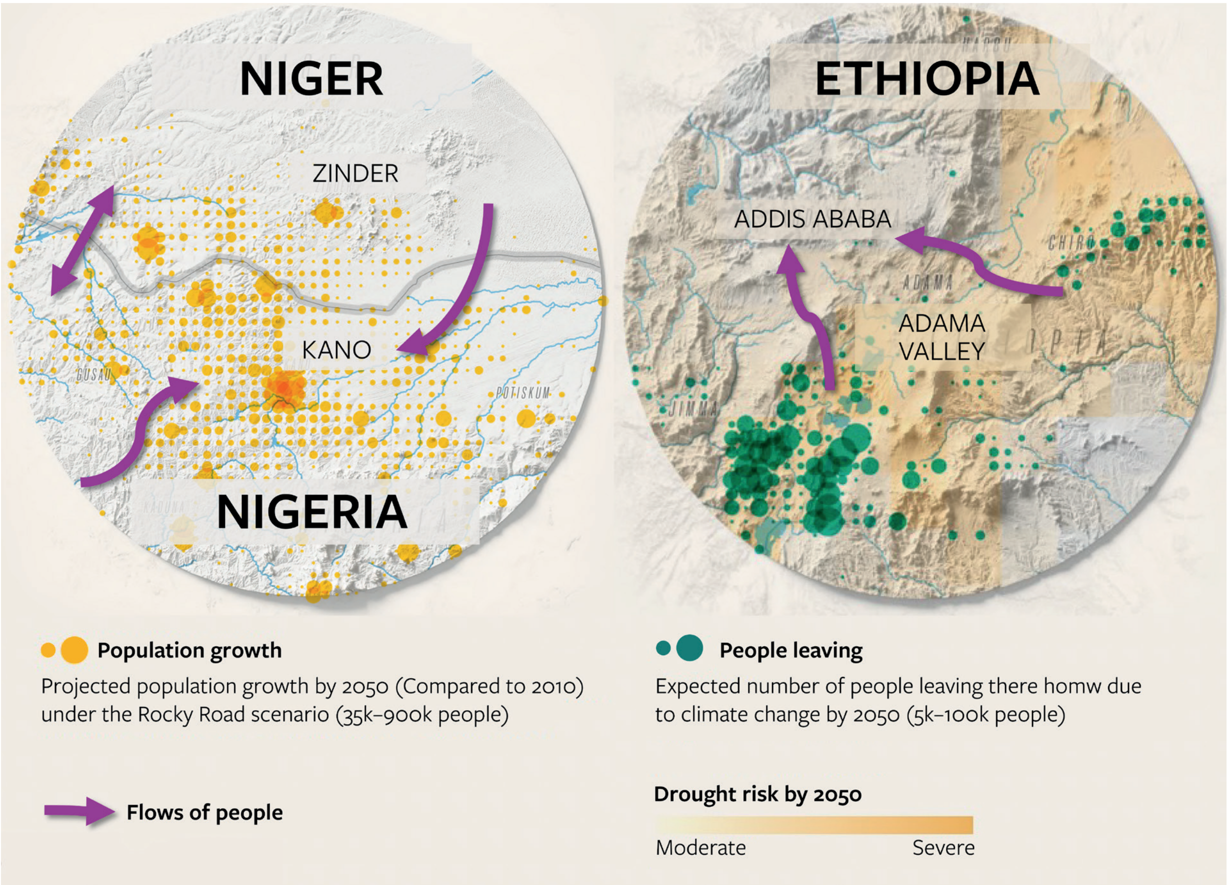
Transboundary transhumance has been used for generations to cope with climate variability in pastoral systems (Cuni-Sanchez et al., 2019; Kima et al., 2015; Zampaligré et al., 2014). For instance, seasonal movement of livestock across countries like Mali, Niger, Burkina Faso, Chad and Mauritania to manage drought and fluctuating rainfall avoid the worst effects of localised climate shocks and sustain their herds (Adaawen et al., 2019; Cottier and Salehyan, 2021). In East Africa, pastoralists from the Somali and Borana ethnic groups have practised transboundary transhumance for centuries with movement of livestock (cattle, goats, and camels) across the Kenya-Ethiopia border in response to drought and flooding (Defere et al., 2022), as have the Karimojong pastoralists across the borders of Uganda, Kenya, Ethiopia and South Sudan (Byakagaba et al., 2018). This system helps maintain animal health and productivity by accessing better pastures and water sources in different areas. But climate change has affected pastoralists' access to grazing lands, land degradation and the loss of traditional knowledge to manage livestock and rangeland resources (Ntombela et al., 2024). It is forcing flows of people and their livestock beyond the boundaries of their customary rangeland to access forage (Ntombela et al., 2024; Abrahams, 2021; Egeru, 2016; Waiswa et al., 2019).

On the one hand, transboundary mobility can improve material well-being through higher incomes, and investments in assets that allow upward social and economic mobility (Thankappan, 2024; Sakdapolrak et al., 2024; Adger et al., 2024). Migration can also be an effective adaptation strategy (Simpson et al., 2024; Adger et al., 2024; Tebboth et al., 2023; Caretta et al., 2023; Thorn et al., 2022) – depending on the local particularities such as the local food system, customary rules for mobility, and strategies for social integration as well as agreements between countries to allow pastoralists move livestock across borders (Scheffer et al., 2024; IGAD, 2020). On the other, migrants and transhumant populations often enter precarious livelihoods, suffer from weakened social networks and inadequate social safety nets, and are often exposed to different and greater climate risks while on the move or in their new location, all of which impede adaptive capacities (Tebboth and Locke, 2023; Maharjan et al., 2020; Tebboth et al., 2019; Munene, 2023).

Two recent transboundary policies show African governments' appetite to cooperate around climate mobility: the Kampala Ministerial Declaration on Migration Environment and Climate Change (UNHCR, 2019) and the IGAD Protocol on Free Movement of People (IGAD, 2020). Moreover, the *African Shifts Report* highlights the need to anticipate and plan for climate-forced displacement and migration to foster social cohesion in affected communities, prevent involuntary immobility, and provide safe and legal options to protect people on the move (Amakrane et al., 2023; Scheffer et al., 2024; Simpson et al., 2024). A key intervention is extending social protection programmes to address inequalities that limit people's agency in mobility decisions regarding gender, age, ability, income, employment, education, or otherwise (Amakrane et al., 2023).

Internal climate mobility within countries could reach up to 113 million people by 2050 (Amakrane et al., 2023). In contrast, cross-border climate mobility is forecast by current best estimates to reach a maximum of 1.2 million people by 2050 (Amakrane et al., 2023). These empirical flows and those presented in Figure 5 help understand where adaptation and development investments can support transboundary adaptation in Africa. But they also challenge common myths increasingly instrumentalised in politics across Europe and North America such as the notion of the 'mass migration' of Africans to Europe due to climate change. Such rhetoric misrepresents Africans' climate mobility as a security risk and is used to justify highly restrictive immigration and border control policies on migration (Bettini, 2017; El-Enany, 2013; Boas et al., 2019).

Figure 5 Cross border and within country flows of people in response to impacts of climate change



Note: Panel (a): Kano (Nigeria's Northwest) is expected to grow in 10.3 million people by 2050. Panel (b): around 750,000 people may need to leave Ethiopia's Adama Valley by 2050 as a result of climate risks like droughts. Most of these people will end up moving elsewhere within Ethiopia as people throughout the continent will generally prefer to stay within their countries. Climate mobility projections shown here from the *African Shifts Report* assume people will move based on push and pull factors associated with climate impacts and future development scenarios (Amakrane et al., 2023). Where impacts will be negative, projections show movement out of those regions. Where impacts are projected to result in comparatively better conditions (such as suitability for certain crops), projections indicate movement to and a growth of population in such areas. Both panels show projections of climate mobility based on high emissions and inequitable development scenario (RCP6.0; SSP3).
Source: adapted from Amakrane et al. (2023)

Policymakers concerned with transboundary adaptation need to manage not just changes in stocks of people but also public opinion and support of newcomers (Banulescu-Bogdan and Huang, 2024), which is neither easy to predict nor static (Banulescu-Bogdan and Huang, 2024). International coordination will be essential for planning and highlighting the benefits of migration to host societies (Scheffer et al., 2024). Migration, development and adaptation planning policies need to recognise and support mobility as a legitimate strategy for climate adaptation in local, national, regional, and international policies, and build cross-sector partnerships to support people and communities in staying, moving, and receiving (Amakrane et al., 2023; Simpson et al., 2024). As most local actors do not have jurisdiction over migration policies, this highlights the important role of states and international organisations in transboundary adaptation.

4 Conclusion

Shared resources and interconnections in flows of information, finance, people and ecosystems open communities and countries to transboundary climate risks. Transboundary adaptation can also offset risks or create potential for common benefits, such as hydroelectric power generation and regional food security (Trisos et al., 2022). The next generation of transboundary adaptation needs to operationalise the governance of flows (of people, water, finance, technology, energy, information, food, vaccines, data and livestock) within broader adaptation thinking and policies. There is also growing need to adapt not only to transboundary impacts of climate change but also to other countries' responses to them (Mason et al., 2023; Simpson et al., 2021).

Across the sectors discussed here, several common themes emerge. In general, transboundary adaptation may reduce risks by focusing interventions:

- at an origin or source of the climate change impact
- along transmission channels
- in recipient country or region of the impact.

The following recommendations are for policymakers, stakeholders and international partners.

A nexus approach is important in improving adaptation outcomes. Transboundary adaptation for water, energy and agriculture can foster cooperation and manage financial losses associated with extreme events by connecting regions of uncorrelated risks of wet and dry periods (Denaro et al., 2020; Conway et al., 2017). Governments, policymakers and regional bodies should therefore adopt a nexus approach to improve transboundary adaptation outcomes in water, energy, and agriculture. Such an approach considers, for example, how interconnected flows such as hydropower changes affect irrigation and/or energy needs, and how subsequently impacted productivity and food prices influence each other. This would ensure WEF sectors and countries can enhance the flow of water and food while ensuring energy security.

Hydropower investments on shared rivers could impact the provision of energy, water and food security across borders. Policymakers, energy ministries, and environmental agencies must collaborate to ensure that hydropower projects consider the interconnected impacts on local ecosystems and agricultural productivity. Engaging with local communities, agricultural stakeholders and water management authorities is crucial for addressing potential conflicts and optimising resource allocation. By fostering transboundary cooperation and sustainable hydropower development, African countries can collectively strengthen regional resilience and enhance the security of vital resources.

Enhancing cooperative governance systems is essential to ensure the level of cooperation necessary for effective transboundary adaptation is achieved. As climate change intensifies and its impacts become increasingly unpredictable, there is more need for robust adaptation strategies and planning processes. National Adaptation Plans (NAPs) serve as critical frameworks for countries to assess vulnerabilities, outline strategies, and mobilise resources for effective climate adaptation planning and action. Subsequently, NAPs could evolve to explicitly consider inter-regional as well as domestic effects. By integrating cross-border considerations into NAPs, countries can foster collaborative governance systems that enhance resilience and adaptability. This approach not only addresses the direct impacts of climate change but also recognises the interconnectedness of ecosystems, economies and communities across regions, paving the way for a more holistic and effective response to climate variability. By coordinating NAPs regionally and internationally, and by building capacities and closing knowledge gaps at the country level, resources can be better directed toward reducing inter-regional risks and enhancing systemic resilience to climate change on a global scale. NAPs should evolve to explicitly consider inter-regional as well as domestic effects.

In some parts of Africa, as in the case of SADC, strengthening legal and political frameworks that improve cross-border cooperation offers significant potential, but to be effective this needs to be done together with addressing critical dimensions of vulnerability and promoting integrated management of shared resources. For instance, states in West and Southern Africa have developed legal and governance mechanisms to address potential conflicts, ranging from international water law principles, to basin management plans, to environmental impact assessments and to ensuring basin treaties incorporate dam-specific provisions (e.g. the Climate Change Strategy and the SADC Shared Watercourses Protocol). These emphasise the importance of coordinated political frameworks among national and regional governments.

Additionally, to enhance cooperate governance systems, there is a pressing need to strengthen collaboration and promote water markets in regions with unevenly distributed water resources, as this can mitigate water scarcity challenges and foster regional integration through coordinated transboundary water transfers. For example, Malawi and Mozambique could benefit from exploring establishing water markets, dependent on the infrastructure investments required. Successful cooperation, as seen between some SADC countries like Mozambique and Zimbabwe, Botswana, Namibia, and South Africa, demonstrates that straightforward steps can trigger meaningful collaboration across transboundary basins.

Furthermore, regional integration and effective governance within the energy sector by national governments, regional economic communities (ECOWAS, IGAD, SADC), infrastructure investment agencies, energy ministries, and local communities is crucial for sharing resources, promoting renewable energy and developing interconnected grids. Addressing Africa's energy deficits necessitates significant infrastructure investment for reliable energy access and cross-border trade, with power generation capacity increased substantially by 2030. Collaboration with regional economic communities as well as the African Union will facilitate cooperation in resource management and governance, enhancing adaptation efforts.

Focus on addressing knowledge gaps: there are critical gaps in our understanding around the effectiveness of technical adaptation options in terms of reducing climate change risk at future global warming levels. Also of growing concern for Africa is the transboundary risk arising from climate change policies in other parts of the world, such as the EU Carbon Border Adjustment Mechanism. These are critical areas for technical assistance to governments as well as for research investment including a specific focus on assessing transboundary adaptation to risks arising from other regions of the world.

There is also a need for more comprehensive research on how climate change will affect transboundary water management and the interdependencies within the WEF nexus. Understanding the interactions between these sectors in the context of climate variability is crucial for developing effective strategies that ensure sustainable resource allocation, enhance resilience, and foster cooperation among countries sharing water resources.

To enhance cooperation in transboundary adaptation, it will be crucial to conduct comprehensive assessments of existing policies and governance structures. Research on evaluation of how frameworks either facilitate or hinder collaboration in the context of climate change in Africa is essential. This should include analysing the effectiveness of regional agreements, institutional arrangements, and stakeholder engagement processes among countries. By identifying gaps and opportunities within current governance systems, countries can develop more cohesive and adaptive policies that promote integrated resource management, encourage joint investments, and foster cooperate mechanisms. Addressing these knowledge gaps would inform policies and frameworks that can respond effectively to the multifaceted challenges posed by climate change in transboundary contexts.

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