

Exploring water-energy-food nexus connections between climate action and regional development in the East African community

Wambua, Tumaini J.; Jewitt, Graham; Sušnik, Janez; Masia, Sara; Mabhaudhi, Tafadzwanashe

DOI

[10.1016/j.crm.2025.100760](https://doi.org/10.1016/j.crm.2025.100760)

Publication date

2025

Document Version

Final published version

Published in

Climate Risk Management

Citation (APA)

Wambua, T. J., Jewitt, G., Sušnik, J., Masia, S., & Mabhaudhi, T. (2025). Exploring water-energy-food nexus connections between climate action and regional development in the East African community. *Climate Risk Management*, 50, Article 100760. <https://doi.org/10.1016/j.crm.2025.100760>

Important note

To cite this publication, please use the final published version (if applicable). Please check the document version above.

Copyright

Other than for strictly personal use, it is not permitted to download, forward or distribute the text or part of it, without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license such as Creative Commons.

Takedown policy

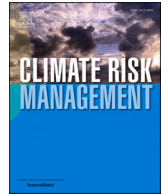
Please contact us and provide details if you believe this document breaches copyrights. We will remove access to the work immediately and investigate your claim.



ELSEVIER

Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Climate Risk Management

journal homepage: www.elsevier.com/locate/crm

Exploring water-energy-food nexus connections between climate action and regional development in the East African community

Tumaini J. Wambua^{a,b}, Graham Jewitt^{a,b,c}, Janez Sušnik^{a,*}, Sara Masia^{a,d},
Tafadzwanashe Mabhaudhi^{e,f,g}

^a IHE Delft Institute for Water Education, Westvest 7, 2611 AX Delft, the Netherlands

^b Centre for Water Resources Research, University of KwaZulu-Natal, Pietermaritzburg, South Africa

^c Civil Engineering and Geosciences, Delft University of Technology, Delft, the Netherlands

^d CMCC Foundation – Euro-Mediterranean Centre on Climate Change, Italy

^e Centre for Transformative Agricultural and Food Systems (CTAFS), School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Pietermaritzburg 3209, South Africa

^f Centre on Climate Change and Planetary Health, London School of Hygiene & Tropical Medicine, London, UK

^g United Nations University Institute for Water, Environment and Health, Richmond Hill, Ontario, Canada

ARTICLE INFO

Keyword:

National adaptation plans
Nationally determined contributions
Nexus
Sustainable development
Water-energy-food

ABSTRACT

Policy siloes between national adaptation plans (NAPs), nationally determined contributions (NDCs) and sustainable development hinder effective climate action and resource governance in East Africa. Further, rapid population growth and climate change impacts intensify demands for water, energy, and food (WEF), fuelling resource exploitation. This study employs a mixed-qualitative methodology using document analysis, and semi-structured interviews to examine the interlinkages between NAPs, NDC and regional development priorities. Results show implied connections between policy instruments, sustainable development, and climate action form the crux of WEF interlinkages. In practice, incoherence between these instruments create competition and trade-offs that increase WEF resource security. For example, the focus on food security, mostly through extensification, has created tradeoffs with water and energy security, undermining development goals. There are implicit interlinkages in policy and, to a certain extent, in practice. Although insufficient, these are foundations for a bottom-up approach to implementing integrated climate action commitments. Understanding the interconnectedness and interdependencies between sector policies, climate actions, and supranational development plans could catalyse and accelerate sustainable development while building resilience, through a multi-sectoral approach. We posit the need for a transdisciplinary, WEF approach to catalyse cooperation for development and climate action in East Africa. Ultimately, a transdisciplinary approach focused on equity, social justice, sustainability, and a just transition is required to support development agendas.

1. Introduction

Increased anthropogenic pressures have accelerated the impacts of climate change from predictable climate variability to

* Corresponding author.

E-mail address: j.susnik@un-ihe.org (J. Sušnik).

<https://doi.org/10.1016/j.crm.2025.100760>

Received 24 July 2025; Received in revised form 13 October 2025; Accepted 27 October 2025

Available online 1 November 2025

2212-0963/© 2025 The Author(s). Published by Elsevier B.V. This is an open access article under the CC BY-NC license (<http://creativecommons.org/licenses/by-nc/4.0/>).

uncertain, adverse, intense and frequent extreme weather events (Armstrong McKay et al., 2022; Bornemann et al., 2019; McGregor and Ebi, 2018). This has resulted in unmanageable global climate risks, inadequate response time and capacity to respond (Bodansky, 1993; IPCC, 2014; Keen, 2022; Ngcobo et al., 2013; Scott et al., 2020; UNFCCC, 2015). The 2023 Intergovernmental Panel on Climate Change (IPCC) report predicts exceeding 1.5°C warming compared to the pre-industrial era (IPCC, 2023a, 2023b). More alarmingly, predictions from various Global Climate Models (GCMs) point to an increasingly realistic possibility of exceeding 2°C (Armstrong McKay et al., 2022; Hoegh-Guldberg et al., 2019; IPCC, 2014, IPCC, 2018b; Rogelj et al., 2016). Anthropogenic pressures are the dominant catalytic drivers for shifting from natural weather variability to climate change extremes (Chirambo, 2020; Hoegh-Guldberg et al., 2019; IPCC, 2022).

Against this backdrop, the impacts of climate change disproportionately affect the least developed and developing economies (Camazzola, 2023; Overland et al., 2022; Trisos et al., 2022). Paradoxically, the countries with the lowest greenhouse gas (GHG) emissions in Africa are among the most climate-vulnerable countries. Furthermore, the continent is recording a rapidly growing population, increased food poverty, degrading environmental resources, increasing demand for infrastructural development, and intense extreme weather events. The combination of these factors has galvanized national and regional climate action ambitions to secure natural resources in the face of accelerating global change. However, fragmented policy and governance coherence (John et al. 2023; Suda et al., 2024) mean that management and development of resources are still sub-optimal and often have contradictory goals.

In this context, the study adopts a water-energy-food (WEF) nexus approach to answer the question- are nationally determined contributions, national adaptation plans and regional development in the EAC context interlinked?. The WEF approach encourages a system-thinking modality through which the interconnections between WEF sectors are considered (Albrecht et al., 2018; Boas et al., 2016; Hoff, 2011). It provides an integrated and holistic framework that progresses beyond a siloed approach in developing natural resources management strategies (Hoff, 2011). For instance, water systems are developed to meet projected energy and agricultural demands that vary from domestic to industrial scales. The WEF nexus approach can support linking people and developmental outcomes through coordination and collaboration across WEF resources security in the long term through enhanced coordination of plans and policy (Lucca, 2025). The biggest challenge is the highly fragmented (siloed) operationalization of development and climate action strategies across national and regional scales (John et al., 2023; Suda et al., 2024). Specifically, this study fills research gaps on assessing how the East African Community (EAC) region adaptation and mitigation approaches premised on the Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs) developed under their commitments to the Paris Agreement, and their alignment with the Africa development agenda, can be better linked and harmonized with development using a WEF nexus lens. It explores the interlinkages between national demands (i.e. food, water, energy), shared resources management, sustainable development, and climate action, and further explores whether the WEF nexus approach considers cross-sectoral, multi-level, intra and intergovernmental collaborations in the EAC region in terms of adapting to the climate crisis whilst meeting the demands of a rapidly growing population via the NDCs and NAPs. Through this, the research contributes to knowledge by setting a foundation to unpack the intricate interlinkages espoused by complex multi-actor governance scenarios regarding climate action, sustainable development and contextual demand pressures.

1.1. Study objectives

This study aims to:-

- i. Analyze the policy content of NDCs, NAPs and regional development strategies in the EAC to identify implied interlinkages and conflicts,
- ii. Assess through key informant interviews, the practical, on-the-ground linkages and challenges in operationalizing these policies within the Lake Victoria Basin's riparian states,
- iii. Identify the key synergies and trade-offs in policy and practice,
- iv. Evaluate the potential of the WEF nexus approach to bridge these gaps

1.2. Global climate crisis context

The IPCC points out three major global climate risks (i.e. global mean sea level rise (GMSL), increasing GHGs, and rising global mean temperature) and advocates a scientifically robust foundation for policymaking with emphasis on a globally coordinated connection of mitigation and adaptation framework to deal with these crises (IPCC, 2022, 2023b). The United Nations Framework Convention on Climate Change (UNFCCC) aims to operationalize global cooperation for climate change action using cooperation frameworks such as the Paris Agreement and Kyoto Protocol (Rogelj et al., 2016; Tompkins and Amundsen, 2008). The industrial era's demand-driven growth, fuelled by population expansion, the need for food, energy, and water, has accelerated anthropogenic emissions, leading to extensive infrastructure developments that disrupt natural climate stability (IPCC, 2018c; Masson-Delmotte et al., 2019; Shukla et al., 2019). Moreover, while anthropogenic emissions are the major driver of climate change, natural factors such as invasive species and extreme natural events also contribute to the rising rate of global warming, complicating mitigation efforts (Gaba, 2021; Mabhaudhi et al., 2018; Overland et al., 2022; Sušnik and Staddon, 2022).

Overall, climate change has negatively affected and altered ecosystems (Jayaraman, 2015; Shukla et al., 2019), and human systems worldwide (Chirambo, 2020; Hoegh-Guldberg et al., 2019; Masson-Delmotte et al., 2019). In the African context, climate change has directly and indirectly affected aims and led to adjustments to the development agenda (Mpandeli et al., 2018; Taguta et al., 2022; Walker et al., 2022). These impacts create two main multi-level government approaches (Pretorius et al., 2021). On the one hand, is the

logic of optimality whereby the governments utilize jurisdictional mandates, often bestowed upon line ministries, to manage shared resources. On the other, is the logic of community whereby governments appreciate that the optimal functionality of jurisdictional mandates does not purely determine governance. Rather, it is significantly influenced by factors like *trans*-basin communal connections (i.e. communities living in transboundary basins), and language (Diallo and Wouterse, 2022). To mitigate and adapt, government departments should combine the multi-level government approaches, but the extent to which a balance between these can be met is challenging.

Global adaptation and mitigation measures transcend national and supranational economic strategies and climate action frameworks (Falkner, 2016; Mabhaudhi et al., 2016; Mpandeli et al., 2018). National governments regulate critical policy levers like efficiency standards and building codes, while sub-national governments bear extreme events' impacts (Mabhaudhi et al., 2018; Mullan et al., 2013). However, regional economic blocs endeavour to create holistic collaboration and cooperation frameworks for climate action (Mullan et al., 2013; Overland et al., 2022; Walker et al., 2022). Thus, it is national governments that are primarily responsible for developing national policies that strengthen collaborations from sub-national to supranational scales. We posit that global climate action collaborations can be effectively built on NDC ambitions. For example, coordinated efforts to reduce emissions GHG through nexus-doing as argued by (Huang et al., 2025; John et al., 2023; Taguta et al., 2022) support the collective global warming limitation goal of 1.5 °C- that is central to NDCs. Such alignments boost accountability as well as foster synergy between national policies and global climate goals. At the national and regional level, these ambitions are actualized through the NAPs, meaning the NAPs provide the operational implementation modalities across sectors and are often aimed at meeting demands for food, water, energy security while adapting to climate risks. However, it is challenging for nations to consult with one another unless there are robust regional policy frameworks and organizational instruments.

1.2.1. Nationally determined contributions (NDCs)

NDCs can be defined as a set of national non-binding commitments to actualize the Paris Agreement goals (Chirambo, 2020; Mills-Novoa and Liverman, 2019). The Paris Agreement endeavours to reduce GHG emissions to mitigate climate change (Bodansky, 1993; Mills-Novoa and Liverman, 2019; Mullan et al., 2013). NDCs are intended to be the global cornerstones to operationalize UNFCCC goals (Chirambo, 2020; Marchant et al., 2018; Mills-Novoa and Liverman, 2019; Ozor et al., 2020). They are divided into mitigation and adaptation goals (Mills-Novoa and Liverman, 2019; Ozor et al., 2020). Mitigation goals target the reduction of GHG emissions by, e.g., shifting to green energy, and implementing emissions regulation policies across the water, energy, transport, and agriculture sectors (IPCC, 2018c; Revi et al., 2022). Adaptation goals focus on developing strategies to improve resilience to climate change (IPCC, 2023b; Masson-Delmotte et al., 2019; Revi et al., 2022). Adaptation measures like disaster preparedness, climate-resilient infrastructure, and climate-smart agriculture, together with mitigation measures like policy scenario planning, require solid climate-and development-affiliated data often recorded and stored at sub-national levels (Biesbroek et al., 2010; Vörösmarty et al., 2024). The sub-nationally recorded data subsequently provide an amalgamation of composite characteristics that, when available, can be compiled to show the overall state of national resources security (Mabhaudhi et al., 2018; Simpson and Jewitt, 2019; Simpson et al., 2021).

NDCs are the actionable policy tools for implementing the Paris Agreement. Devolved to the national scale (i.e. every state develops, submits and implements specific climate change adaptation commitments), NDCs have a five-year revision/update cycle whereby every nation assesses and updates the national climate change mitigation and adaptation plans. The NAPs are the systematic, national medium-and long-term adaptation and mitigation climate change targets (Chirambo, 2020; Mills-Novoa and Liverman, 2019). The overarching goal for developing NAPs is to provide an implementation vehicle to achieve NDC ambitions. These plans in the EAC are embedded in cooperation for shared resources management, integrated infrastructural developments, and cross-sectoral partnerships. Adaptation and mitigation strategies inherently consider water, energy and food and proposes that a WEF approach can catalyse the cooperation for climate action, development and equitable exploitation of natural resources.

2. Methodology

2.1. Description of study area

The transboundary Lake Victoria Basin (LVB) is one of East Africa's most populous transboundary basins. The population in LVB is approximately 40 million people, and about 60 % live in rural areas (LVBC, 2015; Marchant et al., 2018). Covering parts of Burundi (7 %), Kenya (22 %), Rwanda (11 %), Tanzania (44 %) and Uganda (16 %) in the EAC (LVBC, 2015), the LVB basin plays critical ecological, economic, and social roles in regional development and integration. In particular, major characteristics of LVB include:

- The EAC-LVB strategic regional development and management programmes for cooperation on climate change adaptation and mitigation;
- Increased pollution (industrial and domestic) of Lake Victoria resulting from a push for food security;
- Increased deforestation (approx.70–80 % forest loss) across the LVB, mainly due to agricultural expansion and infrastructure development;
- A population of 40 million inhabitants across the five countries exploiting the basin's natural resources for food, water, and energy security.

The LVB basin provides a wider regional profile for studying how NDCs, NAPs, and regional development are interlinked in the EAC

context.

The LVB is upstream of the Nile River Basin, comprising some of the world’s largest lakes, rivers, and wetlands (Fig. 1). It covers approximately 195,000 km² and is a major regional resource base for the EAC (LVBC, 2015), while Lake Victoria itself, with an area of 68,800 km², has been central to regional operations, especially between Kenya, Uganda and Tanzania. Tanzania contains 51 %, Uganda 43 % and Kenya 6 % of Lake Victoria’s area (LVBC, 2015). Approximately 33 % of Lake Victoria’s inflow comes from River Kagere (Rwanda, Uganda, Burundi and Tanzania), 5 % from Mara River, 15 % from Nzoia River and 5 % from River Yala, all in the Kenyan part of the basin (LVBC, 2015).

In this study, the focus is on the riparian nations (i.e. Kenya, Tanzania, and Uganda). Hence the findings should not be over-extrapolated to represent the entire EAC. Rather, these findings highlight contextual connections between the riparian states that significantly influence the larger basin. The basin lies in the equatorial climate zone characterized by a bi-modal precipitation pattern, with annual rainfall varying between 2400 mm (in Uganda) and 1,350 mm (in Kenya) with a short rainy season (October–December) and longer rainy season (March–May) (LVBC, 2015; Marchant et al., 2018; McGregor and Ebi, 2018). Agriculture and fishing are the main livelihood activities. Other socio-economic activities include sand mining, beekeeping, and gold and minerals mining, with urban populations engaged largely in entrepreneurship.

2.2. Data collection

Contextually, NAPs, NDCs and sustainable development create conceptual interlinkages between national policy, regional and global instruments. Thus Fig. 2 is a conceptual framework used in this study.

2.2.1. Policy documents

This study applied a stepwise document identification approach, summarised in Fig. 3, employing a mixed qualitative approach to explore the interactions between development and climate change action within the EAC context using the WEF Nexus approach as a framework for analysis. First, a comprehensive desktop study of continental development and cooperation strategies (i.e Comprehensive Africa Agricultural Development Programme (CAADP), Agenda 2063, Feed Africa Strategy 206–2025 (FAS-2016–2025), Financing Climate Action in Africa, 2023, Continental Africa Water Investment Programme) was conducted. Second, a content and coherence analysis of the NDCs and NAPs for Kenya, Uganda and Tanzania was conducted.

Five continental African strategic development blueprints, one EAC strategy, and NDCs were already predetermined, submitted and available on the NDC and Africa Union registry websites. Inclusion criteria were developed as follows: (1) the five continental Africa Development blueprints and updated NDCs; (2) NAPs and national policies on climate change adaptation and mitigation; (3) regional development and cooperation plans and strategies directly linked to climate change action sectors; (4) other relevant EAC climate change grey literature, and economic documents cited in NDCs, NAPs, and national policies. A total of 36 documents were identified (Supplementary Table 1.1). The corpus scope comprised of 28 national-level documents (i.e. Kenya –10; Tanzania –10, Uganda –8)

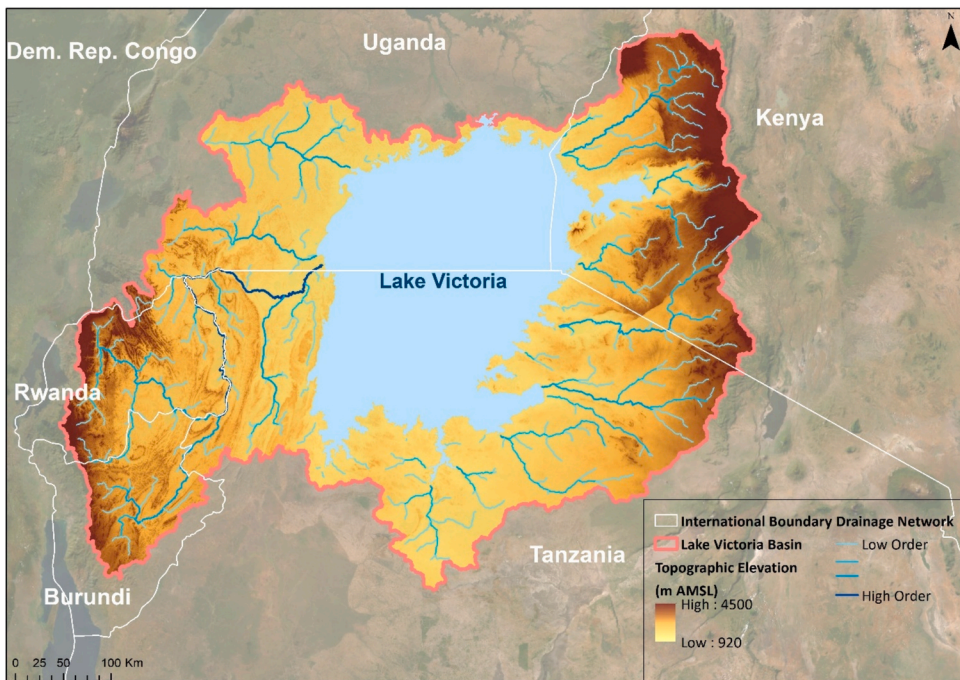


Fig. 1. Map of the Lake Victoria Basin. Map created by the author using ArcGIS data.

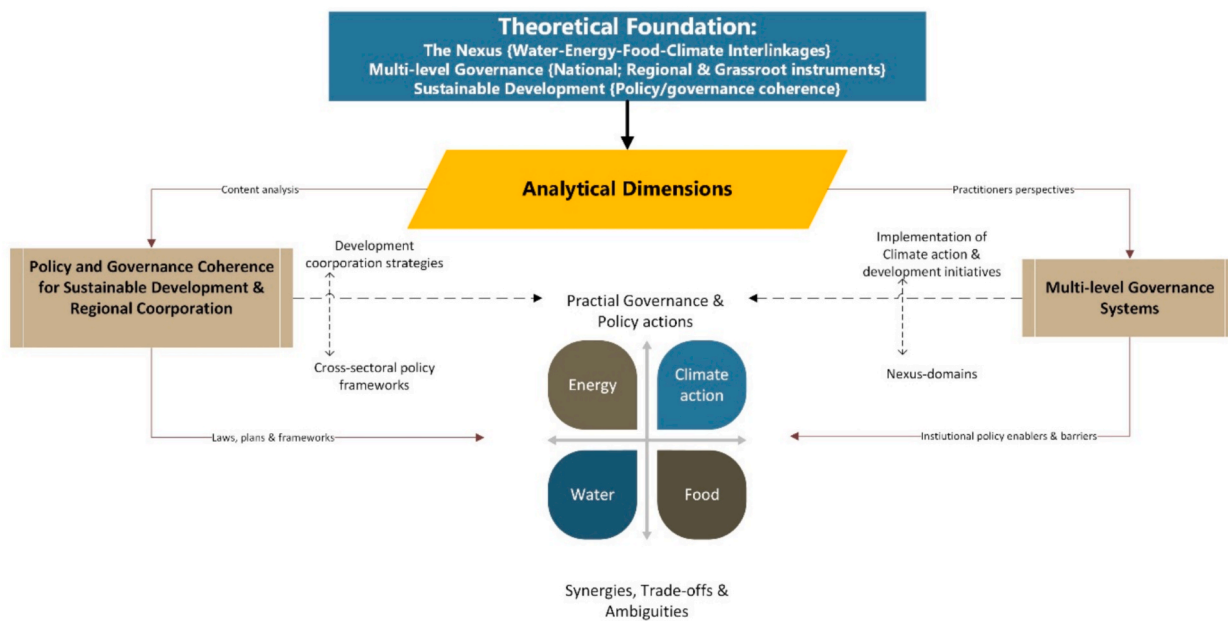


Fig. 2. A conceptual framework for Climate-Development Nexus in the LVB.

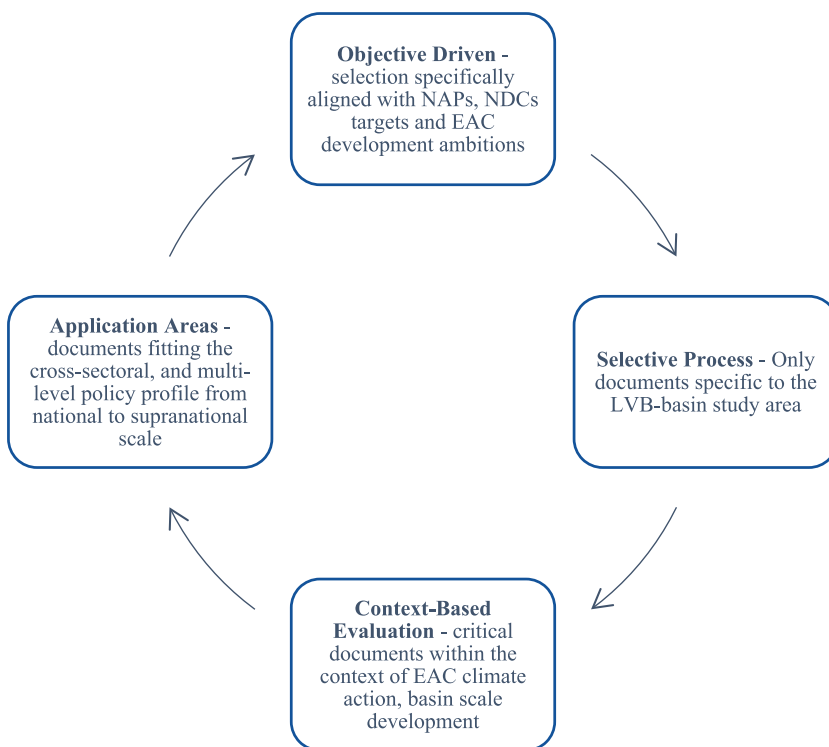


Fig. 3. Stepwise purposive document identification.

and 8 regional/continental in focus. Corpus types included policies (n = 13), strategies (n = 10), acts (n = 2), plans (n = 9) and development frameworks (n = 2)- all published between 1999 and 2023.

2.2.2. Key informant interviews

A purposive sampling approach was adopted to select key informant interviewees (KIIs). Purposive sampling is a sampling

approach whereby respondents are selected based on their knowledge, experience, and expertise in a specific context combined with their comprehension of a specific problem (Creswell and Poth, 2016). Thirty key informant interviewees (KIIs) were selected across Kenya –11, Uganda –8, and Tanzania –11, summarized in [Supplementary Table 1.8](#). These participants were drawn from 12 main climate action line ministries and covered water, energy, environment, and agricultural sectors. The respective nations' UNFCCC points of contact and regional institutions (i.e., Lake Victoria Basin Commission and EAC secretariat) also contributed as KIIs. The KIIs distribution was proportional to specific institutional landscapes (i.e. tripartite institutional arrangements in the LVB) targeted at minimizing operational ambiguities. Thus a snow-balling approach was employed based on approximate years of expertise and hierarchy in terms of designing and implementing supranational actions. Thematic saturation was achieved between 25th (Theme B) and 30th (Themes A&C) KII's. Finally, a thematic analysis was employed to analyse and match data derived from content analysis.

To achieve the study objectives- exploring the interlinkages between NDCs, NAPs and EAC development agenda, and how a WEF-nexus approach impacts the cross-sectoral and multi-level partnerships in the EAC-KIIs data was collected via face-to-face, telephonic, and virtual (online) interview methods. All interview sessions were recorded with the express permission obtained from the interviewee and anonymously coded for analysis. Further, these records were transcribed verbatim and analysed, applying an established thematic analysis approach. The analysis process applied the six-phased approach proposed by (Terry et al., 2017). First, data familiarisation entailed scanning through the data to get overall meaning. Phase two and three (i.e. code generation and construction) were skipped due to a predefined theme structure from CA, meaning themes were predetermined and applied deductively to the KIIs. Phases four and five (i.e. definition and naming of potential themes) were guided by themes emanating from the CA approach. [Table 1](#) summarizes emergent themes from this process.

2.3. Data analysis

2.3.1. Content analysis of core documents

[Terry et al. \(2017\)](#) describe content analysis as a constellation of approaches that can be applied to conduct systemic examinations to identify themes, intents, and patterns. For this study, a combination of summative content analysis (CA) and conventional CA was applied. Summative CA mainly focuses on counting and comparing keywords, followed by interpretation of the contextual factors. Conventional CA focuses on the content of the selected documents ([Hsieh and Shannon, 2005](#)). [Hall and Steiner \(2020\)](#) argue for the need to develop a stepwise CA approach for clarity in analysis. The CA approach for this work employed the following six steps:

- i. Searching for and compiling the updated NAPs and NDCs;
- ii. Identifying the main continental Africa development and cooperation blueprints;
- iii. Identification of EACs regional economic cooperation and LVB development strategies;
- iv. Identifying core keywords and primary themes through qualitative inductive text reading;
- v. Employing Atlas.ti for quantitative policy attributes and trends using keywords;
- vi. Thematic evaluation of Key interview informant (KII) findings using qualitative deductive comparison

2.3.2. Survey data analysis

Several steps were incorporated for the content analysis of the Climate Action Policies (CAPs), NAPs and NDCs. First, a keyword list was created as the foundation for a standardized analysis. This keyword list in [Supplementary Table 1.9](#) was developed from national and regional climate action and regional development (RD) interests. The list includes: WEF nexus, CAPs and RD, interlinkages, adaptation, mitigation, regionalization, food security, water security, energy security, ecosystem integrity, biodiversity, emission, sustainable development, resilience, synergies, ambiguities, and tradeoffs. Crucially, the keyword truncation and stemming approach in this work was confined within predetermined databases (i.e. the UNFCCC-NDC registry, Kenyan, Tanzanian and Ugandan national policy, and African Union databases). As such, singular standardized truncation approach was not employed due to different database syntax and indexing. Conventional CA was applied for the NAPs and national climate policies content analysis. Using Atlas.ti, the analysis continued with a search to identify keywords and their frequency of occurrence. Atlas.ti was used because of its robust coding capability to deal with overlapping and multiple codes whilst maintaining the original context. Atlas.ti autogenerated document

Table 1
Themes emanating from the LVB-EAC Study.

Themes	Sub-themes
A. Interlinkages between CAPs, WEF and RD	Interlinkages between CAPs and WEF Interlinkages between CAPs and RD Interlinkages between WEF and RD
B. The extent to which policy and legislative support/promotegovernance/ policy connections/collaborations	Content in CAPs and strategic plans promoting governance/policy coherence Content of WEF-centric national policies and blueprints promoting governance/policy coherence Content of RD strategies blueprints promoting coherence
C. Potential synergies, tradeoffs, and ambiguities for not/or explicitly using content to promote interlinkages	Synergies, tradeoffs and ambiguities for coherence between CAPs and WEF strategic blueprints

coding- ‘D-code’ (Supplementary Table 1.1). Further, an inductive and deductive document coding exercise was applied based on the following code clusters: Climate Action Plans (CAPs); WEF-Nexus (WEF), and Regional Development (RD). Inductive coding entailed document analyses to establish core themes, while deductive coding entailed a systematic document analysis to establish the inter-linkage pathways. The aim was to quantify the frequency of every code per document. Keywords were used to identify and exhaustively read key documents for text analyses and verification. Regarding methodological limitations, the approach employed in this study did not incorporate standardized empirical data on key regional components like resource allocations flows and socio-economic impacts because there lacked specifically such standardized quantitative or empirical measures within the study area. Therefore including such outcomes in this work would potentially create bias. However, inclusion of such in cases where standardized measures are available is highly encouraged.

3. Results and Discussion

3.1. Continental Africa climate change action and development agenda

Africa’s development agenda can be categorized into four priority areas situated in the WEF-Nexus sectors, namely:

- i. Increasing food security and enhancing actions for food emergencies;
- ii. Improving energy, water, transport, and communication infrastructure for economic growth;
- iii. Diversifying land and water management approaches to address population growth and climate change pressure;
- iv. Improving research on agriculture, energy, and technology adoption for increased productivity and socio-economic growth.

These priorities reflect a continental paradigm shift toward resource security, achieved through the governance of shared resources across jurisdictions. This is particularly pertinent given that 70 % of Africa’s population depend on rainfed agriculture, despite 75 % of the landmass being arid or semi-arid (African Union Commission, 2015; Malzbender and Earle, 2009). Further, 60 % of agriculture-dependent communities are prone to food poverty. The increased vulnerability argued by (Armstrong McKay et al., 2022; Bornemann et al., 2019; Walker et al., 2022) was reiterated in the document analysis and by all KIIs. Climate vulnerability is deeply entrenched, with severe droughts, flash floods, and land degradation creating pressures on critical infrastructure and food production systems (Armstrong McKay et al., 2022; Walker et al., 2022). The document analysis and KIIs collectively suggest that development cooperation in Africa has been catalyzed by five key drivers: rapid population growth, urbanization, shrinking agricultural land, climate shocks, and expanding land-use frontiers. These drivers are shaping an increasingly integrated development agenda, albeit one that is beset by inter-sectoral tradeoffs and governance fragmentation.

Continental scale analysis illustrates WEF-nexus interlinkages aimed at achieving the four development priorities. For example, Africa’s food security ambitions in D33 and D36 targeted the expansion of irrigation agriculture, while D31 targeted increasing the resilience of water infrastructure as a catalyst for job creation. In practice, interlinkages in the LVB combined jurisdictional mandates (logic of optimality) with on the ground socio-political context (logic of community) to respond to resource demands or extreme events. However, as Allouche, Middleton, and Gyawali (2015) posit, situating the WEF nexus as the predominant techno-managerial coordination catalyser risks overlooking underlying structural inequalities that impact access and control of shared resources. Notably (Allouche et al., 2015; Sušnik and Staddon, 2022) caution that a nexus approach could potentially create power asymmetries depending on contextual factors such political and economic stability. This underscores the importance of (Daher and Mohtar, 2015; Javan et al., 2023) propositions to adopt dynamic system approaches by incorporating critical stakeholders in a nexus setting. Nonetheless, increased resource scarcity negatively impacts the availability of sufficient food, reliable energy, and sanitation. Hence adopting a nexus approach was a preferred policy to practice tool. Others argue (Hussein and Ezbakhe, 2022; Mabhaudhi et al., 2018; Mpandeli et al., 2018) that the WEF-nexus risks becoming a typical policy buzzword, undermining nexus-doing at the grassroots level (John et al., 2023; Nhamo et al., 2020).

3.1.1. Nexus framing and operationalization

The WEF nexus functions as a regional framing device to diagnose competing demands. However, operationalizing this reveals inherent contradictions. For example, NAPs prioritize land and infrastructure expansion to address socio-economic demands, whereas NDCs aim to reduce emissions. These agendas often compete, particularly when food production increases water extraction, energy consumption, and pollution loads (D32, D36). Deliberate coordination is needed to design and consider WEF-nexus resource optimization measures as a catalyst for economic growth. This is built on nationally designed policies and plans as principal governance instruments. However, the scope spills over to the regional/continental scale during implementation. Some actions result in clear tradeoffs. For example, increasing the total arable land (food security), or a pandemic outbreak significantly increases water and energy demands for irrigation and health (Al-Saidi and Hussein, 2021; Nhamo et al., 2025), potentially impacting neighbouring nations. D32 and D36 hint at such competition. All KIIs agreed that implementing the development agendas in a nationalistic approach increased competition for common resources.

Empirical evidence from KII interviews confirms that while nexus thinking has to some extent been mainstreamed into discourse, nexus-doing – the translation of integrated thinking into operational coherence-remains fragmented. Thus, the WEF nexus in the African context acts as both an aspirational framework and a proto-implementation tool. National resources demand pressures created a common multi-government interest for continental development partnerships. D33, D35, and D36 posit that these partnerships have positively contributed to Sustainable Development Goals (SDGs) 1, 2, 3 and 13 reinforcing (Al-Saidi and Hussein, 2021; Nhamo et al.,

2025) arguments for implementing polycentric approaches. However, regionalization of resources could create operational frictions, meaning that efforts to optimize shared resources in a region were constrained by national policy instruments. For instance, in extreme climate events such as flooding, governments often revert to emergency-centric (John et al. 2023), ad hoc coordination, sidelining longer-term multi-government approach. Therefore the degree of coordination as revealed through KIIs depends on contextual factors.

Resources pooling budgetary allocations from national budgets and development partnerships ranked highly among KIIs to support cross-sectoral coordination. Underlined by a US\$30 billion/year budgetary requirement to achieve Africa's water security, financial partnerships have tried to eliminate systemic investment bureaucracies in economic blocs (D31 & D33). Ultimately, development-driven partnerships at the continental level are increasingly premised on multi-level, cross-sectoral collaboration which has proven difficult to achieve. Mitigation and adaptation responses in the African context are delayed and insufficient to restore the environmental and socio-economic conditions before an extreme event (Pretorius, Drewes, and Gumbo, 2022; Trisos et al., 2022). This means that the recovery process takes longer, requires greater financial resources, and is often operationalized in siloed phases that eventually fail to restore the baseline scenario (Diallo and Wouterse, 2022; Trisos et al., 2022), assuming such a scenario is realistic and/or desirable.

3.2. Practitioners Perspectives on coherence and Silos

LVB's climate action approach is a constellation of decision-making arenas, often within line ministries and differentiated along functional and territorial dynamics. It is a multi-level governance approach (cf. Bache et al. (2016)) catalysed by competition between EAC nations to achieve national resources security. Nationally, sector-specific national policies (D1 to D30, Supplementary Table 1.1) are designed to manage resources, which in practice are often competing. To this extent, ministry departments autonomously focus on exploiting natural resources for food, water, and energy security. Increased resource exploitation implies increased competition for resources. Nonetheless, synergies are sought to address recurrent floods and droughts that endanger critical infrastructure, but not when concerning resource exploitation. For instance, recent flooding events have caused severe damage to water, road networks, energy, and communication infrastructures. Consequently, national priorities shifted from optimising food, water, and energy security to rebuilding critical infrastructure. As reported by multiple KIIs, such extreme events are not a factor in national policy instruments.

"Floods are a real risk to us; in such times, there's no water boundary or national policy that transfers responsibility or urgency to one nation or department. On the contrary, it's all hands on deck to adapt and minimize the damage- all departments, governments, development partners all" (Participant, 3, 5, & 8, July 2024; 17,19 & 27 October 2024)

The region demonstrates vertical and horizontal hierarchies (John et al., 2023), whereby national food, energy and water security are the main policy obligations. To achieve these objectives, ministry departments formulate and execute food, water or energy security plans (vertical cooperation) (Suda et al., 2024). As (John et al., 2023; Suda et al., 2024) argue such tripartite configurations create horizontal cooperation comprising ministerial teams across in this case between the Kenyan, Ugandan, and Tanzanian governments, creating linkages between national policy objectives and regional development and sustainability ambitions. These linkages were evident in East Africa's long-term strategy (D32). Industrializing agro-processing, petrochemicals, pharmaceutical, gas, mining, energy and bio-fuels sectors were underpinned by state and private sector partnerships. Public private partnership (PPP) principles empower a basin-scale governance framework aligning national demands with regional development plans. (Nhamo et al., 2020; Taguta et al., 2022) highlight that interlinkages come with contextual complexity, operational design, and strategic fluidity. They exhibit a decentralized model whereby different actors across the LVB are simultaneously involved in various decision and planning processes. For instance, the operationalization of basin-wide climate action plans between the 12 line ministries in the riparian countries is amalgamated under the LVBC to minimize operational challenges while optimizing the net effect of resources management and interventions (i.e., seeking synergies). Importantly, these processes are driven by coordinating institutions (i.e line ministires, basin-wide water utilities, basin authorities) under the EAC community charter. The prioritization of power, resources, and responsibility shifts across the different government levels, subject to contextual factors (Cantor et al., 2025; Nhamo et al., 2025).

3.3. Development, Adaptation, and mitigation in the LVB

The LVB-EAC development agenda is rooted in a multi-dimensional infrastructure development alignment between national demands and regional targets (African Union Commission, 2015; John et al., 2023). The 5th (2015–2020/21) and 6th (2021–2026) EAC development strategies focus on development to boost economic growth through incentivizing agriculture expansion. Documents D1-D36 strongly link the water, energy, and agriculture (food) sectors as the main multi-level policy and governance pillars. About 65 % of EAC's agriculture relies heavily on irrigation and accounts for about 30 % of EAC's gross domestic product (GDP). Yet, agriculture contributed 67 % of intra-regional trade and 70 % of employment regionally (Andanje et al., 2025; John et al., 2023). Energy poverty was identified as a major regional challenge by KIIs. Energy availability and accessibility stood at approximately 45 % (Tanzania), 50 % (Uganda) and 75 % (Kenya) indicating significant energy poverty. NAP objectives effectively targeted increasing food and energy security through agriculture expansion and infrastructure development, putting significant pressure on LVB's water resources.

The adaptation and mitigation agendas focus on enhancing the capacity of the existing water, energy and food infrastructure to cope with extreme events and insufficient funds. Additionally, the state of existing infrastructure was identified as a critical entry point for linking NAPs with NDCs, particularly by tackling the negative impacts of existing establishments, such as reducing carbon emissions from biomass and power plants (Allouche et al., 2015; Chand et al., 2025; Vörösmarty et al., 2024) summarized in Supplementary Table 1.3. To this extent, the LVB espouses interlinkages between policy aspirations and implementation. As two senior-level policy

KIIs argued, these interactions do not always create synergies (John et al., 2023; Suda et al., 2024). For instance, Kenya's 76 % electricity coverage was a key pressure to the region's water resources. While agriculture expansion priorities increase water competition, they also increase the risk of pollution from poor management of farm inputs:

"Development, in our region, is a delicate dance between food, water, and energy need/demands versus the scarcity of financial, natural resources compounded by the yesdifferent socio-political desires by member states...." (Participants 33 & 35 November 2024; 21,26 & 29 October 2024)

3.3.1. Emerging climate action and development interlinkages

Interlinkages between the selected CAPs, WEF and RD approaches are summarised in [Supplementary Tables 1.4–1.6](#). They are based on thematic keywords in national policy documents on climate action in the LVB. These interlinkages do not imply actual connections in the execution of targets, nor do the number of occurrences of a keyword imply actual interlinkages. Additionally, the keyword coding approach did not explicitly do an in-depth multi-sector quantitative analysis of the economic, hydrological or environmental risks reported in different ministerial departments per country or the LVB. Zooming in on national food, water, energy, and development demands was critical in understanding the nexus between regional policy ambitions, national demands, climate action and operational arrangements.

The interlinkages between sectors across scales were guided by the NAPs/ CAPs & NDCs objectives ([Supplementary Tables 1.2 and 1.3](#)) and targets recorded in national policy documents and development blueprints. Further analysis revealed that the intention in the NAPs and development plans implied operational synergies and tradeoffs. In practice, development goals and policy objectives reiterated ([Andanje et al., 2025; Nhamo et al., 2025](#)) arguments that objectives often compete, creating a need for prioritization. Keyword frequencies implied the strength of the relation between policy objectives and development goals, with the main interlinkages implied between CAPs, RD and WEF documents being summarised as follows:

- i. Strategic development interlinkages – linking national (in D2,6,9,10,17,18,19,21,24,25,29) with regional development goals (D31 to 36);
- ii. Climate action interlinkages – aligning national adaptation/mitigation ambitions (in D3,4,5, 6,11,15,16,22,23,30) to regional development goals (D31 to 36);
- iii. Governance interlinkages – linking national policies (in D1,7,8,12,13,14,20,26,27,28, 30 and regional development plans (D31 to 36).

Operationally, LVB's pressures spread beyond national jurisdictions, with population growth and climate change impacts extending beyond national scales (John et al., 2023; Taguta et al., 2022). Particularly, floods and droughts increase strains on infrastructure. Moreover, EAC's free trade economic area agreement was argued to enable transboundary migration, potentially increasing the strain on LVB's resources ([Andanje et al., 2025](#)). Regional development emphasized expanding cooperation as a catalyst for value addition, trade cooperation and strategic collaborations across member states. KIIs reported that actualizing the treaty's ambitions and other EAC development plans significantly increased local competition for available resources. The NAP objectives, summarised in [Supplementary Table 1.2](#), in the Kenyan, Tanzanian and Ugandan contexts primarily target infrastructure development to address the increasing demand for employment, food, energy and water security.

KII interviews highlighted three main findings:

- i. The connections between NAPs, NDCs, and regional development objectives were competing with national ambitions- i.e. competition between increased demand for resources, extreme events, and availability of natural resources;
- ii. Competition for shared resources catalysed strategic policy alignments basin-wise. These strategic alignments were the principal anchors for regionalizing sustainable development and climate change action;
- iii. Implementing the NAPs, NDCs and CAPs ambitions strongly depends on exploiting available water and land resources at a transboundary level.

Three senior government interviewees acknowledged active vertical and horizontal governance cooperations for coherence at the LVB level-agreeing with ([John et al., 2023; Suda et al., 2024](#)) findings on policy and governance coherence configurations in EAC.

"Essentially, the EAC region shares resources such as Lake Victoria at government to government (G2G), government to communities (G2C), and community to community (C2C) levels. In practice, different ministerial departments from Tanzania, Kenya, and Uganda engage with issues on different scales. For policy positions, the G2G, which is predominantly horizontal in nature, is preferred, while for emergencies, a hierarchical sector-based approach is employed in close coordination with partner departments." (Participants, 4, 6, 13, July 2024).

The coordinating institutions included government departments, and development partners where key interviewees were based. A summary of these institutions is provided in [Supplementary Table 1.8](#).

3.3.2. Thematic keyword clusters analysis

Three thematic keyword clusters were identified from the analysed documents ([Supplementary Table 1.1](#)): CAPs & WEF codes (2429 times); CAPs & RD codes (3116 times); and WEF & RD codes (2818 times) ([Supplementary Tables 1.4–1.6](#)). The code 'WEF –

food, water, energy security-CAPs' had the highest occurrence (547 times), suggesting basin-wide strategic alignment between adaptation plans and resource security. In this context, coordination across government levels aims to enhance the adaptive capacity of existing infrastructure and increase productivity (Andanje et al., 2025; John et al., 2023). The 'CAPs & WEF' (CAPs-shared resource management-WEF: 35 quotations) scored the lowest occurrence. The weak density suggests the potential lack of consideration of how shared national and regional development plans impact resources such as land, and water. The interlinkages between CAPs and RD focused on socio-economic development and climate resilience. In particular, code 'CAPs-climate resilience-RD' recorded the highest cluster density (390 times). In summary, code frequencies (e.g. 2,429, 3,116 and 2,818 quotations) are illustrative density indicators denoting the breadth of coded materials spanning 650 main and numerous sub-codes, but are interpreted qualitatively rather than as statistical measures for importance. Therefore, raw frequency counts should not be over-interpreted as importance indicators or actual connection strength in practice. It is noted that a key challenge with Atlas.ti is that keyword frequencies cannot represent actual connections or dominance of connections. Moreover, these frequencies do not directly imply competition, synergy or tradeoffs in practice. This may result in ambiguity when analysing how NAP objectives connect and align with NDC targets. Thus, such keyword frequency counts must be supported by in-depth document and interview analysis to contextualise each situation, as was done in this study.

Because code density does not represent actual connections, the study sought to interact with LVB development projects to understand how the implied policy connections manifest in practice. Findings pointed to strong water-centric connections between CAPs and RD. In particular, eight regional water service boards are working on rehabilitating and developing water pipelines and treatment facilities. The Lake Victoria South Water and Sewerage Board (LVSWSB) operationalizes development using a devolved approach, in which a centrally positioned actor (LVSWSB) delegates core planning and operational roles to strategic partners (i.e. Kisumu Water and Sewerage Company-Kenya (KIWASCO), National Water and Sewerage Corporation –Uganda (NWSC), and Mwanza Urban Water and Sewerage Authority (MWAUWASA). These utilities, and the the water sector and associated institutions were the centre for cooperation/collaboration for basin-wide development. 32 of the 36 analysed documents were developed post-2000 and explicitly referenced climate change and population growth as interlinked variables to WEF security as argued by (Nhamo et al., 2025; Taguta et al., 2022). Quotations regarding governance and cooperation were centred on optimality (Bache et al., 2016), whereby government departments would centralize and decentralize actions when necessary. For instance, financial resources were mobilized from different government line ministries during floods in the LVB and channelled to LVBC for emergency action. In this context, floods empowered governments to tradeoff their territorial and policy preferences to save lives and property, as recorded from KII 4, 9 & 13 –linking to the CAPs & RD codes.

“In times of disasters (floods), we're not motivated by territorial or policy interests, No. During such periods, we're brothers at war; we tradeoff the territorial interests for the utmost safety of our people” (Participant 4, 9 & 13, September 2024)

Nationally, ministry departments designed policies (D1 to D10) stipulating legal budgetary parameters and ambitions regarding WEF demands. Specific mandates like land ownership and energy production licencing were exclusively controlled nationally. However, mandates such as water supply and allocation are administratively and geographically run at the county level (lower governance level). This creates a dual policy instrument model between ministry departments – horizontal and vertical (ministry departments to county-level departments and utilities), leading to national to county government WEF intersectionality that directly influences the extent to which land, water and energy resources are exploited supporting findings by (Andanje et al., 2025; Cantor et al., 2025; John et al., 2023; Nhamo et al., 2025; Suda et al., 2024) on multi-centricity, intersectionality and complex nexus interconnections emerging in supranational contexts. Tanzania and Uganda policies are coordinated at the national ministry level (D11 to D30). Subsequently, these measures support NDC targets yet are insufficient to meet wider objectives-supporting the implied low code frequency interlinkages between CAPs & WEF. Rather, meeting NDC objectives entails an integrated multi-system approach. Complicating matters, the frequency and intensity of extreme weather events have exacerbated competition for available resources, and KIIs 1, 2, 10,18, and 22 pointed out the operational, organizational and policy ambiguities between resources demands versus environmental integrity. This highlighted the implied trade-off in the frequency analysis between competing interests between governments' plans to ensure WEF security and the subsequent environmental impacts (Andanje et al., 2025; John et al., 2023; Taguta et al., 2022).

“All the EAC governments have a primary obligation to ensure that there is enough food, water and energy for everyone, this has of course not been achieved thanks to severe floods, droughts and other climate change issues, and that's the reason we as governments work together to find the most practical solutions in matters feeding and providing water for our communities regardless of the complexities of policy frameworks” (Participant 2,5 & 18, August 2024).

Additionally, synergies in resource management emphasised adaptation and mitigation approaches. For instance, developing EAC-water infrastructure to meet the increasing demand and cope with the increased frequency of floods (adaptation) linking with WEF & RD codes suggesting connections between resource-driven development. Further, there was a focus on reducing the impacts of existing infrastructure, such as environmental rehabilitation (mitigation) supporting the contextual linkages implied between CAPs & RD; WEF & RD and CAPs & WEF. This implied a link to adaptive capacity in NAP objectives and links to keyword analysis. Specifically infrastructure development as a flood management and mitigation in the flood-prone LVB lowlands, as established by four key informants and in related cases reported by (Andanje et al., 2025; John et al., 2023; Suda et al., 2024):

“Floods in LVB are not only a risk, but also a reality. Nowadays, we are all experiencing extreme short and long rains such that both water and sediment loads overwhelm all available infrastructures; be it roads, hydro-power, water, you name it. As such, we have to work together to try and solve these problems.” (Participants, 1, 9, July 2024; 25, 30, September 2024).

3.4. Regional development and climate action in the LVB

Regional development from an adaptive approach focused on expanding the capacity of existing water utilities to meet national and supranational water demands. Mitigation focuses on increasing the capability of infrastructure to deal with the severity and intensity of extreme events (Nhamo et al., 2025; Vörösmarty et al., 2024). In LVB, the focus is on improving the operational functionality of existing utilities, particularly sustaining the capacity of water and energy utilities to maintain optimal operating capacity during extreme weather events (Andanje et al., 2025). This was identified as a primary source of competition. KIIs acknowledged that balancing national and regional demands often resulted in operational ambiguities in prioritising water uses and users. In this case, a nexus approach is envisioned to combine NAP objectives with infrastructure development plans. Regional development espoused linkages between the water, energy, environment, and agriculture sectors. The connections depict both intentional and unintentional objectives in the EAC region. As argued by KIIs, connections between governments were inherently demand-driven and strategically actioned:

“In the recent past, climate change accelerated deliberate government-to-government collaborations to address emergencies like flooding in Budalangi (Kenya), Jinja (Uganda) and Musoma (Tanzania) at the local level” (Participants, 5,21,26 October 2024).

The interactions between climate adaptation policies and regional development were anchored on infrastructure expansion projects. Findings from KIIs showed that interactions emanate from pursuing development to achieve national demands. Interlinkages in this context exhibited two main levels. Firstly, enhancing the resilience of existing infrastructure was the foundation for development-oriented NAPs. To this extent, interlinkages in the WEF sectors span technological designs, legal agreements, data, organizational arrangements, and implementation mechanisms focused on surviving shocks (resilience) (Nhamo et al., 2025; Taguta et al., 2022). On the other hand, increased pressures, predominantly from extreme events and rapid population growth, catalysed cooperation for incremental changes (transition). Thus, the regional focus is on building the resilience of existing systems to shape, create and implement new advances such as co-financing for regional infrastructure development. Nhamo et al. (2025) argues that such transitions often create cross-sectoral resource planning and management alignment and catalyse cooperation for sustainable development. Therefore, the connections between CAP and RD in the LVB culminated in operational interlinkages, and linked to keyword analysis emphasised in critical policy instruments as summarized in [Supplementary Table 1.5](#), which increase resilience and transition through adaptive capacity.

3.5. Water, Energy, food and regional development.

The EAC region promotes a WEF-nexus-centric approach to development, as argued by (Walker et al., 2022). To this end, connections between NAP objectives, climate change, and development agendas were rooted in land and water utilization (Nhamo et al., 2025). The region manifested a nexus approach in three main levels:

- The policy level exhibited a robust ecosystem of detailed blueprints, laws, and strategic partnership legal frameworks;
- The governance level showed active coordination between line ministries, regional, and continental to provide WEF and employment security;
- The implementation level combined the inputs from policy and governance levels to implement development programmes.

The agriculture sector was identified by KIIs as the most impactful in terms of employment and economic growth, increasing human-induced land use change agreeing with the findings by (Mabhaudhi et al., 2016; Nhamo et al., 2019; Taguta et al., 2022). By extension, the energy sector was presented as a critical enabling sector to achieve food security. Operationally, interlinkages were manifested in agriculture, water for agriculture, and energy for energy (Sušnik, 2022; Vörösmarty et al., 2024). The food and water sectors are the dominant points of government-to-government interactions. Synergies were identified at the basin level to manage public goods spilling over national boundaries. For instance, LBV’s watershed cannot be managed by one nation, yet one nation’s actions impact the entire watershed. Although there are national differences, e.g., in the NDC ambitions, there are strong reasons to harmonise actions and implementation to benefit from WEF security and accumulate gains across nations.

KIIs reported the existence of deliberate coordination to balance agricultural expansion, energy and road infrastructure enhancement, creating a multi-agency, holistic model for regional development. The nexus approach was argued to have already been working, albeit in small-scale cases across governments (Chevalier, 2021; Diallo and Wouterse, 2022; Terrapon-Pfaff et al., 2018). LVB’s vulnerability to extreme events and population growth catalysed the nexus between resource security and development. To this extent, national policy objectives were actualized in joint regional flood and drought mitigation measures. KII’s described these as supranational partnerships for development and climate action.

“In some years, the lake rises to unexpected levels when the rivers reach their peaks, floods then back-up to agricultural lands, houses, and spoil roads, electricity grinds, as well as cause devastating health calamities such as malaria and diarrhoea——Now, in such scenarios, there’s no way we can have a solution if we work in isolation” (Participant, 6, 17, 25 September 2024).

Such strategic alignments supported the policy goals discussed in Sections 3.3 and 3.4, whereby regional development, and adaptation and mitigation interventions were driven by infrastructure development. The interlinkages strongly emphasise economic growth through joint infrastructural development programmes such as the Lake Victoria Water Supply and Sanitation (LVWATSAN) programme (water-centric), the Lake Victoria Environment Program I & II (LVEMP 1&II (food and environment centric), and the Planning for Resilience through Policy Adaptation Research and Economic Development (PREPARED; policy/governance coherence centric) (Andanje et al., 2025; Walker et al., 2022). While all codes exhibited some connection (Sections 3.3, 3.4, and 3.5) and are summarized in Supplementary Table 1.7, evidence from the practitioners (KIIs) established the practical water-centric coordination in the LVB. Basin level ambitions align with NAP objectives and promote a multi-sectoral operation approach. The multi-sectoral connections put the water, environment, energy, and agriculture sectors central to the common goal of dealing with climate-change-induced risks and sustainable development. Therefore, it can be argued that a WEF-nexus approach is evident in the EAC region.

Regarding synergies in the LVB, flood mitigation and management are coordinated at the basin level. The EAC case emphasizes achieving economic growth and food security through a regional shared resources management approach. Programmes like LVWATSAN, PREPARED, and LVEMP I & II aim to reduce climate-change-induced risks, while enhancing access to clean, affordable energy to power economic growth. Ultimately, the NDCs and NAPs show strong synergies in mainstreaming climate-smart agriculture technologies as a key step towards achieving food security, optimizing the financial viability of the agriculture sector, and strengthening early warning systems. The LVB case study shows a strong water, energy, and agriculture-centric approach to achieving NAPs objectives. Nonetheless, ambiguities and competition arise between NAPs and regional development plans. For instance, large-scale agriculture projects were identified as a threat to environmental and ecosystem integrity. While mechanized agriculture would potentially boost job creation, food security, and economic growth, it increases water competition and pollution rates.

Crucially, evidence from the LVB highlights how interlinkages emerge through both intentional design and reactive necessity. Infrastructure development, resource shocks, and political incentives jointly drive cross-border collaboration. In contrast to common assumptions that high-level policy bodies or inter-ministerial councils lead nexus governance, the evidence from LVB suggests that operational utilities-like LVSWB, NWSC, and MWAUWASA-act as institutional integrators. These utilities could be seen as defacto grassroots level nexus coordinators. Water utilities such as LVSWB and NWSC operate under a delegated governance model that aligns local action with basin-wide mandates. Such arrangements demonstrate the gradual institutionalization of nexus-based governance, albeit constrained by contextual asymmetries and fragmented financing mechanisms. Such entities could further function across administrative and political boundaries, managing resources in ways that inherently bridge food, water, and energy sectors. This reveals a bottom-up dimension of nexus governance, wherein implementation agencies become the nexus by necessity rather than design. There is incoherence between the EAC-NDCs, the UNFCCC framework and local development plans (Dupuis and Knoepfel, 2013; John et al., 2023; Malzbender and Earle, 2009), stemming from external consultants developing the NDCs and ignoring some key regional development plans. NAPs, on the other hand, are developed by line ministries and rely heavily on external funding/investments from development partners. There is substantial financial investment in developing the content of NDCs, typically led by external development partners and are not anchored in domestic development strategy (John et al., 2023; Terrapon-Pfaff et al., 2018). On the other hand, NAPs in the EAC context are collective government programmes aimed at addressing regional pressures. To this extent, the NAPs are strongly related to infrastructural development at a national level as the catalyst of the regional development agenda. NDCs mainly focus on reducing emissions and promoting sustainable development. Nonetheless, NDCs and NAPs espouse linkages within the water, agriculture and energy sectors. However, these linkages are not aligned and often compete for the same resources. Ultimately, LVB's climate risks and population demands drive close cooperation among communities and governments. We argue that this shows an initial operationalization of a WEF-nexus approach and an opportunity for its enhancement.

This study methodologically relied on policy document analysis and key informant interviews and did not include triangulation with quantitative basin indicators such as allocation flows, empirical emissions reduction data or socio-economic impacts as there lacked standardized measures for such indicators. Secondly, the study was limited to the riparian states in the LVB hence it does not represent entirely basin complexities. Additionally, the current socio-political climate (e.g. instability in Southern Sudan, and DRC) was a further limitation. Nonetheless, this work sets a solid foundation for developing an adaptive policy framework to intergate NAPs, NDCs and development ambitions in the EAC region.

4. Conclusion

This study investigated the connection inter and intra- national food, water, and energy demands, NDC targets and climate action policies in the EAC region. It sought to investigate if existing linkages espoused WEF-nexus or sectoral connections in regional development, climate mitigation and adaptation. The region exhibited significant coordination between policy, development and climate action instruments. The main finding is;

- Interlinkages between NDCs, NAPs, and regional development plans, though present, are inconsistently aligned in practice, often creating tradeoffs and contextual inefficiencies rather than cohesive, synergistic action.

Therefore, answering the core research question;

- Are nationally determined contributions, national adaptation plans and regional development in the LVB context interlinked?

Existing connections reflect partial sectoral integration but fall short of embodying a comprehensive, WEF nexus-based framework

in regional planning and climate adaptation strategies.

Regarding this study's contribution to knowledge, we posit that it offers a strong foundation for systematic unpacking of how multi-level governance in the LVB has catalysed policy and governance linkages anchored in the water, agriculture, and energy sectors. Notably, the study highlights the disjoint between policy intention on paper and practical implementation, especially development ambitions versus climate action targets. The study introduces a nuanced understanding of contextual tradeoffs and synergies espoused by the riparian nations in the LVB, exposing how overlapping sectorial priorities, spatial scales, and temporal targets interact. It offers a conceptual and empirical foundation for embedding WEF-nexus thinking into existing governance scenarios and frameworks in the wider EAC region.

Importantly, this study recommends a multi-governance WEF-nexus approach to catalyse policy, governance coherence and sustainable development in the LVB. To this end, the following 3-tier recommendations are proposed.

1. At the National Level: EAC Member states

- Harmonize NDCs, NAPs and National development plans: Leverage existing cross-sectoral task forces to align sectoral development ambitions with climate action goals to ensure coherence and minimize ambiguities;
- Explicitly budget for WEF-nexus implementation: Allocate significant share of financial resources for nexus-based programmes demonstrating co-benefits across water, energy, agriculture sectors and climate action ambitions;
- Technical capacity strengthening: Targeted investment in training of government planners and technical personnel on complex scenario planning for shared resources management using WEF-nexus methodologies.

2. At the Regional Level: EAC

- Institutionalize the LVB-WEF-Nexus Coordination Platform: Presently, coordination occurs reactively (during floods) through the de facto nexus coordinators (water utilities). Hence there is need to establish a formal regional coordination mechanism founded on the existing coordination and embedded within the EAC Secretariat to champion, execute, and oversee nexus scenario planning in the LVB, comprising of representative from riparian states;
- Mandate WEF-nexus impact assessments: Require all transboundary projects/programmes to incorporate a WEF-nexus-based sustainability assessment prior to approval;
- Strengthen regional data systems: Facilitating development of a shared WEF data and monitoring framework to inform evidence-based decision-making across member states.

3. At Basin Level: LVB

- Bolster basin-wide planning: Building on existing basin-level programmes, develop WEF-nexus strategy led by operational actors such as the LVBC, integrating grassroots, national climate commitments with regional development ambitions;
- Proactive action on tradeoffs: Identify potential high-risk conflict zones (e.g. competing water uses for hydropower vs irrigation vs industrial) and co-create a cooperative shared resources management approach;
- Pilot multi-sector demonstration programmes: Promulgate cross-border WEF-nexus pilot initiatives such as climate-smart agriculture driven by renewables with water-efficient irrigation to showcase practical integrations and scalability.

These recommendations detail how a LVB-WEF-nexus-based multi-governmental approach could look in practice. The study offers useful insights for improving coordination across governance scales, aligning climate action and development agendas, and securing long-term water, energy, and food security in the face of the triple planetary crisis.

Ethics Statement

The authors adhered to data and research ethics standards in accordance to the IHE-Delft Institute for Water Education Research Ethics Committee and the University of Kwa-Zulu Natal Humanities and Social Sciences Research Ethics Committee (HSSREC) guided by the University Research Ethics Policy and the National Health Research Ethics Council (NHREC).

CRedit authorship contribution statement

Tumaini J. Wambua: Writing – review & editing. **Graham Jewitt:** Writing – review & editing, Validation, Supervision, Resources, Project administration. **Janez Sušnik:** Validation, Supervision, Resources, Project administration, Funding acquisition, Conceptualization. **Sara Masia:** Writing – review & editing, Validation, Supervision, Conceptualization. **Tafadzwanashe Mabhaudhi:** Writing – review & editing, Supervision, Resources, Methodology, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors acknowledge the EC Horizon Europe project 'ONEPlanET' (grant number 101084127) for funding the writing of this manuscript. This project has received funding from the European Union's Horizon Europe research and innovation programme under

Grant Agreement No. 101084127 ONEPlanET. This paper and the content included in it do not represent the opinion of the European Union. This project has received funding from the Water Research Commission (South Africa) (CON2021/2022-00911).

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.crm.2025.100760>.

Data availability

Data will be made available on request.

References

- African Union Commission. (2015). *Agenda 2063: The Africa we want. A Shared Strategic Framework for Inclusive Growth and Sustainable Development*. . Roosevelt Street, Addis Ababa, Ethiopia: African Union.
- Al-Saidi, M., Hussein, H., 2021. The water-energy-food nexus and COVID-19: Towards a systematization of impacts and responses. *Sci. Total Environ.* 779, 146529.
- Albrecht, T.R., Crotofo, A., Scott, C.A., 2018. The Water-Energy-Food Nexus: a systematic review of methods for nexus assessment. *Environ. Res. Lett.* 13 (4), 043002.
- Allouche, J., Middleton, C., Gyawali, D., 2015. Technical Veil, Hidden politics: Interrogating the Power Linkages behind the Nexus. *Water Altern.* 8, 610–626.
- Andanje, B.C.A., Handa, S.H., Nyadera, I.N.N., 2025. Regional Integration and Economic Security: evaluating Kenya's Experience under the EAC Framework. *Natl. Security* 3 (1), 1–19.
- Armstrong McKay, D.I., Staal, A., Abrams, J.F., Winkelmann, R., Sakschewski, B., Loriani, S., Lenton, T.M., 2022. Exceeding 1.5 C global warming could trigger multiple climate tipping points. *Science* 377 (6611), eabn7950.
- Bache, I., Bartle, I., Flinders, M., 2016. Multi-level governance. In *Handbook on theories of governance*. Edward Elgar Publishing, pp. 486–498.
- Biesbroek, G.R., Swart, R.J., Carter, T.R., Cowan, C., Henrichs, T., Mela, H., Rey, D., 2010. Europe adapts to climate change: comparing national adaptation strategies. *Glob. Environ. Chang.* 20 (3), 440–450.
- Boas, I., Biermann, F., Kanie, N., 2016. Cross-sectoral strategies in global sustainability governance: towards a nexus approach. *Int. Environ. Agreem.: Politics Law Econ.* 16, 449–464.
- Bodansky, D., 1993. The United Nations framework convention on climate change: a commentary. *Yale J. Int'l L.* 18, 451.
- Bornemann, F.J., Rowell, D.P., Evans, B., Lapworth, D.J., Lwiza, K., Macdonald, D.M., Way, C., 2019. Future changes and uncertainty in decision-relevant measures of East african climate. *Clim. Change* 156, 365–384.
- Camazzola, F. (2023). Climate change impacts on the insurance industry.
- Cantor, A., Bartholomew, E., Berry, K., Blair, J., Mulvaney, D., Hunter, N., 2025. Unseen Connections: a StoryMap Exploring Case Studies in Water-Energy Transitions and Environmental Justice. *Geogr. Teacher* 22 (2), 92–98. <https://doi.org/10.1080/19338341.2025.2490584>.
- Chand, D., Susnik, J., Masia, S., Jewitt, G., 2025. A policy analysis of low carbon development in the context of the water-energy-food nexus: Examining the low emission development strategy in Fiji. *Cambridge Prisms: Water* 3, e8.
- Chevalier, R., 2021. Enhancing Nationally Determined Contributions across the SADC Region. *JSTOR Sustainability Collection*.
- Chirambo, D., 2020. The emerging threats and opportunities for implementing nationally determined contributions (NDCs) and sustainable development goal 7: policy insights from sub-Saharan Africa and Malawi. *Cent. Eur. Rev. Econ. Manage. (CEREM)* 4 (3), 23–52.
- Daher, B.T., Mohtar, R.H., 2015. Water–energy–food (WEF) Nexus Tool 2.0: guiding integrative resource planning and decision-making. *Water Int.* 40 (5–6), 748–771. <https://doi.org/10.1080/02508060.2015.1074148>.
- Diallo, M. A., & Wouterse, F. (2022). How can CAADP implementation help countries achieve the SDGs and become resilient to climate change? A tale of six African countries. Retrieved from <https://akademiya2063.org/publications/awps/AWPS%20No-002.pdf>.
- Dupuis, J., Knoepfel, P., 2013. The adaptation policy paradox: the implementation deficit of policies framed as climate change adaptation. *Ecol. Soc.* 18 (4).
- Falkner, R., 2016. The Paris Agreement and the new logic of international climate politics. *Int. Aff.* 92 (5), 1107–1125.
- Gaba, A. (2021). APA at the United Nations–2021 annual report. In: United Nations.
- Hall, D.M., Steiner, R., 2020. Policy content analysis: Qualitative method for analyzing sub-national insect pollinator legislation. *MethodsX* 7, 100787.
- Hoegh-Guldberg, O., Jacob, D., Taylor, M., Guillén Bolaños, T., Bindi, M., Brown, S., Ebi, K., 2019. The human imperative of stabilizing global climate change at 1.5 C. *Science* 365 (6459), eaaw6974.
- Hoff, H. (2011). Understanding the nexus.
- Hsieh, H.-F., Shannon, S.E., 2005. Three approaches to qualitative content analysis. *Qual. Health Res.* 15 (9), 1277–1288.
- Huang, D., Li, Y., Su, H., Li, G., Zhuang, J., 2025. Operationalizing food-energy-water nexus toward carbon neutrality. *Front. Eng. Manage.* 12 (1), 208–218. <https://doi.org/10.1007/s42524-025-5006-1>.
- Hussein, H., Ezbakhe, F., 2022. The Water-Employment-Migration nexus: a buzzword or a useful framework? *Dev. Policy Rev.* 41. <https://doi.org/10.1111/dpr.12676>.
- Ipcc, 2014. *IPCC Fifth Assessment Report—Synthesis Report*. IPCC Rome, Italy.
- IPCC. (2018b). Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (ed.)]. In Press pp. Retrieved from <https://www.ipcc.ch/sr15/download/>.
- IPCC. (2018c). Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, . Retrieved from https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf.
- IPCC. (2022). Summary for Policymakers. In C. Intergovernmental Panel on Climate (Ed.), *Global Warming of 1.5°C: IPCC Special Report on Impacts of Global Warming of 1.5°C above Pre-industrial Levels in Context of Strengthening Response to Climate Change, Sustainable Development, and Efforts to Eradicate Poverty* (pp. 1-24). Cambridge: Cambridge University Press.
- IPCC. (2023a). Climate Change 2023 Synthesis Report: A report of the Intergovernmental Panel on Climate Change. Retrieved from https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_FullVolume.pdf.
- IPCC. (2023b). Section. In: *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, H. Lee and J. Romero (eds.)]. . Retrieved from Geneva, Switzerland: https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_LongerReport.pdf.
- Javan, K., Altaee, A., Darestani, M., Mirabi, M., Azadmanesh, F., Zhou, J.L., Hosseini, H., 2023. Assessing the Water–Energy–Food Nexus and Resource Sustainability in the Ardabil Plain: a System Dynamics and HWA Approach. Retrieved from *Water* 15 (20), 3673. <https://www.mdpi.com/2073-4441/15/20/3673>.

- Jayaraman, T., 2015. The Paris agreement on climate change: Background, analysis, and implications. *Rev. Agrarian Stud.* 5 (2369–2021-047).
- John, T.W., Sušnik, J., Masia, S., Jewitt, G., 2023. Towards realization of nexus-doing at the grassroots level: Water-energy-food governance assessment in the Songwe River Basin (Tanzania and Malawi). *Environ Sci Policy* 150, 103596.
- Keen, S. (2022). The appallingly bad neoclassical economics of climate change. In *Economics and Climate Emergency* (pp. 79–107): Routledge.
- Lucca, E. (2025). The water-energy-food-ecosystems nexus: concepts and application to address water scarcity in Northern Italy. LVBC. (2015). Lake Victoria Basin Commission-Facts. Retrieved from <https://www.lvbcom.org/>.
- Mabhaudhi, Mpendeli, S., Madhlopa, A., Modi, A.T., Backeberg, G., Nhamo, L., 2016. Southern Africa's Water-Energy Nexus: Towards Regional Integration and Development. Retrieved from *Water* 8 (6), 235. <https://www.mdpi.com/2073-4441/8/6/235>.
- Mabhaudhi, Simpson, G., Badenhorst, J., Mohammed, M., Motongera, T., Senzanje, A., Mpendeli, S., 2018. Assessing the state of the water-energy-food (WEF) nexus in South Africa. *Water Research Commission (WRC): Pretoria, South. Africa* 76 (1).
- Malzbender, D., Earle, A., 2009. Water resources of the SADC: Demands, dependencies and governance responses. *Rethinking Natural Resources in Southern Africa* 85–106.
- Marchant, R., Richer, S., Boles, O., Capitani, C., Courtney-Mustaphi, C.J., Lane, P., Wright, D., 2018. Drivers and trajectories of land cover change in East Africa: Human and environmental interactions from 6000 years ago to present. *Earth Sci. Rev.* 178, 322–378. <https://doi.org/10.1016/j.earscirev.2017.12.010>.
- Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pidcock, R., 2019. Global warming of 1.5 C. An IPCC Special Report on the Impacts of Global Warming of 1, 93–174.
- McGregor, G.R., Ebi, K., 2018. El Niño Southern Oscillation (ENSO) and health: an overview for climate and health researchers. *Atmos.* 9 (7), 282.
- Mills-Novoa, M., Liverman, D.M., 2019. Nationally determined contributions: material climate commitments and discursive positioning in the NDCs. *Wiley Interdiscip. Rev. Clim. Chang.* 10 (5), e589.
- Mpendeli, S., Naidoo, D., Mabhaudhi, T., Nhemachena, C., Nhamo, L., Liphadzi, S., Modi, A.T., 2018. Climate change adaptation through the water-energy-food nexus in southern Africa. *Int. J. Environ. Res. Public Health* 15 (10), 2306.
- Mullan, M., Kingsmill, N., Kramer, A. M., & Agrawala, S. (2013). National adaptation planning: lessons from OECD countries.
- Ngcobo, S., Jewitt, G., Stuart-Hill, S., Warburton, M., 2013. Impacts of global change on southern african water resources systems. *Curr. Opin. Environ. Sustain.* 5 (6), 655–666.
- Nhamo, L., Mabhaudhi, T., Mpendeli, S., Dickens, C., Nhemachena, C., Senzanje, A., Modi, A.T., 2020. An integrative analytical model for the water-energy-food nexus: South Africa case study. *Environ Sci Policy* 109, 15–24. <https://doi.org/10.1016/j.envsci.2020.04.010>.
- Nhamo, L., Matchaya, G., Mabhaudhi, T., Nhlengethwa, S., Nhemachena, C., Mpendeli, S., 2019. Cereal production trends under climate change: Impacts and adaptation strategies in southern Africa. *Agriculture* 9 (2), 30.
- Nhamo, L., Mpendeli, S., Liphadzi, S., Mabhaudhi, T., 2025. Catalyzing sustainable development goals through the water-energy-food nexus. *iScience* 28 (2). <https://doi.org/10.1016/j.isci.2025.111902>.
- Overland, I., Fossum Sagbakken, H., Isataeva, A., Kolodzinskaia, G., Simpson, N.P., Trisos, C., Vakulchuk, R., 2022. Funding flows for climate change research on Africa: where do they come from and where do they go? *Clim. Dev.* 14 (8), 705–724.
- Ozor, N., Nyambane, A., Onuoha, C., Makokha, M., & M'mboyi, F. (2020). Nationally determined contributions (NDCs) implementation index, monitoring and tracking tools for selected countries in Africa. Available at: <https://atpsnet.org/wp-content/uploads/2020/07/NDC-Implementation-Index-Report.pdf> (Accessed on 7 November 2023).
- Pretorius, Drewes, E., Van Aswegen, M., Malan, G., 2021. A policy approach towards achieving regional economic resilience in developing countries: evidence from the SADC. *Sustainability* 13 (5), 2674.
- Pretorius, Drewes, J.E., Gumbo, T., 2022. Evidence to Inform Resilience Policy in the SADC: Current Limitations and Future Research areas. *WORLD* 3 (3), 449–469.
- Revi, A., Roberts, D., Klaus, I., Bazaz, A., Krishnaswamy, J., Singh, C., Adelekan, I., 2022. The Summary for Urban Policymakers of the IPCC's Sixth Assessment Report. *Indian Inst. Hum. Settlements, Bangalore, India* 10, 24943.
- Rogelj, J., Den Elzen, M., Höhne, N., Fransen, T., Fekete, H., Winkler, H., Meinshausen, M., 2016. Paris Agreement climate proposals need a boost to keep warming well below 2 C. *Nature* 534 (7609), 631–639.
- Scott, M., Lennon, M., Tubridy, F., Marchman, P., Siders, A.R., Main, K.L., Johnson, C., 2020. Climate Disruption and Planning: Resistance or Retreat? *Plan. Theory Pract.* 21 (1), 125–154. <https://doi.org/10.1080/14649357.2020.1704130>.
- Shukla, P. R., Skeg, J., Buendia, E. C., Masson-Delmotte, V., Pörtner, H.-O., Roberts, D., . . . Van Diemen, S. (2019). Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.
- Simpson, Jewitt, G.P., 2019. The water-energy-food nexus in the anthropocene: moving from 'nexus thinking' to 'nexus action'. *Curr. Opin. Environ. Sustain.* 40, 117–123.
- Simpson, Mach, K.J., Constable, A., Hess, J., Hogarth, R., Howden, M., Mackey, B., 2021. A framework for complex climate change risk assessment. *One Earth* 4 (4), 489–501.
- Suda, A.O., Sušnik, J., Masia, S., Jewitt, G., 2024. Policy coherence assessment of water, energy, and food resources policies in the Tana River Basin, Kenya. *Environ Sci Policy* 159, 103816.
- Sušnik, J., 2022. 3. Global nexus relationships and trends. *Handb. Water-Energy-Food Nexus* 36.
- Sušnik, J., Staddon, C., 2022. Evaluation of Water-Energy-Food (WEF) Nexus Research: Perspectives, challenges, and Directions for Future Research. *JAWRA J. Am. Water Resour. Assoc.* 58 (6), 1189–1198.
- Taguta, C., Senzanje, A., Makurira, H., Jewitt, G. P., Dirwai, T. L., Mpendeli, S., . . . Mabhaudhi, T. (2022). STATUS OF IMPLEMENTATION OF THE WATER-ENERGY-FOOD (WEF) NEXUS APPROACH: CASE OF SOUTH AFRICA AND ZIMBABWE.
- Terrapon-Pfaff, J., Ortiz, W., Dienst, C., Gröne, M.-C., 2018. Energising the WEF nexus to enhance sustainable development at local level. *J. Environ. Manage.* 223, 409–416. <https://doi.org/10.1016/j.jenvman.2018.06.037>.
- Terry, G., Hayfield, N., Clarke, V., Braun, V., 2017. Thematic analysis. *The SAGE Handb. Qualit. Res. Psychol.* 2 (17–37), 25.
- Tompkins, E.L., Amundsen, H., 2008. Perceptions of the effectiveness of the United Nations Framework Convention on climate Change in advancing national action on climate change. *Environ Sci Policy* 11 (1), 1–13. <https://doi.org/10.1016/j.envsci.2007.06.004>.
- Trisos, C. H., I.O. Adelekan, E. Totin, A. Ayanlade, J. Efitire, A. Gemedo, K. Kalaba, C. Lennard, C. Masao, Y. Mgyaya, G. Ngaruiya, D. Olago, N.P. Simpson, and S. Zakieldeen, (2022). *Africa. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Lösschke, V. Müller, A. Okem, B. Rama (eds.)]*. Retrieved from Cambridge, UK and New York, NY, USA.
- UNFCCC. (2015). *Paris agreement*. Paper presented at the report of the conference of the parties to the United Nations framework convention on climate change (21st session, 2015: Paris). Retrieved December. <https://unfccc.int/resource/docs/2015/cop21/eng/10.pdf>.
- Vörösmarty, C., Campana, P.E., Jewitt, G., Lawford, R., Wuebbles, D., 2024. Food-energy-water systems: achieving climate resilience and sustainable development in the 21st century. *Front. Environ. Sci.* 11, 1334892.
- Walker, S., Jacobs-Mata, I., Fakudze, B., Phahlane, M.O., Masekwana, N., 2022. Chapter 7 - applying the WEF nexus at a local level: a focus on catchment level. In: Mabhaudhi, T., Senzanje, A., Modi, A., Jewitt, G., Massawe, F. (Eds.), *Water - Energy - Food Nexus Narratives and Resource Securities*. Elsevier, pp. 111–144.