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Climate adaptation strategies and sustainable paddy production: a systematic policy review of the water-energy-food nexus in Mbarali district, Tanzania

Christopher Sylvester Machibula  and Emmanuely Zephaline Nungula

Institute of Development Studies, Mzumbe University, Mzumbe, Morogoro, Tanzania

ABSTRACT

The Water-Energy-Food (WEF) nexus in Mbarali district is increasingly stressed by climate change, threatening paddy production through rising temperatures, erratic rainfall, and competition for resources. This review examined 15 national policies published between 2006 and 2023, focusing on documents that addressed at least two WEF sectors, included strategic or implementation components, and referenced climate adaptation. Broad development plans, draft documents, and subnational policies were excluded. Policies were identified through targeted searches of official government and organizational websites, last accessed in October 2025. Risk of bias was assessed based on the clarity of objectives, transparency of institutional roles, and adequacy of adaptation measures, while synthesis was conducted narratively to compare sectoral integration and adaptation focus. Findings indicate that agricultural policies demonstrated the highest integration and climate adaptation focus, water strategies improved over time, and energy policies lagged in cross-sector alignment. Despite some progress, sectoral silos, unclear coordination mechanisms, and weak operational links limit effective adaptation. The review highlights the need for explicit cross-sector strategies, strengthened institutional capacity, and coordinated platforms to enhance resilience and ensure sustainable paddy production under changing climatic conditions.

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1. Introduction

Climate change poses a profound threat to global ecosystems, economies, and human well-being through rising temperatures and erratic weather patterns. Global temperatures have risen by about 1.1 °C above pre-industrial levels, intensifying risks to food security, water availability, and agricultural productivity, particularly in vulnerable regions (IPCC, 2022). Since 1961, global agricultural output has declined by approximately 21%, with Africa and Latin America facing losses of 30 to 33% due to heat stress and unpredictable rainfall (Ortiz-Bobea et al., 2021). These impacts heighten malnutrition risks in low-income, rainfed farming communities. International frameworks provide a foundation for addressing climate change. The Paris Agreement of 2015 commits nations to limiting temperature rises to below 2 °C while prioritizing adaptation for at-risk populations, with studies showing its potential to drive national policy alignment (Rogelj et al., 2016). The United Nations' Sustainable Development Goals (SDGs) advance this agenda, with SDG 13 advocating climate action, SDG 2 targeting hunger elimination, and SDG 6 promoting sustainable water management; research highlights their role in integrating climate and development goals (Nerini et al., 2017). Through the United Nations Framework Convention on Climate Change (UNFCCC), countries collaborate to align these commitments with national strategies. However, global agreements must translate into local solutions to address diverse climate impacts across countries.

CONTACT Christopher Sylvester Machibula  machibula94@gmail.com  Institute of Development Studies, Mzumbe University, P. O. Box 83, Mzumbe, Morogoro, Tanzania.

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In Asia, climate-related floods and storms affected 50 million people in 2021, causing over \$36 billion in losses, while China's drought added \$7.6 billion (World Meteorological Organization, 2022). However, Africa bears even more severe challenges, with 42 and 34% of ecoregions witnessing shrinking surface water bodies between 2003 and 2020. In over 80% of these cases, lake decline was tied to upstream irrigation or agricultural abstraction (Sogno et al., 2024). Southern African countries contend with droughts and floods that diminish crop yields, reduce livestock viability, and increase disease prevalence, disrupting food and water security (Hejnowicz et al., 2022).

East Africa faces significant climate stressors that undermine agriculture, which is a cornerstone of livelihoods and food security. Rising temperatures, erratic rainfall, and frequent droughts and floods have curtailed agricultural productivity across the region (IPCC, 2022). The East African Community (EAC) has prioritized climate resilience, recognizing agriculture's vital role. The EAC Climate Change Policy and Strategy promotes coordinated action among member states, promoting integrated approaches to water, energy, and food systems to balance sectoral demands and strengthen adaptive capacity in vulnerable communities (Radeny et al., 2022; Bedasa & Deksis, 2024; Mperejekumana et al., 2024). Tanzania shares these challenges. Employing over 65% of its population, agriculture is highly sensitive to climate variability, with temperature fluctuations and unreliable rainfall reducing yields of staples like rice (World Bank, 2023). Mbarali, located within the Usangu Basin, exemplifies these vulnerabilities, making it a critical case for studying adaptation.

Effective climate adaptation requires policies that integrate climate-sensitive sectors. The European Union's Water Framework Directive aligns water, agriculture, and energy policies, demonstrating how coordinated frameworks improve resilience (Brouwer et al., 2018). It is different in Southern Africa, where fragmented policies lead to inefficient resource use and unsustainable practices (Mpandeli et al., 2018). Gambia's Vision 2020 plan seeks cross-sectoral integration for food security, but standalone water and energy policies limit practical progress, exposing systems to climate risks (Kanyepi et al., 2024). In Tanzania, environmental policies often lack robust climate provisions, and while agricultural policies address adaptation, water policies do not, revealing gaps in integration (Katambara et al., 2016). These cases illustrate the cohesive policies across sectors are essential for addressing climate vulnerabilities in agriculture-dependent regions.

As a key rice-producing area in Mbeya, Mbarali relies on irrigation schemes like Nguvukazi Mwanavala, spanning 6,500 hectares, and the Kapunga project, supporting outgrower farmers (Katambara et al., 2016). Also, the National Rice Development Strategy (NRDS) aims to double yields to 4 tons per hectare by 2030 (Mdoe & Mlay, 2021). Yet, droughts, erratic rainfall, and water management issues threaten these goals (Kulyakwave et al., 2019). Limited fertilizer use and mechanization constrain yields below the 7–8.5 tons per hectare (Busungu, 2023). Hydropower, supplying 39% of Tanzania's energy, faces disruptions from shifting rainfall, affecting irrigation and processing (Pardoe et al., 2018). Land in Mbarali is a finite resource, with limited potential for continuous expansion to sustain rising paddy production (Muhoja, 2025). In contrast, the impacts of climate change are intensifying without natural limits (Mutayoba et al., 2018). This imbalance places the upward trend in paddy production in Mbarali at a precarious threshold, where gains risk being reversed if adaptive measures are not urgently strengthened.

These interconnected issues emphasize the need for cohesive approaches to sectoral challenges, and therefore, this study investigates how Tanzania's national policies, strategies, and implementation plan in water, energy, and agriculture support climate adaptation for sustainable paddy production in Mbarali. Policies alone are insufficient. As Kanyepi et al. (2024) note, even high-level national agendas fail when sector-specific programs lack alignment. Coherent strategies and actionable plans are critical for progress (Williams et al., 2019; Havukainen et al., 2022). Without them, policy remains intent without impact. While Shimwela and Katera (2025) show the importance of integrating water, energy, and food systems, there is still limited understanding of how existing national adaptation policies translate into coherent and fair actions on the ground, and the rationale of this study is to explore how these policies shape climate resilience and address barriers in Mbarali.

2. WEF nexus and political ecology framework

The Water-Energy-Food (WEF) nexus frames national climate adaptation by mapping interdependencies among water, energy, and food systems. Integrated policies can improve resilience, such as when water

management supports both energy production and agriculture. Yet, trade-offs arise when prioritizing one sector, like hydropower, limits water for farming. (Biggs et al., 2015; Albrecht et al., 2018) In Tanzania, where climate stressors strain resources, this framework guides analysis of national strategies to balance sectoral demands and ensure sustainable adaptation. It emphasizes the need for policy coherence to align goals across ministries, reducing maladaptation and optimizing resource use under climate uncertainty (Pardoe et al., 2018) In practice, the distribution and management of water, energy, and land are influenced by political, historical, and power dynamics. Political ecology helps unpack these dynamics by addressing these dimensions and asking who makes decisions, who benefits, and whose priorities are left out (Williams et al., 2019). It critiques how policies reflect state priorities or elite interests and end up sidelining vulnerable groups like small-scale farmers. Historical factors, like Tanzania's post-independence focus on industrialization, shape current resource allocation. This lens questions who benefits from national adaptation plans and identifies institutional barriers, such as fragmented ministries, that hinder outcomes (Kivimaa et al., 2025). It ensures analysis accounts for social justice in policy design. Together, the WEF nexus and political ecology offer a robust framework for analyzing climate adaptation strategies, policies, and implementation plans (Allouche et al., 2019). The WEF nexus maps technical interdependencies, identifying synergies and trade-offs, while political ecology reveals power dynamics and inequities in policy execution (Bazzana et al., 2023). This dual approach examines how strategies achieve coherence and whether implementation ensures equity, addressing both technical and social dimensions of adaptation (Eriksen et al., 2015).

2.1. Empirical studies

Policy integration across water, energy, and food sectors is essential for sustainable resource management and climate adaptation, yet sectoral fragmentation consistently impedes cohesive frameworks. Policies often prioritize isolated objectives, such as energy security or agricultural output, neglecting interdependencies, which results in inefficiencies and trade-offs that undermine resilience (Kivimaa et al., 2025). In many regions WEF policies lack cross-referencing, which limits their ability to address interconnected climate challenges (England et al., 2018; Bazzana et al., 2023). In African settings, policies frequently focus on short-term crisis management, such as flood or drought response, rather than fostering integrated frameworks for long-term adaptation (Suda et al., 2024). Uganda shows partial coherence in agriculture and water policies, though implementation gaps persist due to limited coordination (Tumushabe et al., 2023). In Tanzania, despite growing integration of climate change into agriculture and water policies, coordination remains largely superficial, with limited cross-sectoral alignment to support adaptation (Pardoe et al., 2018). Such fragmentation often generates conflicts, for instance, water allocation prioritizing energy over agriculture, thereby compromising food security (Kanyepi et al., 2024). In Mbarali, strengthening coherence between water, agriculture, and climate policies could address similar challenges and promote coordinated adaptation for sustainable paddy production (Pardoe et al., 2018)

Integrated policies, when achieved, yield synergies across the sectors. Micro-irrigation systems conserve water and increase crop yields but require coordinated energy policies to manage increased demand (Rasul & Sharma, 2016). In Ghana, climate-sensitive policies in agriculture and water show alignment with adaptation goals, yet limited coherence across sectors hinders synergistic outcomes (Antwi-Agyei et al., 2017). Policies need to exist at a macro level, but that alone is not enough. Localized approaches can outperform national mandates, as community stakeholders often better understand resource interdependencies (Greer et al., 2020; Sixt et al., 2020) In Pakistan, federal policies show stronger coherence than provincial ones, especially in water and agriculture, while energy policies lag behind (Waheed et al., 2021). In Mbarali, however, field-level stakeholders often remain unaware of the interdependence between water, energy, and food production, hindering effective policy coherence. These observations make it clear that integration is foundational for climate adaptation strategies, which rely on cohesive policies to ensure resource availability and effective implementation.

Sustainable practices such as improved seeds, fertilizers, and efficient irrigation enhance productivity but face policy gaps that limit adoption. The System of Rice Intensification (SRI) improves yields and conserves water but requires supportive policies for data access and financing (Materu et al., 2018). In Tanzania, farmers' awareness of rainfall variability shows the need for policy-backed adaptation, though

limited education and resources hinder uptake (Kulyakwave et al., 2019). Climate-smart agriculture also holds promise but lacks incentives and awareness support (Mtwanga et al., 2022; Ngailo et al., 2016). Smallholders across Sub-Saharan Africa face similar barriers from weak financial and extension support (Maro et al., 2023; Ojo & Baiyegunhi, 2020). In Mbarali, integrating water, energy, and food policies through a WEF nexus approach could strengthen the adoption of these climate-smart practices in paddy production.

Technologies like drip irrigation and solar-powered systems are effective but costly, and the absence of policy-driven subsidies reflects poor coordination between agriculture and energy sectors (Anugwa et al., 2022; Durga et al., 2024). In Western Tanzania, communities reliant on agriculture face risks from uneven rainfall and increased temperatures, with local adaptations like drought-tolerant crops proving inadequate without policy-backed resource coordination (Kangalawe et al., 2017). But on the flip side, developed countries that have robust guiding policies don't suffer the same fate. In South Korea, the 3rd National Climate Change Adaptation Plan aligns with international adaptation goals through policy-driven interagency coordination, offering a model for effective governance (Han & Kim, 2023). What studies make clear is that adaptation strategies require policies that bridge sectoral divides, provide financial and technical support, and align with institutional mechanisms to ensure effective implementation.

Sector-specific mandates create silos that limit institutional collaboration, while centralized governance structures in most cases lack flexibility for local needs (Laamari et al., 2022). Without policies mandating and resourcing such coordination, adaptation strategies remain unimplemented (Terrapon-Pfaff et al., 2018). Evidence from East Africa is that sectoral silos hinder policy coherence, though multi-stakeholder platforms offer potential for improved coordination (Ampaire et al., 2020). In Tanzania, institutional constraints, such as power imbalances and budget limitations, confine collaboration to ad hoc projects, limiting sustained coordination for adaptation (Pardoe et al., 2018). The National Climate Change Response Strategy aims to stimulate coordination, but rigid structures and limited funding, added to rooted sectoral approach, restrict progress (Ndesanjo & Asokan, 2023). Sub-national initiatives, such as the Songwe River Basin Development Programme, demonstrate that policy-backed, multi-stakeholder governance can address resource management inconsistencies (John et al., 2023).

What is evident is that policy coherence, adaptation strategies, and institutional coordination are interdependent components of effective climate adaptation within the WEF nexus. This necessitates alignment across water, energy, and food sectors. Coherent policies provide the framework for integrating sectoral objectives, yet their absence limits the scalability of adaptation strategies by constraining resource availability (England et al., 2018; Suda et al., 2024). Sustainable practices like SRI and climate-smart agriculture depend on policies that coordinate water and energy access, but fragmented frameworks hinder adoption (Maro et al., 2023; Materu et al., 2018; Mtwanga et al., 2022). Governance mechanisms determine whether policies and strategies translate into practice, with institutional silos undermining even well-designed plans (Ampaire et al., 2020). Effective adaptation requires policies to establish unified priorities, strategies to deliver practical solutions, and governance to facilitate collaborative implementation (Pardoe et al., 2018).

Policies provide a necessary baseline, but they are only the starting point. They establish a starting point where institutions must then come together to create strategies to serve their interests, creating a win-win outcome rather than conflicting expectations. As (Runhaar et al., 2018) argues, easing adaptation into policy achieves little without supporting strategies, operational guidelines, and financing. (England et al., 2018) emphasizes the same disconnect in South Africa, where climate objectives falter without coordination platforms and clearly mandated agencies. The same goes for Tanzania, where policies are observed to remain aspirational due to weak governance and lack of strategies and implementation plans that put the policies into action (Ndesanjo & Asokan, 2023; Pardoe et al., 2018). Even well-designed policies fail when they are not grounded in local institutions or backed by shared implementation rules. In the end, it is not policy alone but the presence of coherent strategies and actionable plans that drives real progress (Havukainen et al., 2022). Without them, policy remains intent without impact. While WEF policies provide a baseline for climate adaptation, there is limited understanding of how these policies translate into coordinated strategies and actionable implementation at local and national levels. In Tanzania and similar contexts, weak institutional coordination, fragmented governance, and limited

financing hinder the effectiveness of policies, leaving adaptation measures largely aspirational (Pardoe et al., 2018). This study addresses the gap by examining how WEF policies can be operationalized through aligned strategies and implementation frameworks to achieve tangible climate resilience outcomes.

3. Methodology

This study adopted a structured screening process based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, adapted to suit the policy and institutional focus of WEF nexus research. PRISMA was chosen because its systematic approach to document identification, screening, and inclusion strengthens transparency, consistency, and completeness, thereby enhancing replicability advantages over other policy analysis frameworks that lack standardized reporting procedures for large document sets (Sohrabi et al., 2021). The adaptation involved tailoring inclusion and exclusion criteria to the specific context of national policies, strategies, and implementation plans.

Policy documents were identified through targeted searches of official government and organizational websites, including the Ministry of Agriculture, Ministry of Water, National Irrigation Commission, UNFCCC document repository, JICA documentation platform, FAOLEX, the Tanzania Development Portal, the Tanzania Forest Conservation Group, and the Sustainable Energy for All (SE4ALL) Knowledge Hub. The search focused on national policies, strategies, and programs related to water, energy, agriculture, and climate change from 1992–2023. All sources were last accessed between 10th and 22nd October 2025. Each document was reviewed for relevance using four core criteria. First, it had to address at least two of the WEF sectors, either explicitly or through cross-sectoral references. Second, it needed to be either a strategic program or an implementation plan created to put its respective policy into action. For example, the policy is the National Water Policy but the strategic program is the Water Sanitization and Development Program. Third, it needed to mention or imply climate adaptation, whether through direct goals or targeted actions. Fourth, broad national development goals such as MKUKUTA and Vision 2025 which, while important nationally, did not provide specific guidance on climate adaptation within WEF, were excluded. Therefore, a targeted search strategy was used to identify national water, energy, agriculture, and climate-related policies from 1992–2023, search focused on relevant keywords including 'policy,' 'strategy,' 'program,' 'water,' 'energy,' 'agriculture,' and 'climate change' (APPENDIX). Only national-level, official documents within the 1992–2023 period were included, while draft documents and project reports were excluded. Risk of bias was assessed using a structured appraisal focusing on the clarity of policy objectives, the transparency of institutional roles, and the evidence supporting adaptation measures relevant to paddy production in Mbarali District. The assessment also considered how well the policies addressed local climate risks, water availability, and irrigation needs. All documents were reviewed by a single researcher working independently, and no automation tools were used. Policies with unclear mandates or weak justification for adaptation strategies were judged to have a higher risk of bias. A summary of the screening process is presented in Figure 1, showing how documents were narrowed down from identification to final inclusion.

For each included document, data were extracted on the based on the variables of interest, including the document characteristics (title, year of publication, issuing authority, policy type, and sector focus), policy content (objectives, provisions related to water, energy, and food interactions, climate adaptation measures, institutional arrangements, and implementation instruments), and governance variables (policy alignment, integration level, and monitoring mechanisms). When information such as publication year or responsible institution was missing, it was inferred from internal document elements. The review focused on outcomes related to climate adaptation and paddy production, including adaptation strategies that strengthen water management and irrigation efficiency, institutional arrangements that influence coordination across the water, energy, and agriculture sectors, and policy measures designed to reduce climate risks for paddy farmers.

3.1. Analytical framework for assessing strategy coherence

To evaluate the extent of coherence among the selected national strategies, this study employed a structured content analysis focused on three dimensions: integration across the WEF sectors,

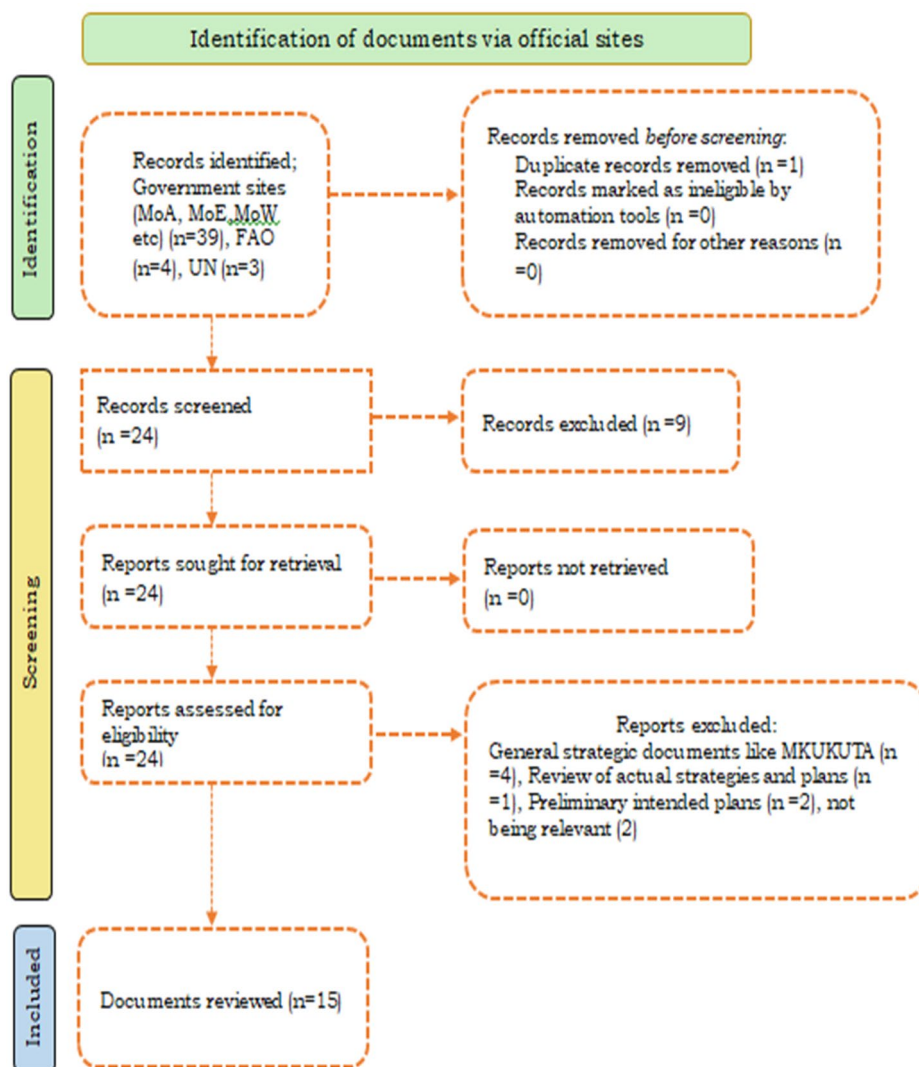


Figure 1. PRISMA flow chart.
Source: Researcher (2025).

institutional coordination, and climate adaptation focus. This framework builds on earlier work by Waheed et al. (2021) and (England et al., 2018), who used similar scoring approaches to assess cross-sectoral policy alignment in the context of environmental planning and climate governance. Each document was systematically reviewed and coded using NVivo 15, applying a three-part scoring scale to ensure consistent, transparent, and reproducible assessment. Certainty in the evidence was assessed by evaluating the credibility, clarity, and consistency of the included policy documents. Factors considered included the issuing authority, publication status, clarity of objectives, and alignment with other national and sectoral policies. The aim was not only to identify whether particular WEF nexus themes appeared, but to assess the depth of integration and strategic intent across sectors as shown in Table 1.

4. Findings

The search identified 15 national policy documents published between 2006 and 2023, covering water, energy, agriculture, and climate change sectors. All documents were screened for inclusion based on national-level scope, relevance to climate adaptation, and applicability to paddy production in Mbarali District. No draft or sub-national policies were included, as only official government and internationally recognized documents were considered. All 15 identified policies met the inclusion criteria and were

Table 1. Evaluation criteria for WEF nexus and climate adaptation.

Dimension	Rating	Explanation
WEF integration	Low	Focuses on a single sector only and there is minimal or no mention of other WEF sectors.
	Moderate	Acknowledges at least two WEF sectors but limited articulation of their interaction.
	High	Explicitly discusses interconnections among all three WEF sectors
Institutional coordination	Not mentioned	No reference to coordination, partnerships, or cross-sectoral collaboration.
	Implied	Mentions multiple institutions or stakeholders, but without detailing coordination mechanisms or structures.
	Explicit	Clearly defines coordination arrangements such as inter-ministerial task forces, steering committees, or multi-sectoral implementation plans.
Climate adaptation	Low	Climate adaptation implied indirectly through sustainability or resilience language but there are no specific adaptation strategies.
	Moderate	Mentions climate adaptation or resilience as an objective but lacks detailed or sector-specific actions.
	High	Provides clear and targeted adaptation strategies, particularly for agriculture, irrigation, or water resource management.

Source: Researcher (2025).

included in the review for full analysis. Risk of bias due to missing results was assessed based on the completeness and clarity of each policy. Documents lacking clear adaptation measures, implementation guidance, or monitoring provisions were judged higher risk, while those with well-defined objectives and institutional responsibilities were considered lower risk. Also, certainty in the evidence was assessed based on the credibility, clarity, and completeness of each policy. Documents with official backing, clear objectives, and well-defined adaptation measures were judged high confidence, while those with unclear authorship, missing dates, or incomplete provisions were considered lower confidence. This section presents the findings from the review of national strategies, policies, and implementation plans related to climate adaptation and the WEF sectors in Tanzania as illustrated in [Table 2](#).

The findings reveal varying levels of integration across the WEF sectors. In the water sector, early strategies such as the WSDP of 2006 exhibit low integration with other sectors, minimal institutional coordination, and limited climate adaptation focus. Subsequent strategies, including WSDP II (2014) and WSDP III (2022), show moderate improvements across these dimensions, reflecting a gradual recognition of the need for holistic resource management. The NIRC Strategic Plan (2023–2028) achieves high WEF integration but retains only moderate coordination and adaptation measures, reveal persistent institutional inertia and limited enforcement mechanisms.

In the energy sector, the BEST (2014) demonstrates moderate WEF integration and climate adaptation while excelling in institutional coordination, whereas the ESIR (2014) scores low across all metrics, illustrating sectoral lag in cross-sectoral alignment. The SE4ALL Action Agenda (2015) shows a more balanced moderate performance. The slower progress in energy compared with agriculture is partly due to its inward-focused policy objectives, prioritization of private sector restructuring, and weak linkage with water and food systems, despite acknowledgment of cross-sector dependencies.

For the food sector, strategies including ASDP (2006) and NRDS (2009) initially show moderate to low performance. Later strategies (ASDP II 2017 and NRDS II 2019) achieve high climate adaptation integration, reflecting stronger institutional alignment and growing recognition of climate resilience in agriculture. This relative success in agriculture may stem from its immediate reliance on water and exposure to climate variability, attracting more targeted interventions and donor support. Sectoral comparison of integration scores indicates that the food sector leads, followed by water, with energy lagging. While WEF integration has improved over time, the energy sector's inconsistent performance reflects limited cross-sector coordination, donor-driven project approaches, and a lack of binding mechanisms to enforce holistic planning.

Table 2. Strategies and implementation plans reviewed.

Strategy	Integration level (WEF)	Institutional coordination	Climate adaptation integration	Average score
Water				
Water Sector Development Strategy (2006)	Low (1)	Low (1)	Low (1)	1
Water Sector Development Programme WSDP II (2014)	Moderate (2)	Moderate (2)	Moderate (2)	2
Water Sector Development Programme Phase III – WSDP III (2022)	Moderate (2)	Moderate (2)	Moderate (2)	2
NIRC Strategic Plan (2023–2028)	High (3)	Moderate (2)	Moderate (2)	2.3
Energy				
Biomass Energy Strategy (BEST) (2014)	Moderate (2)	High (3)	Moderate (2)	2.3
Electricity Supply Industry Reform Strategy and Roadmap (ESIR) (2014)	Low (1)	Low (1)	1 (Low)	1
SE4ALL Action Agenda (2015)	Moderate (2)	Moderate (2)	Moderate (2)	2
Food				
ASDP (2006)	Moderate (2)	Moderate (2)	Moderate (2)	2
National Rice Development Strategy (2009)	Moderate (2)	Low (1)	Low (1)	1.3
Agricultural Sector Development Programme Phase II (ASDP II) (2017)	Moderate (2)	Moderate (2)	3 (High)	2.3
National Rice Development Strategy Phase II (2019)	Moderate (2)	Moderate (2)	3 (High)	2.3

Source: Researcher (2025).

4.1. Water sector interlinkage with other WEF sectors and climate adaptation

The National Water Policy (2002) laid the foundation for integrated water resources management, but early strategies (WSDS 2006) mainly acknowledged cross-sector dependencies without establishing operational coordination mechanisms. Subsequent strategies (WSDP II 2014 and WSDP III 2022) expanded integration with agriculture and energy, emphasizing irrigation and climate-smart approaches. However, these remained largely sector bound, with minimal reference to interlinked adaptation across sectors. The NIRC Strategic Plan (2023–2028) introduced more deliberate WEF connections, yet implementation mechanisms remain limited, reflecting governance constraints and fragmented institutional responsibilities. While no explicit coordination mechanisms were laid out, the strategy emphasized the need for alignment across sectors, noting, for instance, that:

“The NWSDS will support harmonization and realignment between the National Water Policy, the consequent Water Sector legislation, and the policies and legislative provisions of other key water-related sectors, such as agriculture, energy, and industry”

In Mbarali district, climate adaptation in the water sector gradually gained prominence. WSDS 2006 framed climate change as an external risk without systematic integration. WSDP II (2014) aligned with the National Climate Change Strategy (2012), establishing hydrological monitoring and dialogue forums. WSDP III (2022) promoted water storage, harvesting, and smart irrigation, but adaptation measures largely remained siloed. NIRC (2023–2028) strengthened adaptation at the irrigation level, yet upstream–downstream and energy interdependencies remain insufficiently operationalized.

Coordination across sectors persists as a challenge, with early strategies emphasizing internal agency management rather than inter-sector collaboration. Even later strategies (WSDP II & III) outline intent without defining practical cross-sector mechanisms, highlighting entrenched institutional silos and limited enforcement capacity.

Climate adaptation emerged gradually, though earlier documents treated it as peripheral. The WSDS of 2006, while recognizing that climate change effects on rainfall and water supply posed risks, made no effort to integrate adaptation systematically into sector priorities. It mostly framed climate as an external variable affecting resources, rather than a driver of cross-sectoral vulnerability. By the time of

WSDP II of 2014, however, adaptation had gained more visibility, partly due to alignment with the National Climate Change Strategy of 2012. This strategy acknowledged broader interventions being undertaken at national, basin, and regional levels. The document outlines efforts done to adapt to changing climate demands;

“At the basin level, hydrological and climatic monitoring stations to improve availability of water resources data have been installed.”

The water sector established a climate change dialogue forum for stakeholders to exchange knowledge and support climate resilient water safety plans. However, interventions largely remained descriptive, focusing on platforms and monitoring infrastructure, with little integration across energy or agriculture. WSDP III (2022) promoted alternative water storage, harvesting, and smart irrigation techniques, signaling stronger climate resilience, but still within a sectoral silo. Similarly, the NIRC Strategic Plan (2023–2028) introduced irrigation-level adaptation goals, including resilience planning, water use efficiency, and strengthened local systems, yet no mechanisms link these efforts to upstream water governance or downstream energy tradeoffs.

Coordination across sectors remains an ongoing challenge. The WSDS of 2006 primarily framed coordination as an internal concern between divisions or agencies under the water portfolio rather than fostering structured collaboration with related sectors, including energy or agriculture, which specifically drive irrigation processes for paddy farmers in Mbarali. It acknowledges, however, the consequences of fragmented planning:

“Past uncoordinated planning for water use, inadequate water resources data, and inefficient water use have resulted into water use conflicts between the energy and irrigation sectors, between irrigation and the water ecosystems, hydropower and the ecosystem, and between upstream and downstream users.”

Yet no cross-sectorial institutional or operational mechanisms were proposed to address these tensions. WSDP II of 2014 extended coordination discourse to include engagement with NGOs and other sectors, but it remained broad, omitting specific ministries or entities central to the water-energy-food-climate nexus. Collaboration was mostly justified in terms of optimizing water sector performance rather than building cross-sectoral synergies. This sector-centered framing persisted in WSDP III of 2022–2026, which advocated for integrated water resources management and recognized the need for inter-sectoral coordination at various levels.

4.2. Energy sector interlinkage with other WEF sectors and climate adaptation

Energy strategies, starting from the National Energy Policy (2003) and ESIR (2014), gradually acknowledged water and food dependencies but rarely operationalized them. BEST (2014) explicitly mapped inter-sectoral actors and noted cross-sector effects, yet coherence in practice remained weak. The SE4ALL Action Agenda (2015) expanded the WEF framing but focused mostly on aspirations and advocacy rather than actionable implementation. The energy sector’s slower integration reflects internal focus, limited institutional collaboration beyond the sector, and donor-driven priorities. Climate adaptation is recognized in biomass and renewable initiatives, but cross-sector adaptation planning remains minimal. This overlap between energy, agriculture, and water is explicitly acknowledged, with the strategy noting that;

“Almost all policies and regulations that touch on the forestry, agriculture, natural resources, and the energy and environment sectors have an effect on the biomass energy sector.”

Still, these connections are more descriptive than structural. The strategy calls for better alignment, stating that:

“Policies should be taking into consideration existing policies that will be touched by biomass energy policy (energy, forestry, poverty alleviation, environment, agriculture, among many others). Policies and regulations should be developed to ensure they are implemented in a manner that complements existing policies.”

The recommendation is strong, but it also signals that such coherence does not yet exist in practice. The cross-sector dimensions are acknowledged but remain weakly embedded. The SE4ALL Action Agenda

(2015) adds to this landscape with a more intentional framing, pointing to an energy–water–health–agriculture connection. The strategy even notes that:

“The energy service approach is one that goes beyond the most obvious need, and truly serves the basic needs of the user, like electricity and water, as well as productive and community service necessities.”

It goes further to say that energy has a direct nexus with related actions regarding the access to clean water, improvement of public health and education, women’s empowerment and increase in food production. These are promising declarations, yet again, mostly aspirational.

In terms of climate adaptation, the Biomass Energy Strategy (BEST, 2014) frames biomass as an underutilized, low-emissions option for rural households, critiquing reliance on charcoal and commercial fuels as environmentally harmful. However, adaptation focus is mostly limited to resource substitution rather than cross-sector resilience. The Electricity Supply Industry Reform Strategy and Roadmap (ESIR, 2014) identify climate change as a key risk to energy, particularly via rainfall variability affecting hydro-power, but solutions remain sector-internal, with no interministerial strategies to address shared water, energy and food risks. The SE4ALL Action Agenda (2015) slightly broadens this perspective, promoting renewable technologies and resilient infrastructure through awareness campaigns, yet concrete adaptation pathways, financing mechanisms, or intersectoral coordination are largely absent.

This limited integration contrasts with agriculture, where ASDP II (2017) and NRDS II (2019) explicitly embed climate resilience into both strategy and implementation. Agriculture advanced faster because climate impacts on productivity are immediate and visible to both national planners and local stakeholders, driving explicit adaptation measures such as climate-smart crops, water management, and irrigation practices. In comparison, water policies, despite being highly cross-cutting, remain siloed because coordination mechanisms across energy and agriculture are weak, operational linkages unclear, and sector mandates still prioritize internal performance over broader nexus outcomes (SE4ALL, 2015).

As for coordination, BEST (2014) stands out as the most deliberate in identifying institutional linkages across sectors. One of BEST (2014) guiding principles is to join up and ensure coordination of policies, and policy implementation, at all levels. It maps out a wide network of actors including the Ministry of Energy and Minerals (MEM), Rural Energy Agency (REA), Energy and Water Utilities Regulatory Authority (EWURA), Ministry of Agriculture, Food Security and Cooperatives, and the National Environmental Management Council acknowledging the shared mandates and overlapping influence these institutions exert on biomass energy governance. Yet despite this inclusive institutional lens, the strategy notes that coordination across policies remains weak as it plainly states;

“National and local policies that touch upon the biomass energy sector lack coordination,”

The Electricity Supply Industry Reform Strategy and Roadmap (2014) offer a much narrower conception of coordination framed almost entirely in relation to private sector actors. It focuses on enabling investment environments and expanding independent power producers, but it does not propose cross-sector coordination, nor does it engage other ministries or institutions beyond the energy value chain. The SE4ALL Action Agenda of 2015 places some emphasis on coordination, though it remains largely internal to the energy sector. It assigns key implementation roles to MEM, REA, and TANESCO, particularly in advancing mini-grid solutions to improve off-grid energy access. This reflects a drive for institutional synergy within the sector, but like the ESI Reform Strategy, it falls short of proposing linkages with water or food systems even where such linkages are acknowledged in passing elsewhere in the document.

4.3. Agriculture interlinkage with other WEF sectors and climate adaptation

Agricultural strategies show the highest integration. ASDP II (2017) and NRDS II (2019) integrate climate-smart agriculture, water management, and, to a limited extent, energy considerations. Early strategies (ASDP 2006, NRDS 2009) acknowledged climate risks and water–agriculture trade-offs but lacked systemic coordination. The more deliberate integration in later strategies reflects both the sector’s climate vulnerability and targeted donor and policy support. Coordination mechanisms remain broad rather

than specifying institutional roles, highlighting persistent governance challenges even in sectors with higher integration. In fact, energy appeared primarily as a competitor for limited water resources. The strategy noted that;

“Drought, shortage of potable water, increased demand for agricultural, energy, and industrial purposes is leading to a critical water stress situation.”

In Mbarali, water–agriculture interactions were acknowledged mainly as trade-offs, with limited coordinated planning or joint investments. Energy and agriculture links were weak, with mechanization promoted but little consideration of supporting energy systems. ASDP II (2017) expanded the focus on sustainable water and land management and climate-smart agriculture, recognizing competition for water, including with the energy sector, and calling for practices that reduce on-farm energy use. For paddy production, NRDS (2009) emphasized irrigation and water harvesting technologies as key to productivity, while energy considerations remained mechanical, promoting tractors, combine harvesters, and other machinery without addressing their energy source. Yet the power source for these technologies was not addressed. NRDS II of 2019 built on the broader ASDP II of 2017 framework, and its water linkage is far more pronounced, perhaps reflecting a deeper understanding of paddy’s reliance on stable irrigation systems. It states:

“The focus is to invest in expansion of area under irrigation; rehabilitation of existing irrigation schemes; research and development on improving efficiency in water use and management and strengthening irrigators’ organizations.”

This signals a more integrated water and food approach, with investment and institutional support clearly prioritized. The silence on energy is still notable aside from acknowledging an opportunity to invest in solar-powered pumps. Climate adaptation appears with varying levels of clarity and depth across agriculture sector strategies. The ASDP of 2006 recognized climate variability as one of the root causes of environmental degradation, but it did not articulate what resilience would look like in practice, nor did it embed climate concerns in implementation planning. As a result, climate considerations were acknowledged but largely remained on the margins of sectoral planning. A more deliberate integration came with ASDP II of 2017. The strategy incorporated resilience as a central theme not just to economic shocks, but specifically to climate variability and change. The first strategic objective is to expand sustainable water and land resource management and promotion of climate change smart agriculture. It goes further to state that:

“ASDP II interventions will be undertaken with climate change considerations factored into the interventions, including climate smart agriculture in sustainable landscapes and appropriate climate change mitigation strategies.”

This marks a shift in tone and structure, with climate-smart agriculture positioned as a guiding principle for land, water, and production systems. In Mbarali, NRDS (2009) does not mention climate change, yet it points out challenges such as seed varieties tolerant to drought, cold, pests, and diseases, implicitly addressing climate risks. NRDS II (2019) places climate resilience at the forefront, promoting market-oriented varieties, production technologies, and policy tools to mitigate climatic vagaries. Coordination remains limited: ASDP (2006) provides vague guidance with no clear cross-sectoral mechanisms. Comparing these strategies to Tanzania’s Vision 2025 reveals partial alignment: both NRDS II and ASDP II (2017) emphasize agricultural productivity and climate-smart practices, but energy integration and cross-sectoral linkages lag behind national targets for sustainable resource use. Similarly, alignment with international frameworks such as the Paris Agreement and NDC commitments is evident in the adoption of climate-resilient crops and technologies, yet the operationalization of adaptation measures at the local level in Mbarali remains incomplete (NCCRS, 2021; ASDP II, 2017; NRDS II, 2019). It merely states that implementation will

“Continue to be provided through the National Steering Committee,” composed of the Permanent Secretaries of the Agricultural Sector Lead Ministries (ASLMs), along with unnamed “collaborating ministries and stakeholders.”

ASDP II (2017) acknowledges coordination gaps and aims to strengthen sector enablers and collaboration, committing stakeholders to consolidated efforts. However, it does not specify which institutions or mechanisms will enable cross-sectoral collaboration, and water and energy ministries are not listed as formal partners. In NRDS (2009), coordination is only mentioned in passing through vertical reporting lines, without horizontal integration across sectors. NRDS II (2019) shows more proactive language, stating that interventions will address the rice value chain through institutional coordination, though details remain limited.

4.4. Climate adaptation strategies

Key national climate adaptation strategies, including NAPA (2007), NCCS (2012), and NCCRS (2021), reflect Tanzania's evolving approach to resilience across sectors, as illustrated in Figure 2. Their development shows increasing emphasis on integrating climate adaptation within water, energy, and agriculture systems.

NAPA (2007) emphasized the link between climate vulnerability and resource systems, identifying drought as a major destabilizing force affecting food security, water availability, and energy access. Agriculture, water, and energy were ranked as the top three priority sectors. Adaptation measures included adjusting planting dates in specific agro-ecological zones, expanding irrigation with water-saving technologies, and promoting alternative energy sources. This sectoral spread reflected an understanding that resilience depends on interlinked systems. NAPA adopted a project-based approach, emphasizing short-term, localized interventions rather than top-down sector restructuring:

"72 project activities were proposed with a breakdown of 11 in agriculture sector; while water, energy, forestry, health and wildlife sectors had 7 project activities each. Industry and coastal and marine resources sectors had 6 project activities each; human settlements had 9 and finally, tourism had 5."

However, projects were scattered, largely donor-driven, and weakly coordinated, limiting synergies across WEF sectors. NCCS (2012) built on NAPA while responding to international guidance such as the Cancun Agreements (2010) and the National Adaptation Plan (NAP) framework. Organized around adaptation, mitigation, and cross-cutting issues like governance and finance, it retained agriculture, energy, and water as core sectors. Agricultural resilience was framed within food security and rural development, while energy emphasized a low-carbon transition. Importantly, NCCS introduced an institutional coordination framework previously absent in NAPA:

"The Prime Minister's Office–Regional Administration and Local Government will work closely with Local Government Authorities through their various departments in collaboration with lined sectoral ministries."

This institutional grounding sought to link national planning with local realities, addressing a key implementation gap. The Agriculture Climate Resilience Plan (ACRP, 2014) operationalized NCCS objectives within the agricultural sector. ASDP II (2017) recognized the ACRP as its roadmap:

"The ACRP will serve as a roadmap for mainstreaming climate change within current agricultural policies, plans, and practices. It will be the guiding framework for a more comprehensive and consistent approach for confronting one of the major risks to current crop productivity and future investments."

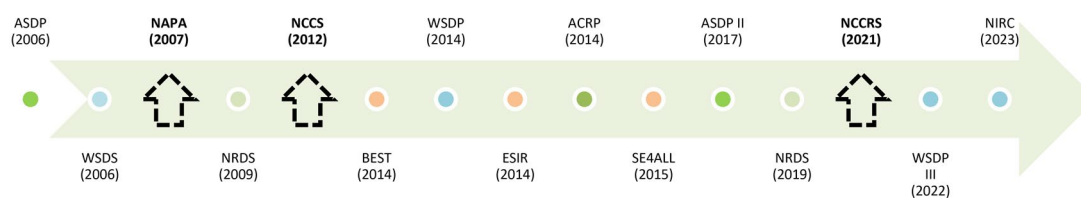


Figure 2. Climate Adaptation Strategies trend.
Source: Researcher (2025).

ASDP II further committed to strengthening Agricultural Sector Lead Ministries (ASLMs) to ensure effective implementation at national and local levels, positioning the ACRP as a core pillar rather than a standalone document. The NCCRS (2021) was developed post-COVID-19 to integrate global climate commitments, including Tanzania's obligations under the Paris Agreement (2015):

"Paris Agreement informs development of new national vision and climate change strategies based on the projected global trend in emission and the required adaptation and mitigation interventions and associated costs within the realm of climate change regime and responsible corporate business for sustainable global economic growth."

NCCRS aimed to address persistent gaps such as weak public awareness, inadequate institutional capacity for climate data management, and limited infrastructure and human resources for monitoring and research. Overall, the evolution from NAPA through NCCRS shows increasing integration and institutional grounding, yet challenges remain in operationalizing strategies across WEF sectors. [Figure 2](#) illustrates this progressive emphasis on climate resilience and cross-sectoral coordination.

5. Discussion

Tanzania's climate and development policies have gradually evolved to recognize the Water-Energy-Food (WEF) nexus, yet fragmentation persists. The National Adaptation Programme of Action (NAPA, 2007) embedded adaptation within a nexus-oriented framework, prioritizing water, energy, and food security and recommending interventions such as irrigation improvements, renewable energy, and adjusted planting calendars. Despite this, coherence among sectors was weak, and operational mechanisms to implement integrated strategies were absent. Early frameworks such as the Water Sector Development Strategy (WSDS, 2006) and ASDP (2006) highlighted conflicts between irrigation and hydropower but failed to propose joint solutions, while early energy policies remained inward-focused. In Mbarali, these gaps translated into limited guidance for rice farmers, who navigated climate risks without institutional support, relying instead on traditional coping strategies (Biggs et al., 2015; Eriksen et al., 2015). During this NAPA era, policy coherence was not as strong since it was heavily project-based rather than full systematic integration. Of all the 72 proposed projects during NAPA only a few were implemented since then due to insufficient funds for all the projects (Pardoe et al., 2018). From a political ecology perspective, this can indicate donors might not see these projects as beneficial for them to finance them for the benefit of the whole. It might also mean donors are the decision makers, which makes them the ones coming up with the criteria of which projects to choose.

The NCCS (2012) sought to unify sectoral planning and align with global frameworks such as the Cancun Agreements, emphasizing adaptation, mitigation, and governance. While programs including WSDP II (2014) and SAGCOT initiatives showed moderate alignment with agricultural adaptation goals, energy integration remained weak. Similarly, the BEST (2014) mapped biomass linkages but lacked operational coordination, and the ESI (2014) strategy focused narrowly on energy. In Mbarali, this institutional fragmentation left paddy farmers without support for energy-efficient irrigation or climate-informed water management, illustrating the challenges of translating national strategies into local action (Tumushabe et al., 2023).

Subsequent strategies attempted to improve coherence, but challenges remained. The ACRP, (2014) integrated resilience into programs including ASDP II (2017), while the NRDS II (2019) prioritized climate-resilient rice varieties and water-efficient irrigation. These measures strengthened food-water integration but largely excluded energy, limiting a full WEF nexus approach (Kangalawe et al., 2017). When communities do not experience meaningful benefits from such centrally formulated policies, it may indicate that decision-making is driven more by national priorities rather than the everyday realities of those most affected (Mberekko et al., 2018). While the policies may show in national documents and on the ground level it is not reflected, it suggests locals may be marginalized in the decision-making process. In Mbarali, paddy farmers continued to face insufficient access to extension services, credit, and climate information, constraining adoption of improved practices despite the presence of supportive national policies.

The NCCRS (2021), along with WSDP III (2022) and the NIRC Strategic Plan (2023–2028), further advanced irrigation modernization and climate-smart practices, aligning more clearly with the Paris

Agreement. Yet energy integration remained fragmented, reflecting persistent sectoral silos and institutional hierarchies (Ampaire et al., 2020). This is similar to Pardoe et al. (2018), which describes an existence of partial coherence manifests as surface-level support for paddy production, with farmers still managing water, energy, and food systems largely in isolation. Embedding a WEF nexus at both national and local levels could enhance coordinated planning, strengthen farmer access to climate information and financing, and improve the adaptive capacity of smallholders, demonstrating that operational integration, not just policy rhetoric is essential for climate-resilient rice production.

Despite the above comprehensive discussion, the evidence included in this review is limited to publicly available national policy documents, which may not capture all ongoing or unpublished adaptation initiatives. Some policies lacked detailed guidance on implementation, monitoring, and resource allocation, making it difficult to fully assess their practical impact on paddy production in Mbarali District. Variations in clarity, completeness, and alignment across documents also limited the ability to directly compare adaptation measures. The review process was limited by its reliance on manual searches of publicly available policy documents, which may have missed relevant unpublished or inaccessible materials, screening and risk-of-bias assessments were conducted by a single reviewer, which could introduce subjective judgment.

Finally, the findings highlight the need for better coordination across water, energy, and agriculture policies to support climate adaptation and paddy production. Policymakers should strengthen cross-sectoral planning and actionable adaptation measures, while future research should assess local-level interventions and their impacts on farmer resilience.

6. Conclusion

Tanzania's national climate adaptation strategies, spanning from NAPA of 2007 to NCCRS pf 2021, demonstrate a growing recognition of the WEF nexus interdependencies. Early efforts in NAPA of 2007 identified agriculture, water, and energy as priority sectors, proposing measures such as water-efficient irrigation and alternative energy sources. However, coherence remained passive, with strategies like WSDS (2006) and ASDP (2006) acknowledging trade-offs without explicit coordination mechanisms. This pattern persisted in later strategies, where even improved alignment, as seen in WSDP III of 2022 and NRDS II of 2019, lacked operational frameworks to integrate energy with water and food systems (Biggs et al., 2015; Albrecht et al., 2018). The absence of active, cross-sectoral platforms reflects persistent governance and institutional barriers, as seen in other regions, including Pakistan, where water-agriculture coherence exceeds energy integration (Waheed et al., 2021). While NCCS (2012) and ACRP (2014) advanced WEF integration by aligning with global frameworks and promoting climate-smart agriculture, their implementation was constrained by vague coordination structures and sector-focused priorities, as evidenced in ESIR (2014), which ignored agriculture and water linkages.

The NCCRS (2021), developed post-Paris Agreement and preceding the forthcoming National Action Plan, strengthened adaptation by addressing gaps in data, infrastructure, and awareness. Strategies such as the NIRC (2023) improved water-food integration through irrigation modernization but continued to lack energy coordination. Passive coherence, characterized by declarative statements without actionable mechanisms, remains a significant barrier to effective adaptation (Pardoe et al., 2018). Moving beyond aspirational alignment requires concrete coordination platforms, clear policy instruments, and institutional mechanisms that enforce cross-sectoral collaboration to ensure WEF strategies are operationalized and responsive to local needs.

7. Recommendations

To enhance WEF integration in Tanzania, a resilient national coordination framework is essential. This could take the form of an inter-ministerial WEF task force with a clear legal mandate to ensure authority, sustainability, and accountability, bringing together the Ministries of Agriculture, Water, and Energy to develop joint policies that synchronize irrigation, energy access, and food production. Policies should be explicitly designed so that progress in one sector depends on complementary actions in the other sectors, fostering synergistic rather than competitive outcomes. To support

effective coordination, institutional capacity must be strengthened through dedicated funding, structured training programs on WEF nexus approaches, and monitoring mechanisms to track performance and ensure accountability. Existing implementation plans should be revised to embed explicit cross-sectoral collaboration, moving beyond declarative statements to actionable plans with defined roles, timelines, and coordination mechanisms. Inclusive stakeholder engagement is critical, particularly involving smallholder farmers and local communities who are often excluded from national-level planning, ensuring that policies and strategies reflect on-the-ground realities and local priorities (Ndesanjo & Asokan, 2023; Allouche et al., 2019). Finally, alignment with international frameworks, such as the Paris Agreement, should guide the design of the forthcoming National Action Plan, incorporating lessons from global models of interagency coordination to embed sustained WEF coherence. Therefore, combining legal authority, institutional capacity, clear implementation pathways, and inclusive stakeholder engagement, these measures can transform passive policy integration into a dynamic, actionable framework for sustainable and equitable climate adaptation across Tanzania's water, energy, and food systems.

Authors' contributions

CRedit: **Christopher Sylvester Machibula**: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing; **Emmanuel Zephahline Nungula**: Data curation, Investigation, Methodology, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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About the authors

Christopher S. Machibula is an Assistant Lecturer in Development Studies at Mzumbe University. He holds a strong academic and professional interest in project management, research, data analysis, and climate change. With practical experience as a junior researcher and data analyst, Christopher has actively contributed to various projects involving monitoring and evaluation.

Mr. Emmanuel Zephahline is a soil scientist and an agronomist with specialization in the field of pedology/soil survey/land evaluation. Emmanuel is also interested in research, outreach activities, and consultancies in not only his area of specialization but also the fields of agronomy, soil fertility, digital soil mapping, management of the environment and natural resources, agroforestry and sustainable agriculture.

ORCID

Christopher Sylvester Machibula  <http://orcid.org/0009-0005-1291-1471>

Data availability statement

Upon reasonable request, the appropriate author (CSM) will provide the data.

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Appendices

Year	Document name	Category	Link
2006	Agriculture Sector Development Programme (ASDP) I	Agriculture	ASDP
2006	Water Sector Development Programme (WSDP) I	Water	WSDP
2007	National Adaptation Programme of Action (NAPA)	Climate change	UNFCCC
2009	National Rice Development Strategy (NRDS I)	Food	JICA
2012	National Climate Change Strategy (NCCS)	Climate change	FAOLEX
2014	Water Sector Development Programme (WSDP) II	Water	WSDP
2014	Biomass Energy Strategy (BEST)	Energy	TFCG
2014	Electricity Supply Industry Reform Strategy (ESIR)	Energy	TZDP
2015	ACRP (Agriculture Climate Resilience Plan)	Food, Climate change	FAOLEX
2015	Sustainable Energy for All (SE4ALL) Action Agenda	Energy	SE4ALL
2017	Agriculture Sector Development Programme (ASDP) II	Food	ASDP
2019	National Rice Development Strategy (NRDS II)	Food	JICA
2022	Water Sector Development Programme (WSDP) II	Water	WSDP
2021	National Climate Change Response Strategy (NCCRS)	Climate change	FAOLEX
2023	National Irrigation Commission Strategic Plan	Water, agriculture	NIC