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WATER-ENERGY-FOOD NEXUS



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8.1 Background

The security of water, energy, and food is a critical concern for South Africa, as the recurrence of extreme weather events, depletion, degradation, and the increasing demand from a growing population exacerbates the country's risk and vulnerability. The three sectors—energy, water, and food—are intricately interconnected (Figure 8.1). This is due to the fact that energy generation necessitates a significant amount of water for the purposes of fuel production, mining, hydropower, and power plant cooling. Conversely, energy is required for the collection, treatment, and discharge of wastewater and for water pumping, treatment, and distribution. Concurrently, the production of food necessitates both water and energy, while crops such as maize, soybean, and sugarcane have been identified as potential biofuel sources (Gerbens-Leenes et al., 2009). The water-energy-food (WEF) nexus is the term used to describe these mutual interconnections (Leck *et al.*, 2015).

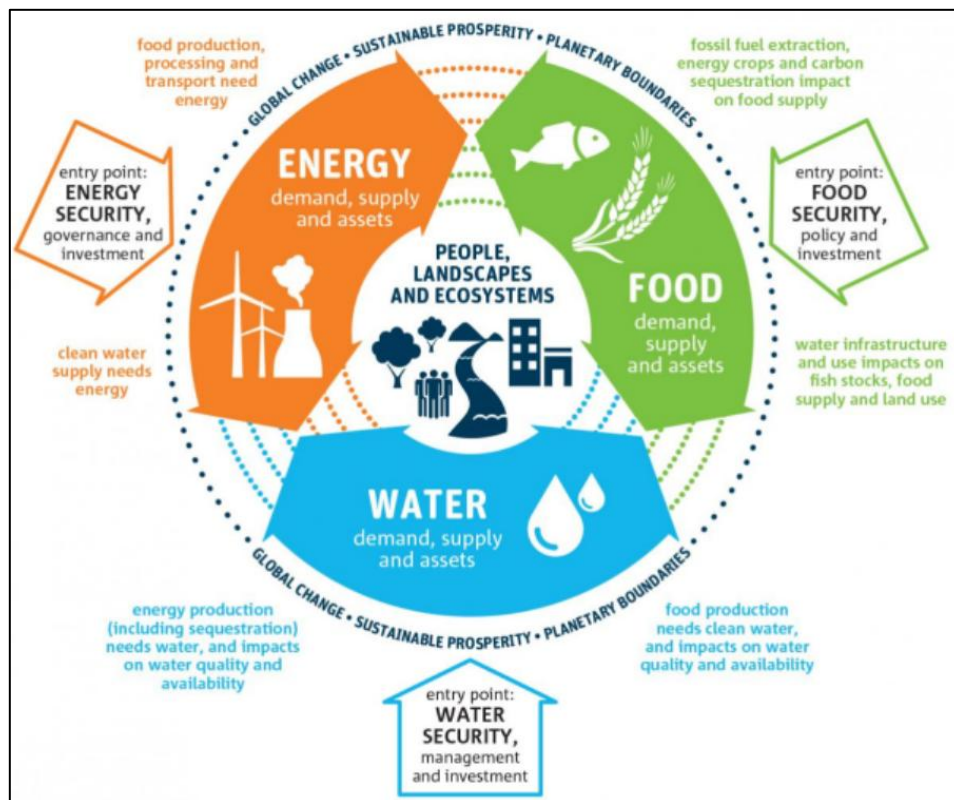


Figure 8.1: The interconnectedness of water, energy and food sectors (Source: IWA, 2018).

The WEF nexus, a three-way mutual interaction among WEF sectors, has become a critical subject for facilitating the transition from a linear to a circular economy since

2008. It has experienced significant growth in popularity since the Sustainable Development Goals (SDGs) were implemented in 2015, as it is closely associated with sustainable development. However, the absence of a unified governance framework has impeded the adoption of the WEF nexus and the realization of the SDGs. The transition from the linear to the circular economy and integrated resource management has been impeded by the sectoral nature and lack of coherence of South Africa's well-written policy documents, which include strategies, acts, plans, and white papers. The country is confronted with the triple challenge of poverty, inequality, and unemployment, with over 50% of households experiencing food insecurity, 98% of water resources already allocated, and severe energy insecurity challenges. The absence of a comprehensive and integrated governance framework to facilitate the concurrent development of the three sectors has resulted in the slow adoption and implementation of the WEF nexus.

A WEF nexus integrative decision support tool was created in South Africa to facilitate the management of the country's three WEF resources and to pinpoint areas that require immediate attention. Resource insecurity is further exacerbated by climate change, extreme weather events, and the growing population. The WEF nexus is transformative and integrated, providing strategic guidance for holistic resource management decisions. It has the potential to incorporate strategies to address the challenges posed by population growth, rural-urban migration, urbanization, increased consumption demands, and climate change. This method generates numerous efficiencies by removing inefficiencies and duplication in resource allocation and utilization. However, a transformation in governance structures is required to facilitate the transition to a circular economy and sustainable development.

8.2 Climate change impacts on WEF sectors

Climate change projections for South Africa show that temperature will increase by between 1 to 2°C for coastal regions and between 3 to 4°C for interior regions by 2050 (Davis and Vincent, 2017). The changing rainfall patterns are expected to shift, resulting in the western parts of the country experiencing significant stream flow reduction (Xulu *et al.*, 2023). This will have some implications for agriculture as yields will decline, impacting food security. The WEF nexus significantly balances resource allocation and enhances climate change resilience and adaptation, benefiting mostly smallholder farmers who are the most vulnerable (Nhamo *et al.*, 2020a). Climate change is also impacting water resources in South Africa, with high spatial variability (Davis and Vincent, 2017). Recently, most areas have been affected by climate change-induced flash floods (Figure 9.3), resulting in property destruction and loss of lives.



Figure 8.2 Climate change-induced flash floods in Durban in October

The adverse impact of climate change will continue to worsen the existing systemic water insecurity challenges. As previously stated, South Africa's agricultural sector accounts for more than 60% of water use, but it is projected that irrigation water demand will have to increase by between 4% and 6% by 2030 to meet the food demands of a growing population (Ngarava, 2021). The increased demand for irrigation water should also be viewed within the context of increased demand for water for energy generation and domestic use due to a growing population. The increased frequency in the recurrence of droughts and floods is threatening rainfed agriculture as the risk of crop failure increases (Davis and Vincent, 2017; Nhamo *et al.*, 2019). This highlights the need to adopt and implement the WEF nexus for holistic and sustainable resilience and adaptation. Although the country has clear policy documents on climate change, it tends to be silent on policy integration and cross-sectoral interventions (Nhamo *et al.*, 2025; Ntombi, 2017).

8.3 Selected WEF sectors related institutions and policies

The Constitution of South Africa is the overarching policy document that guides all legal and policy instruments in the country. The right to water is enshrined in the Constitution and implemented through different statutes framed around the Constitution. The Constitution is clear on sufficient access to sufficient water, food, and energy by all. The legal framework governing WEF sectors in SA is presented in (Table 8-1).

Table 8-1: Main policy and legal frameworks governing WEF sectors in South Africa

Water sector	Energy sector	Agriculture (food) sector
<ul style="list-style-type: none"> ▪ National Water Act 36 of 1998, with the Amendment Bill (2023) ▪ National Environmental Management Act 107 of 1998 ▪ National Water Resource Strategy 3 (2013) ▪ White Paper on a National Water Policy for South Africa ▪ Water for Growth and Development Framework 	<ul style="list-style-type: none"> ▪ The National Energy Act (2008) ▪ White paper on energy policy (1998) ▪ White paper on renewable energy (2003) ▪ Integrated Energy Plan (IEP, 2003 and 2005) ▪ Integrated resource plan (IRP, 2019) 	<ul style="list-style-type: none"> ▪ Agricultural Policy in South Africa (1998) ▪ White paper on energy policy (1998) ▪ Agriculture and Agro-processing Master Plan (AAMP) (2022) ▪ White paper on agriculture (1995) ▪ Integrated resource plan (IRP, 2011) ▪ Strategic Agriculture Sector Plan

8.4 Current WEF Resource Management in South Africa

An overview of the current status of WEF resources governance and management in South Africa in 2015 and 2020 is given in Table 8-2 (WorldBank, 2024). The data were used in an integrative analytical WEF nexus model (Nhamo *et al.*, 2020a), which applies the Analytic Hierarchy Process (AHP), a multi-criteria decision method (MCDM) (Saaty, 1977). The AHP was used to establish the pairwise comparison matrix (PCM), normalise the indices, and provide the numerical relationships between the distinct indicators (Nhamo *et al.*, 2020a). The model, which is applicable at any spatial scale, assessed resource management in 2015 and 2020, and the results are key to assessing progress in achieving the SDGs over time. The approach simplifies the human understanding of the interconnectedness of interlinked sectors, facilitates easy interpretation of the complex relationships between the WEF sectors and guides policy decisions on holistic priority interventions (Naidoo *et al.*, 2021; Nhamo *et al.*, 2020a).

Table 8-2. State of the WEF resources indicators for South Africa in 2015 and 2020
(Source: World Bank, 2024)

Indicator and short name	Indicator status		
	2015	2020	Units
Proportion of available freshwater resources per capita (availability)	821.3	821.4	m ³
Proportion of crops/energy produced per unit of water used (water productivity)	26.2	26.2	\$/m ³
Proportion of population with access to electricity (accessibility)	85.5	84.4	%
Energy intensity measured in terms of primary energy and GDP (productivity)	8.7	8.7	MJ/GDP
Prevalence of moderate/severe food insecurity in the population (self-sufficiency)	5.7	6.2	%
Proportion of sustainable agricultural production per unit area (cereal productivity)	3.5	5.6	kg/ha

The PCM and the normalisation of the indices generated the composite indices for the two reference years (Table 8-3). A five-year interval was selected in this case as it is a reasonable period where resource management and governance changes can be appreciated. The composite indices represent the quantitative relationships between the WEF sectors; however, the relationship is difficult to interpret and understand when shown in a table format. The quantitative relationships are then represented through a spider graph (Figure 8.3Figure 9.3Figure 9.4), vividly illustrating how resources are related and managed. The WEF nexus integrated index is a weighted average of the composite indices that indicate the level of the country's resource management.

Table 8-3. WEF resources security composite indices for South Africa in 2015 and 2020

Indicator	Composite indices	
	2015	2020
Water availability	0.126	0.099
Water productivity	0.128	0.221
Energy accessibility	0.141	0.079
Energy productivity	0.111	0.199
Food self-sufficiency	0.314	0.292
Cereal productivity	0.180	0.111
WEF integrated index	0.203	0.155

The composite indices (Table 8-3 and Figure 8.3) are dimensionless relations between 0 and 1. The spider graph, therefore, quantitatively relates WEF nexus indicators in terms of management (Nhamo *et al.*, 2020a). For example, the water availability indicator is related to other indicators by 0.126 in 2015, which decreased to 0.099 in 2020. However, an indicator of 1 represents the best possible resource management, and 0 represents poor management.

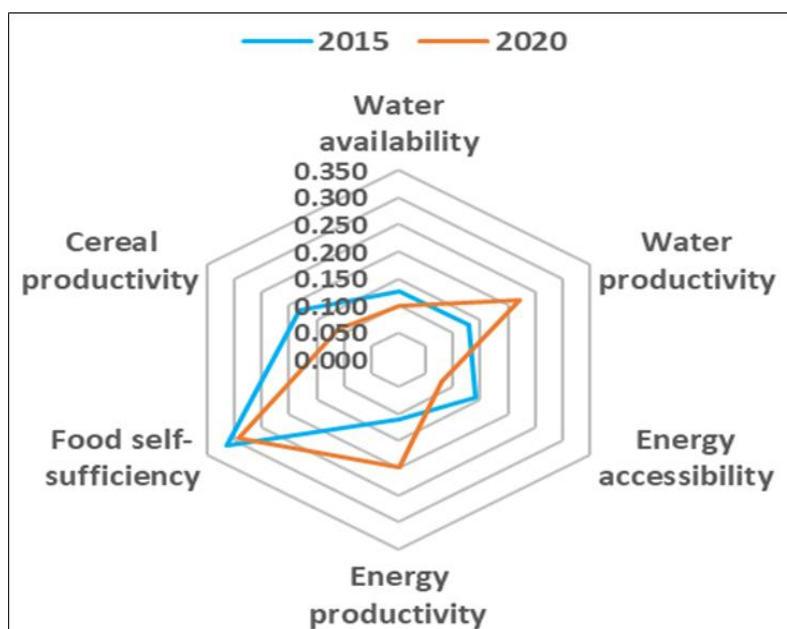


Figure 8.3 Spatio-temporal changes in South Africa WEF resources management in 2015 and 2020.

The centrepieces are irregular in shape, an indicator of linear and sector-based governance systems still being pursued. The centrepieces should be circular to indicate balanced resource management indicating a clear path towards sustainability. Therefore, the shape of the centrepieces gives a synopsis of the state of resource management and governance and the economic model being pursued. Sector-based and linear models in resource management only compound current cross-cutting challenges. The shape of the centrepieces is key to indicating priority areas for priority intervention from a cross-sectoral and holistic perspective. Therefore, the key to the spider diagram is to identify trade-offs and synergies for timely intervention. The shape of the centrepieces shows areas needing either to mitigate trade-offs or maximise synergies. The changes indicated in the spider graph show that the approach can be used to assess progress towards achieving the SDGs (Mabhaudhi *et al.*, 2021).

Therefore, the integrative analytical WEF nexus model is a decision-support tool for assessing the state of resource management and governance at any given time and at any spatial scale. The model has been used at the local scale (Nhamo *et al.*, 2020b), national scale (Nhamo *et al.*, 2020a) and regional scale (Mabhaudhi *et al.*, 2019). The approach provides pathways to (a) enhance holistic, sustainable, and resource use efficiency of the WEF resources, (b) promote equitable and balanced resource

management and distribution, (c) ensure human and environmental health, and (d) support the provision of ecosystem services. These attributes make the WEF nexus an essential systems approach to assess resource management. However, besides the current evidence of the importance of the WEF nexus, its implementation has been hindered by the lack of an integrated, harmonised, holistic governance framework.

8.5 Conclusions and Recommendations

Considering the interlinkages between WEF sectors and the impact of climate change on resources, there is a need for coherence in governance frameworks of interlinked sectors to facilitate policy harmonisation, coordination and management of resources. The current linear approach in managing resources in South Africa is resulting in optimal efficiency attributes in some sectors at the expense of equally important resources. The presence of a harmonised WEF nexus governance framework guides integrated resource development and management and identifies cross-sectoral synergies and trade-offs for timely intervention.

The South African case study has highlighted that the WEF nexus approach offers opportunities for policymakers to sustainably meet set targets, including achieving SDGs and the NDP goals (Nhamo *et al.*, 2025). Advancing integrated planning, policy coherence and management is critical for raising inter-sectoral awareness about the WEF nexus. Efforts should focus on eliminating barriers, including lack of collaboration, fragmented and sector-based policies, uncertainty and anxiety among key stakeholders, and inequality (Naidoo *et al.*, 2021). These are the major challenges hindering the implementation of the WEF nexus. The following recommendations are proposed for the successful operationalisation of the WEF nexus:

- Evidence from the case study has shown that at the level of governance, it is necessary to ensure that horizontal linkages exist during the design and implementation phases of the WEF nexus model. It is also important to harmonise and coordinate policies on water, energy, food and climate to guide a sustainable transition from the current linear approaches to the circular model. The WEF nexus, therefore, provides opportunities to stabilise competing demands in an environment of scarce resources by ensuring that development in one sector has minimal impacts on the other sectors.
- Despite the SDGs being intended to be accomplished by 2030, there has been minimal progress in achieving the established objectives within the designated timeframe (UN, 2023). The SDGs are intended to be driven and catalyzed by the WEF nexus; however, the concept has been adopted at a glacial pace.
- Energy insecurity in South Africa has contributed to the country's credit status being downgraded. The 'crises' in the energy sector have also led to the 'explosion' of new coal mines. This has raised renewed fears of acid mine drainage and conflicts with the water and agriculture sectors, as mining pollutes

water and competes for land with agriculture. While energy might receive more attention as an important economic driver, it must be noted that many of the pressures that drive energy demand also apply to water and agriculture. Therefore, water, energy and food are all central to South Africa's vision of delivering a better quality of life to its citizens. This highlights the urgent need for better convergence of policy amongst the three sectors.

- As an initiative to start the WEF nexus discussions, there is a need for an inter-sectoral dialogue that also includes all stakeholders to establish a Community of Practice at the national level. The platform should be used to promote WEF nexus research and harmonisation of policies.