8

# WATER-ENERGY-FOOD NEXUS

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## 8.1 Background

The connectedness of current challenges (climate change, environmental degradation, population growth, migration, and the emergence of novel infectious diseases) requires circular and transformative approaches that holistically address these cross-cutting challenges. Managing the intricate relationships between distinct but interconnected sectors through nexus planning has provided decision-support tools to formulate coherent strategies that drive resilience and sustainability. As a result, the Water-Energy-Food (WEF) nexus has gained increasing attention in the research and decision-making communities in recent years as a prominent approach for integrated resources management. The systematic thinking embedded in the WEF nexus is priceless as it considers the synergies and trade-offs in resource planning, utilisation, and management. The developments in one of the three WEF sectors should always consider the impacts on the other two to avoid transferring problems from one sector to the other.

Over the past decade, the WEF Nexus has emerged as a useful concept to systematically reduce trade-offs and increase synergies in promoting water, energy, and food security goals. This, in turn, supports the attainment of several Sustainable Development Goals (SDGs), particularly SDGs 2, 6 and 7, with interlinked positive effects on several other SDGs. The nexus is driven by a holistic vision of sustainability that seeks to strike a balance among key resources (water, energy, and food), the different goals, interests, and needs of people and the environment in a region faced with population growth, urbanisation, industrialisation, resource depletion and degrading ecosystem services. The nexus builds understanding around interlinked resources and can be applied to achieve resource security and sustainable development. Focusing on addressing challenges in any one of these sectors only promotes optimal efficiencies in that one sector at the expense of the other two, as the same challenges will manifest in the other neglected but equally important sectors.

Furthermore, the three resources are the most climate-sensitive sectors, a cross-sectoral challenge needing cross-sectoral and holistic interventions. The WEF concept is, therefore, promoted as a governance solution to complex resource management challenges. The intricate interlinkages between the three WEF sectors manifest as food production needs water and energy, water management (extraction, treatment, and redistribution) requires energy; and energy production requires water. Despite these interlinkages and the fact that decisions taken in one sector can spill over and affect the other sectors, traditional and sector-based research approaches have fallen short in addressing the linkages between WEF resources. Moreover, existing WEF insecurities are exacerbated by climate change, increasing uncertainty for future development plans.

## 8.2 Overview of the WEF Resources

South Africa is currently grappling with the poverty-inequality-unemployment challenges, with unemployment over 34% (StatsSA, 2021). Most government initiatives are driven by the urgent need to address this problem and deliver the promise of a better life for all. In these efforts, water, energy, and food are critical to delivering socio-economic reforms, sustainable economic development, and achieving national and international goals. South Africa is slowly adopting the WEF nexus as a transformative approach that drives the transformational agenda at the national level (Liphadzi et al., 2021; Mabhaudhi et al., 2021; WRC, 2018). A working group of the country's WEF Community of Practice (WEF-COP) was formed to support the development and implementation of a 5-year country WEF programme. The working group is meant to harmonise policy documents and reduce sector-based management of resources that are still fragmented, sitting in distinct departments. Through its WEF nexus Lighthouse, the Water Research Commission (WRC) has been leading work and discussions as well as pilot projects that highlight the benefits of the WEF nexus approach. However, despite these efforts, South Africa still lacks a guiding WEF policy document to guide the implementation, monitoring, and evaluation of the nexus (WRC, 2018).

South Africa faces water, energy, and food insecurity (Figure 8.1). While the country is food secure at a national level, over 50% of households still face food insecurity, 98% of the country's water resources are already allocated, and the country currently faces instability in the energy sector (StatsSA, 2019). The recurrence and increasing droughts, coupled with sectoral resource management and climate change, compound the challenges of resource insecurity (Mpandeli et al., 2019; Nhemachena et al., 2020). Given these cross-cutting and interlinked challenges (Figure 8.1), there is an urgent need for South Africa to speed up the implementation of the WEF nexus approach to enhance resource security in an integrated and sustainable manner.

Ensuring water, energy and food security is a priority in South Africa, centred on improving livelihoods, building resilience, employment creation, and economic development (Nhamo et al., 2020; Von Bormann and Gulati, 2014). The current cross-cutting challenges require adopting transformative approaches such as the WEF nexus at the national level, a platform for stakeholder engagement, as evidenced by forming a community of practice at the national level. Importantly for South Africa, the WEF nexus has been recognised as a framework to guide integrated resource management and drive the country towards resource use efficiency, poverty reduction, employment creation, and achieving SDGs (Mabhaudhi et al., 2021; StatsSA, 2019, 2021). This is also motivated by the need to produce more food and energy to meet the demands of a growing population.

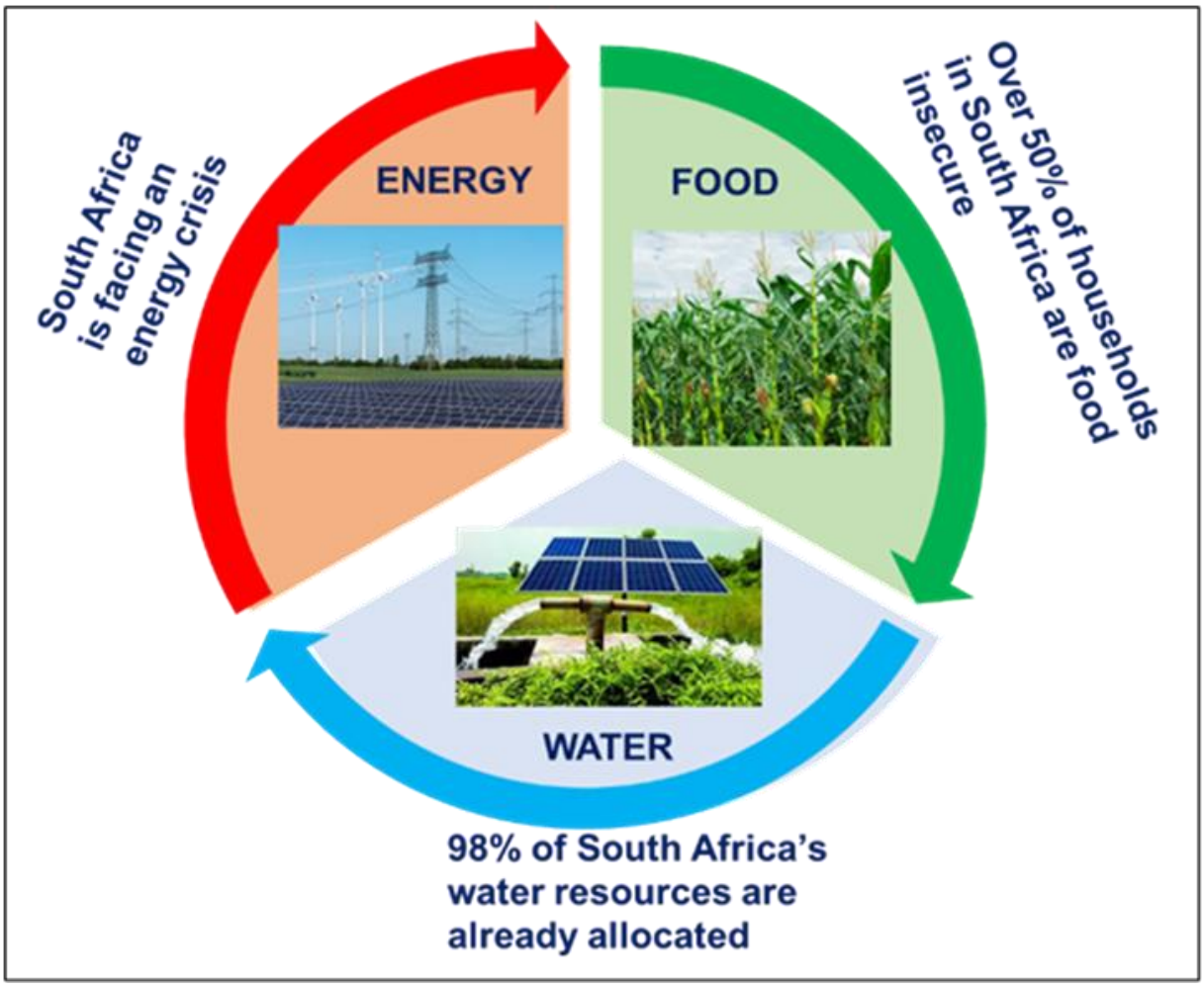


*Figure 8.1: The WEF nexus sectoral challenges (Source: WRC).*

### 8.2.1 Water Resources

South Africa is a water-scarce country (StatsSA, 2017). Water insecurity has become severe as almost 98% of the available freshwater resources are already allocated, and over 60% is used for crop production (StatsSA, 2017). Water availability is highly variable, determined by rainfall variability in the national territory (Figure 8.2).

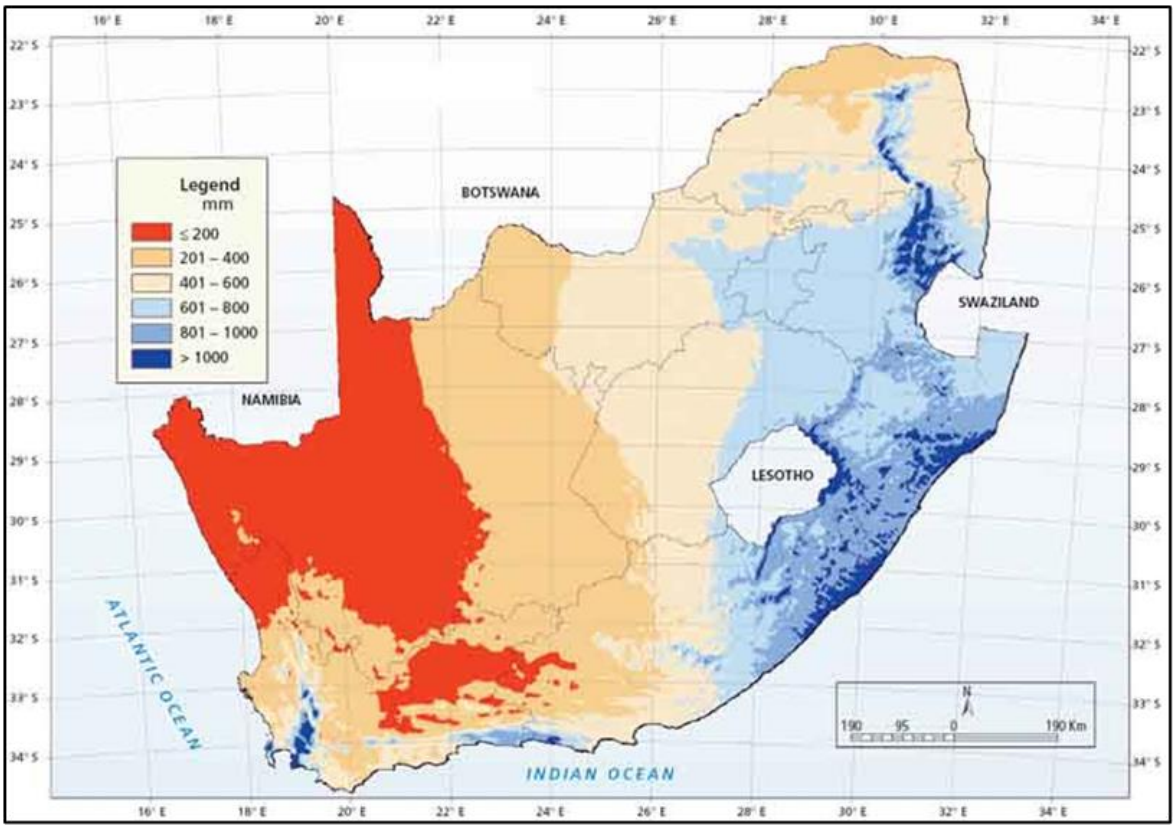


*Figure 8.2: Average annual rainfall across South Africa (Source: ARC-ISCW, 2004).*

Rainfall varies from less than 50 mm in the northwest to more than 3,000 mm in the mountains of the southwestern Cape. Thus, the eastern parts of the country receive considerably more rain than the dry western parts. However, the country has a well-developed water infrastructure (Pitman, 2011). South Africa has the highest level of artificial water storage per capita in Africa, at around 700 $m^3$ per capita per annum (StatsSA, 2010). The well-developed water infrastructure has enabled the country to manage long periods of drought. Still, the recurrence and intensity of drought in recent years have resulted in the depletion of reservoirs, causing an increased use of groundwater resources (GreenCape, 2017).

Although groundwater resources availability in South Africa is still unknown, 13% of the country's freshwater resources come from groundwater, of which 59% is used in irrigation, 13% in water supply, 13% in mining, 6% in livestock, and 9% for other uses (Figure 8.3). South Africa has 1,000 $m^3$ of renewable water available per capita per annum, which is too high for a water-scarce country (StatsSA, 2017). The country has a dependency ratio of 13%, meaning that 13% of its freshwater water resources are generated from other countries (GreenCape, 2017). At the same time, 170 million $m^3$/yr of water resources generated in South Africa are transferred to Botswana, Mozambique, Swaziland, and Namibia (Kumwenda et al., 2015). South Africa has formed Water Management Areas (WMAs), and in almost all of them, there are currently water deficits as demand outstrips supply (GreenCape, 2017; StatsSA,

2010). This is projected to worsen as the population grows and water demand increases (GreenCape, 2017). Estimates indicate that by 2030, South Africa will face a 17% demand-supply gap (GreenCape, 2017).

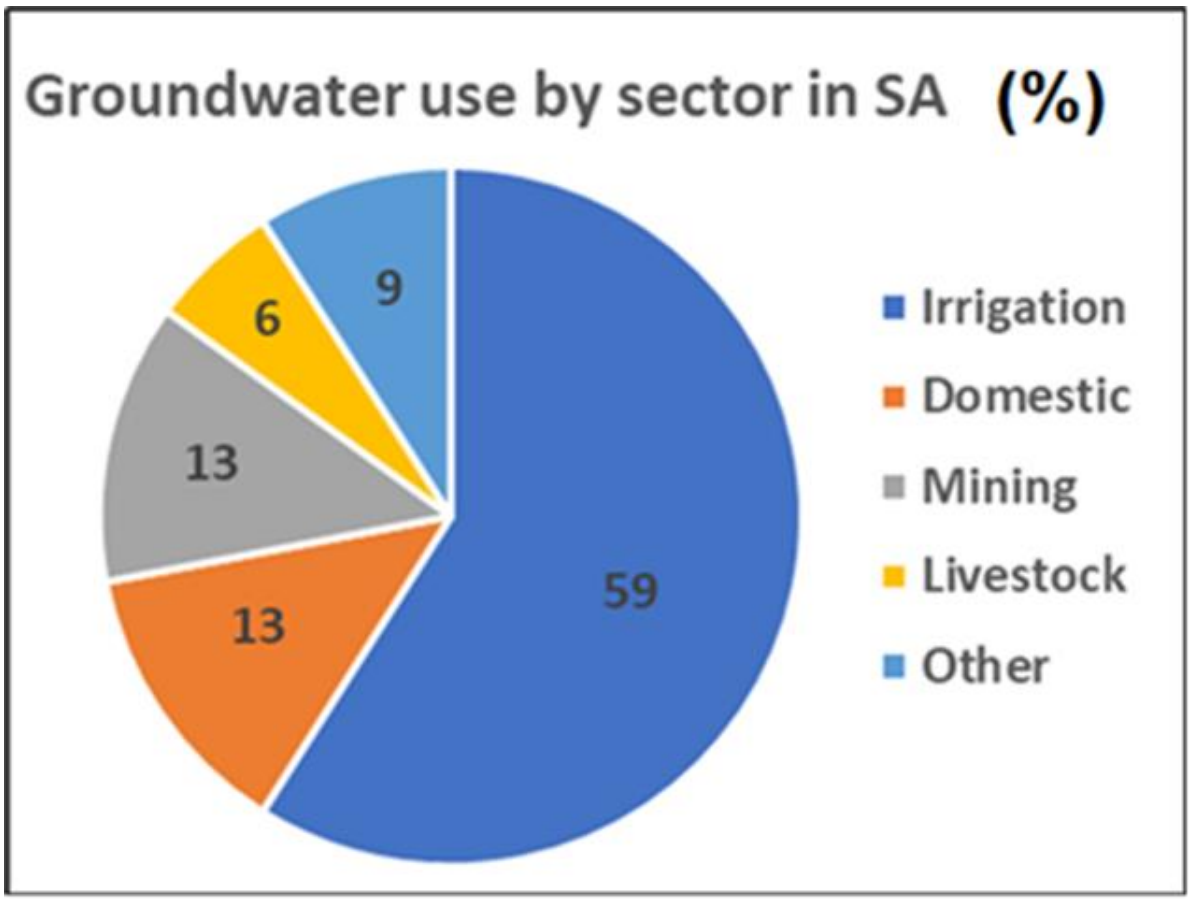


*Figure 8.3: Sectoral groundwater in percentage (Source: GreenCape, 2017).*

Agriculture alone uses approximately 9.7 $km^3$ (about 63%) of total annual water withdrawals in South Africa (Donnenfeld et al., 2018) (Figure 8.4). There is an urgent need to enhance water-use efficiency, promote sustainable food systems through circular models, and improve water productivity, particularly in agriculture. Agriculture is the largest consumer of water in South Africa; therefore, adopting agricultural water management technologies and innovations is critical for the country to enhance water use efficiency in the agriculture sector. The situation is worsened by the low average annual rainfall of about 450 mm, well below the world average of 860 mm (Davis and Vincent, 2017).

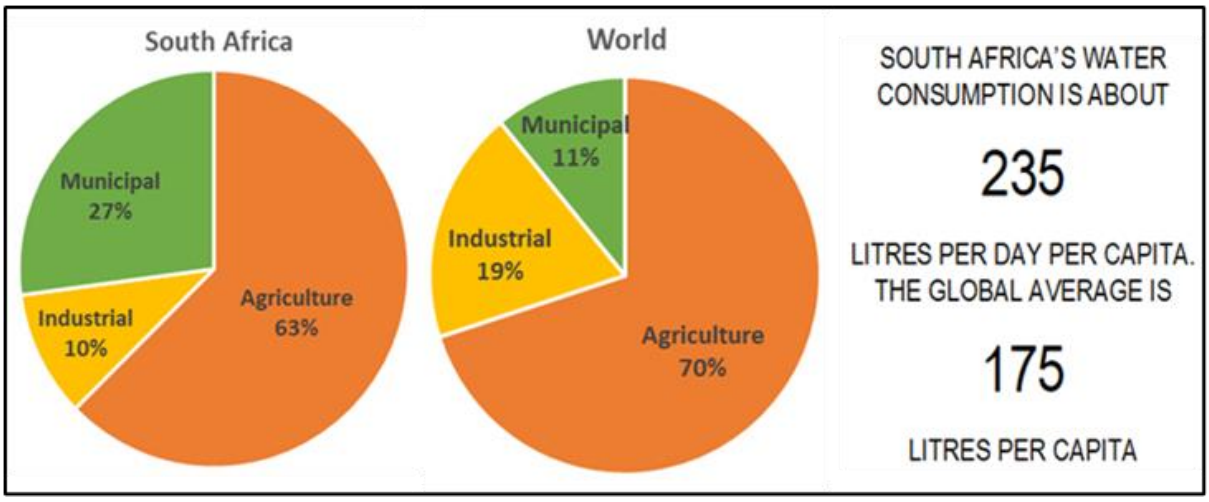


*Figure 8.4: Total water withdrawals in South Africa versus the world by sector (Source: World Bank Indicators, 2020).*

As already alluded to, agriculture accounts for about 63% of water use in South Africa, followed by domestic (24%) (Figure 8.4) (GreenCape, 2017; Von Bormann and Gulati, 2014). As a mitigatory measure to the challenge of water scarcity, South Africa and Lesotho initiated the Lesotho Highlands Water Project, where Lesotho transfers some of its abundant water resources to the Gauteng region (Nhemachena et al., 2020). In return, Lesotho uses the revenues from the project to develop its hydropower capacity and improve water distribution within the country (Matchaya et al., 2019). There is a need to build on such transboundary transfers to address water scarcity at the regional level.

### 8.2.2 Energy Resources

Energy is a key economic driver, especially in an emerging economy such as South Africa. Strategies to increase levels of industrialisation, mining output, growth in manufacturing, and associated activities are all key contributors to increasing demand for energy. In addition, the growing middle class, rural-urban migration, and focus on developing rural economies also add to the increasing demand for energy. The International Energy Agency (IEA) forecasts that demand for energy in South Africa is set to increase by more than 30% between 2010 and 2035 (IEA, 2016). Over the same period, climate change predictions indicate increased frequency and intensity of extreme weather events in the country (particularly drought and floods) (Nhamo et al., 2019). The increased demand for energy and the increased water scarcity highlights a challenge that requires transformational approaches such as nexus planning, circular economy, and scenario planning that enhance resource use efficiency (Mabhaudhi et al., 2021). For example, water and energy availability have become topical issues in recent years. Most parts of the country have been experiencing water supply shortages due to a lack of power and cable theft. The main water purification systems are not getting enough energy. The lack of power supply and water

unavailability is due, in part, to a lack of recognition of the relationships between the water and energy sectors or slow implementation of the nexus approach.

About 4% of South Africa's water is used for power generation (Figure 8.5), a low figure compared to that used in agriculture. However, this figure only considers water used for hydroelectric power and cooling coal and nuclear plants. It does not take into consideration water that is used in biofuel feedstock production, nor does it take into consideration the entire water footprint in power generation. However, energy is used for services by municipalities in South Africa. Drinking and wastewater use 45% and 55% of energy in urban areas respectively (Figure 8.5).

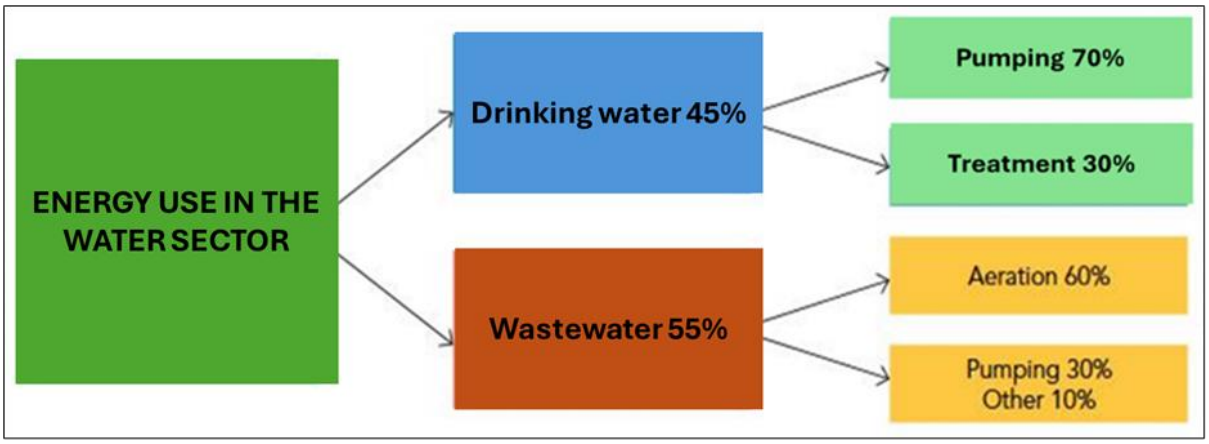


*Figure 8.5: Average energy use in the water sector in South Africa (Source: GreenCape, 2017).*

### 8.2.3 Land and Agriculture

South Africa is food secure at the national level; however, it is faced with extreme poverty and high-income inequality, in that approximately 56% of the population lives in poverty (StatsSA, 2019). Many households face food insecurity daily (Chakona and Shackleton, 2019). Most people facing food and nutritional insecurity live in rural areas and informal settlements. Statistics South Africa (StatsSA, 2019) reports that approximately 25.2 % of the population lived below the poverty line of R14.70 per person per day. Rainfed agriculture is the third-most important means of livelihood, after remittances and government grants, but it contributes only 10% to household survival (StatsSA, 2019). Given the political and human rights challenges of hunger and unemployment that the Covid-19 pandemic has exacerbated, there is an urgency to provide practical, cost-effective support to smallholder farmers that can be implemented at different agroecological zones.

Figure 8.6 is a map of South Africa showing the agricultural area by the system (rainfed and irrigated) and the percentage of each system by province. Over 23 million ha of land in South Africa is under cultivation, of which 18 million ha is rainfed and only 5 million ha is irrigated. The Western Cape, Northern Cape, Limpopo, and KwaZulu-

Natal provinces have the highest proportion of agricultural land under irrigation. The rest of the provinces have irrigated areas of less than 15%, and they are the provinces that show extreme dry conditions. The most rainfed area is under smallholder farmers. As smallholder farmers produce most of the food crops and yet are the most vulnerable to the impacts of climate change, intervention should, therefore, target the smallholder farming system. Dependence on rainfall for agriculture implies that once there is a climate shock in the system, such as drought or flood, there would be total crop failure that season.

Eighty percent of South Africa's agricultural land is suitable for animal production. Cereals and grains occupy about 42% of cultivated land (StatsSA, 2017). Although South Africa is defined as a food-secure country, producing enough staple food or having the capacity to import food, if needed, to meet the basic nutritional requirements of its population, (Chakona and Shackleton, 2019), 20% of the population remains food insecure, and 50% do not have enough food (StatsSA, 2019). On average, South Africa has been self-sufficient in agricultural production and a net food exporter. The impact of extreme weather events has been impacting on food security of the country, as evidenced by the 2015/16 drought that saw the country importing the staple maize crop for the first time (Nhamo et al., 2019). Agriculture contributes about 3% to South Africa's gross domestic product (GDP) and about 7% to formal employment (StatsSA, 2019).

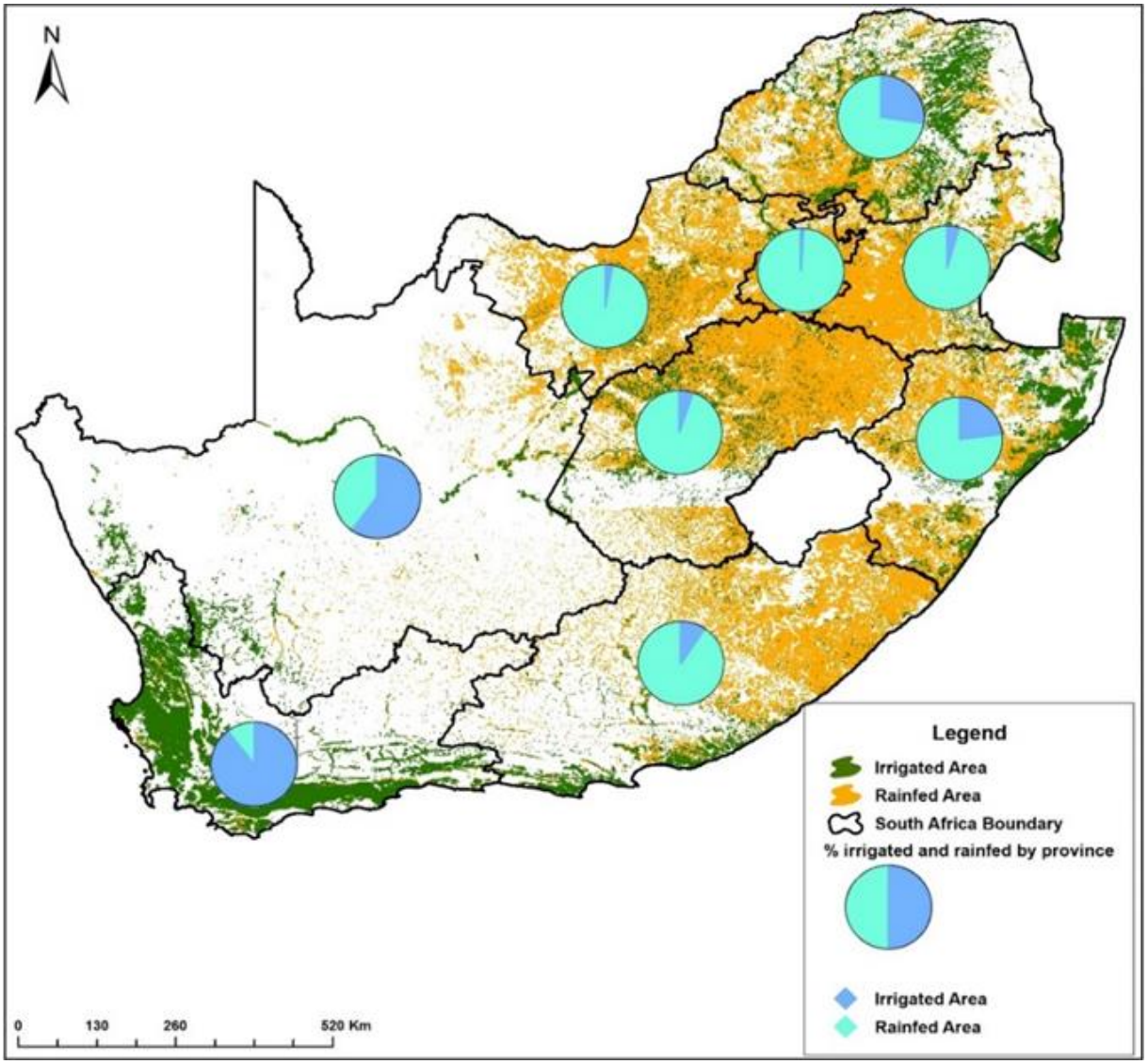


*Figure 8.6: Irrigated and rainfed areas and the proportions by province (Source: Siddiqui et al., 2016).*

## 8.3 Importance of Nexus Approaches

The insecurity of the WEF resources in South Africa is compounded by climate change, resource depletion, and degradation, migration, the emergence of novel pests and diseases, poverty and inequality, and unsustainable food systems, among others, a situation that has triggered the need for transformational change. Apart from the challenges within the three WEF sectors that are also causing negative environmental changes, there are also spill-overs into other sectors, such as health and the environment. For example, the disruptions caused by the COVID-19 pandemic caused immense disruptions in all sectors of the economy while policy and decision-makers were proving reactive measures, focusing on the health sector. The COVID-19 experience has demonstrated that focusing on a single sector during a crisis only exacerbates the stressors in other sectors as decision-makers have often viewed the

world from a linear perspective, with the thought that a click of a button would get the economy and society back on track (Nhamo and Ndlela, 2021).

South Africa has developed a natural resources atlas that provides access to a comprehensive set of data and a framework for strategic planning at national and provincial levels for implementing programmes focusing on biodiversity, climate change, and land assessment for long-term sustainability. The atlas provides access to 63 national spatial layers of information on soil, climate, vegetation, terrain, land capability, and high-resolution satellite data. These are being implemented with other national departments, provinces, and municipalities. The LandCare programme was established to promote productivity through the sustainable use of natural resources, improve food security, and create employment, encouraging South Africans to use sustainable methods of cultivation, livestock grazing, and harvesting of natural resources to limit land degradation.

## 8.4 Establishing the Context and Case for Supporting WEF Nexus Investments

South Africa's natural resources and the location of economic development nodes are unevenly distributed; this amplifies management constraints and inequality of access to these resources. A delicate scenario South Africa faces is water, energy, and food insecurity, yet the security of these resources forms the basis of a resilient economy. Apart from being a water-scarce country, the country has limited arable land (StatsSA, 2019) and is highly dependent on fossil fuels for energy generation (86% of the country's electricity is generated from coal); the country also depends on oil imports. Estimates show that by 2030, 65% of South Africa's electricity will still be generated from coal. The population will have increased to 60 million, and as early as 2025, the country will face a water deficit of 1.7% (Von Bormann and Gulati, 2014). At the same time, the National Development Plan (NDP) targets an increase of more than 50% of land under irrigation (NDP, 2013). Indications are that the country's resources will be stretched to the limit soon, and this calls for urgent adoption of an integrated approach to resource utilisation and management through the WEF nexus.

The challenges posed by resource constraints in South Africa indicate a looming crisis in providing clean water, electricity, and nutritious and affordable food, which are at the heart of national security and welfare. The WEF nexus is central to the sustainability of South Africa's future. The situation requires enhanced information, coordinated planning, wider technology use, adaptation, and greater governance through policy to guide the WEF sectors.

## 8.5 Institutional and Legal Frameworks at the National Level

### 8.5.1 Existing Institutional Arrangements Governing WEF Resources

The Constitution of the Republic of South Africa (RSA, 1996) is the overarching document that guides all other legislative and policy instruments adopted by the government. The water right is enshrined in the Constitution and implemented by the work of ordinary statutes. The Constitution states that everybody has the right to access sufficient water, food, and energy. The Bill of Rights informs the development and implementation of the National Water Act, Energy Act, and The White Paper on Agriculture, among others. It is important to note that domestic legislation is also influenced by international agreements. An example of this is the United Nations Framework Convention on Climate Change. Also, South Africa is governed by regional frameworks like those of the Southern African Development Community and the African Union. Given this, the country is making policy and regulatory shifts in line with international law. South Africa has good legislative and policy instruments that direct the management of WEF sectors (Figure 8.7), and the country still has started initiatives to integrate these resources through the WEF nexus. The nexus is an opportunity to distribute the WEF components equitably.

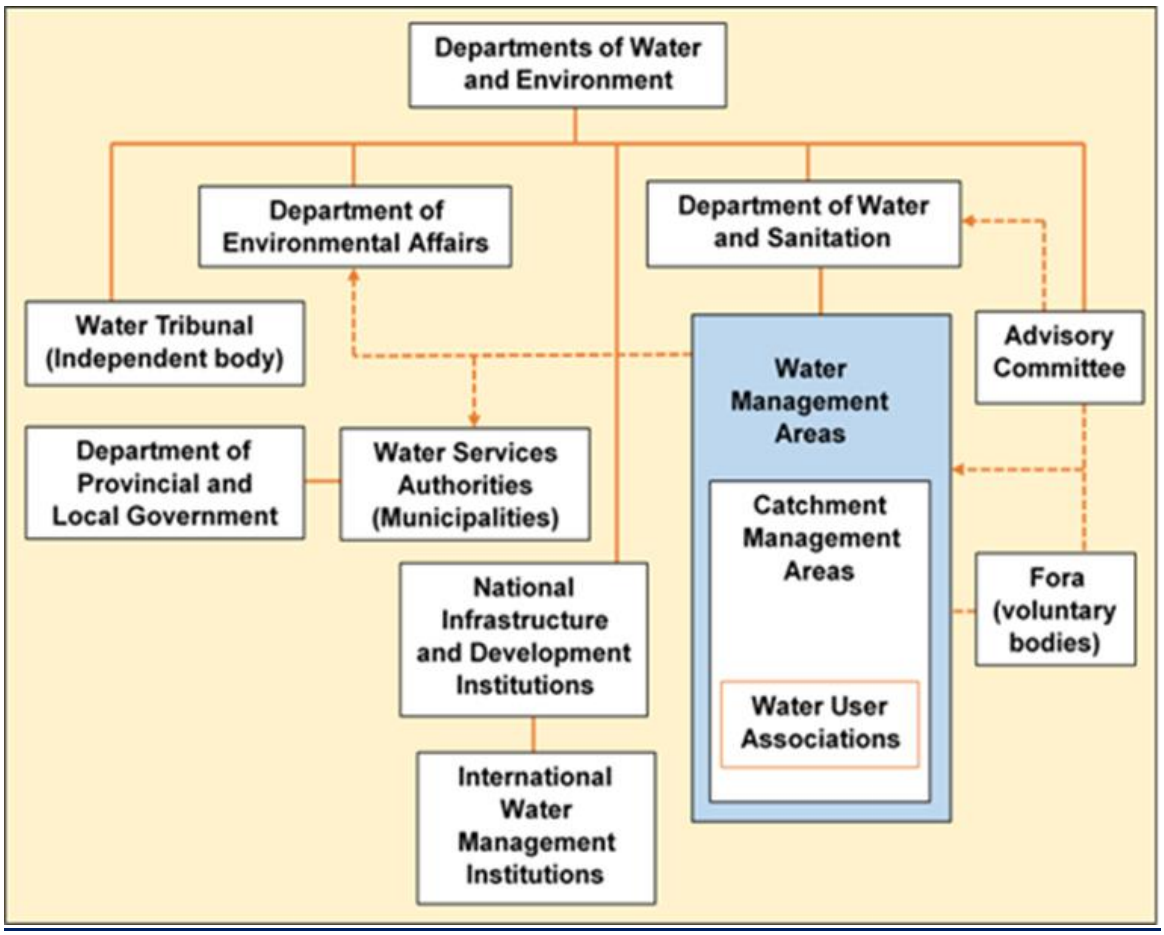


*Figure 8.7: National water institutional arrangements (Source: DWS, 2009).*

### 8.5.2 Challenges to Current Policy Frameworks Set Up in South Africa

Water, energy, and food resources remain at the core of human well-being, poverty reduction, and sustainable development (FAO, 2014). These tenets are enshrined in South Africa's Constitution. Pressure on these resources is set to increase owing to population growth, migration and urbanisation, economic development, international trade, improved standards of living, and climate change. This will increase competition for resources and prioritisation between the water, energy, and food sectors, negatively impacting the country's socio-economic security.

Various factors affect water, energy, and food security differently (Figure 8.8). Hence, while it is important to understand the interlinkages in the nexus, it is also important to realise that an overall approach to resolving the challenges must be underlined by specific cases of solving national and regional problems. The absence of a WEF nexus policy results in conflicts among sectors. There is, therefore, a need to harmonise current sector-based policy frameworks. The National Development Plan has made commendable attempts to encourage integrated planning across government departments. There is a need for a framework that facilitates proper coordination and identifies synergies and trade-offs across sectors to avoid duplication of activities, create opportunities for harmonising government priorities, and allocate resources effectively and efficiently. This should enable the government to meet its targets, including the SDGs and the National Development Plan. A mismatch in planning objectives by different factors can inadvertently limit the capacity to deliver what may otherwise be good policies.

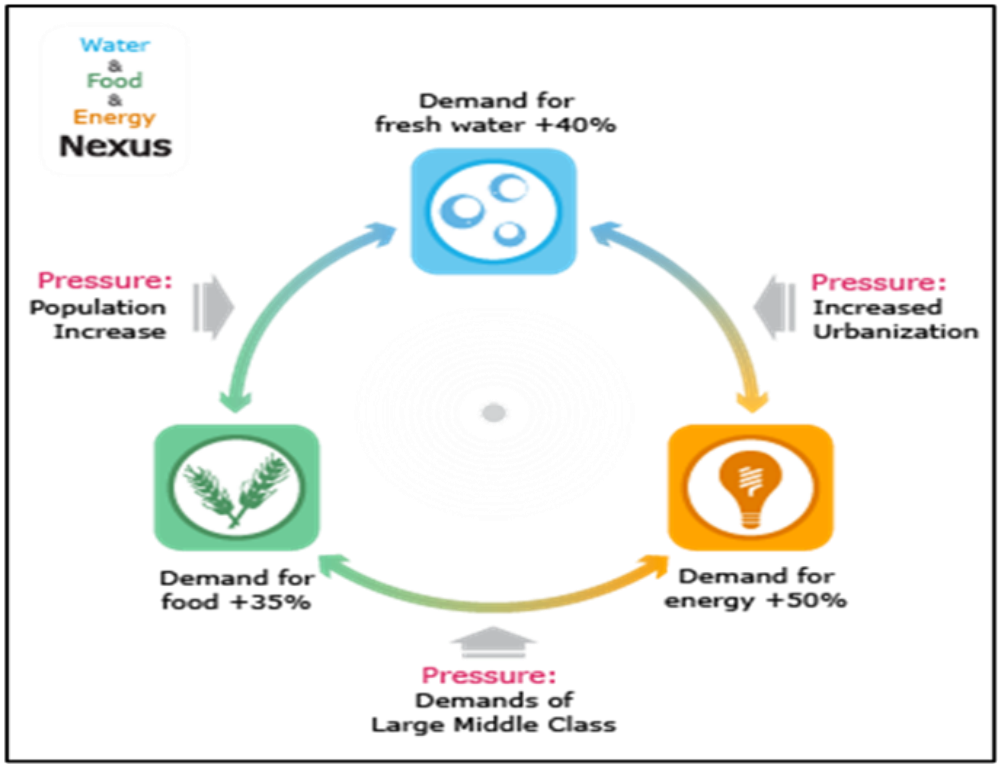


*Figure 8.8: Factors affecting the WEF nexus (Source: FAO, 2014).*

## 8.6 Recommendations for Enhancing WEF Nexus Investments

The cross-cutting challenges affecting WEF resources, coupled with climate change, require a framework that facilitates proper coordination and identification of synergies and trade-offs across sectors to avoid duplication of activities, create opportunities for harmonising government priorities, create employment, and allocate resources in effective and efficient ways. The WEF nexus offers opportunities for the government to meet its targets, including the SDGs and the National Development Plan. There is a need to advance integrated planning, policy, and management and raise inter-ministerial awareness about the WEF nexus. Efforts should highlight the fact that all key factors within the nexus need to ensure that there is increased sectoral coordination. We recommend the following:

- At the level of legislation, it is necessary to ensure that horizontal linkages exist during the design and implementation phases. It is also important that legislation regarding water, energy, agriculture, land, climate and other related matters be harmonised to efficiently use all resources concerned. In turn, this legislation should influence the vertical development of relevant strategies/policies which are horizontally synergistic. Similarly, national water, energy, and agriculture plans/programmes should emanate from national strategies/policies. These plans should also be comprehensively aligned. There is a need to capture elements of resource use efficiency at all policy levels.

- The review of South Africa's water sector legislative and policy framework highlights that South Africa is a physically water-scarce country. This scarcity is mainly regarding the limited water resources that the country has coupled with low mean annual rainfall, which is unevenly distributed thus rendering huge swathes of the country arid and semi-arid. This has dictated much of the water policy, emphasising managing the country's limited water resources. Secondary to that is the need to ensure access to water for the country's population, a right enshrined in the Constitution. Except for the Water for Growth and Development Framework, existing water policies neither explicitly nor adequately highlight linkages between the water, energy, and agricultural sectors. This is even though agriculture, on its own, accounts for the bulk of water use and the strong linkages between water and energy. Adopting the WEF nexus thus promotes coordinated development, improves people's livelihoods, and improves resilience-building initiatives.

- Energy insecurity in South Africa has previously contributed to the country's credit status being downgraded. The 'crises' in the energy sector have also led to the signing of nuclear power deals with Russia and China and an 'explosion' of new coal mines with new prospecting licenses issued in areas like Mpumalanga. This has raised renewed fears of acid mine drainage in the Vaal River; the mushrooming of new mines is set to clash with 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. In addition, water, energy, and food security are all central to South Africa's independence vision of delivering a better quality of life to its citizens. This highlights the need for better convergence of policy amongst the three sectors and a movement from the 'silo' approach.

- As an initiative to start the WEF nexus discussions, there is a need for an inter-ministerial and other stakeholders' dialogue (WRC, Non-Governmental Organisations, and academia) at a national level to discuss how the WEF nexus can be implemented and monitored. Table 3 provides potential WEF nexus stakeholders.

- The government should promote WEF nexus research, development, and innovation and formulate nexus guidelines and indicators in the same form as the SDG indicators.

- As the three WEF sectors are inextricably linked, current uncoordinated management creates imbalances in resource allocation with the effect of threatening to reduce the economic gains made in the past. Thus, the WEF nexus provides an opportunity to stabilise competing demands in an environment of scarce resources by ensuring that the development of one of the sectors has minimum impacts on the other. Thus, there should be a review of past and ongoing projects to identify opportunities for embedding WEF nexus thinking; this will contribute towards the overall sustainability of these initiatives.

As already alluded, the three WEF components are dealt with in silos. To achieve the country's goals, South Africa needs to adopt the WEF nexus as it is a more balanced approach based on the interlinked management of resources and capable of improving national management of the links between water, energy, and food and increase the resilience of the economy from the risks of climate change and economic volatility. The adoption should be practical; for example, existing government departments with cross-cutting mandates, such as the Department of Science and Technology and the Department of Planning and Monitoring, could be tasked with driving the WEF nexus and ensuring that it is embedded in new policies and strategies across government.