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An evaluation of infrastructure systems to foster the food-energywater (f-e-w) nexus: the case of Botswana

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2023
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AN EVALUATION OF INFRASTRUCTURE SYSTEMS TO FOSTER THE FOOD-ENERGY-WATER (F-E-W) NEXUS: THE CASE OF BOTSWANA

University of the Witwatersrand, Johannesburg, South Africa

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Master of Urban Studies in Urban Management

January 2023

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DECLARATION

I hereby declare that this thesis represents my own work.


…….

(Signature of candidate)

07/12/2022

ABSTRACT

In this paper, I discuss the significance of recognising the intertwined nature of the Food, Energy, and Water (F-E-W) resources for comprehensive planning and management towards achieving sustainable development. Botswana is a land-locked country subjected to harsh climatic conditions and rapid urbanization which exacerbates the food, energy, and water resource insecurities and increases the demand for the resources. Despite such challenges, the F-E-W resource sectors are governed and managed in the conventional approach by addressing the respective resources as silos. The conventional silo thinking and practice is not sustainable and impacts the nation's resilience to resource scarcity. Overlooking the F-E-W interlinkages presents a ripple effect from the actions taken in one resource affecting the others. Botswana policy, decision-makers, and practitioners operate on silo thinking due to limited understanding and limitations of the siloed nature of the policy framework. The research argues that analyzing and understanding the F-E-W resources' interconnectedness is critical to attaining trade-off mitigation and fueling the synergies for sustainable development. The research report reviews the current nexus concept, theoretical underpinning, and Botswana national policies to explore the current status, challenges, and opportunities to achieve F-E-W nexus-oriented solutions implementation in Botswana.

Key Words: food, energy, water, nexus, governance, conventional approach

DEDICATION

I dedicate this Research Report to my dearest grandmother, Ntshimo Joyce Mochotlhi and her daughter my mother Ruth Priscilla Mochotlhi.

ACKNOWLEDGEMENTS

I would first like to express my humble gratitude to the Wits-TUB-UNILAG Urban Lab for awarding me a scholarship to further my studies, Ms. Taki Sithagu, the Programme Coordinator, and other senior fellows at the Urban Lab, particularly Dr. Carmel Rawhan for supporting me throughout the research towards pursuing this master's degree in Urban Management. But, most significantly, for his guidance, Dr. Brian Boshoff, my research Supervisor from the School of Architecture and Planning. The calmest, gentle man who helped me discover my perfectionism and anxiety issues and directed me in so many ways to overcome them.

My late grandfather, Jonas Ntoisang Mochotlhi, my late father Basha Anthony Mazhinye, for looking out for me during the hurdles from start to completion. My grandmother, Ntshimo Joyce Mochotlhi and my mother Ruth Priscilla Mochotlhi for the continuous support without fail, being my alarm, waking up to wake me up at odd hours, across borders,to keep pushing the work on this research and constantly reminding me to pray and speak to God, to give me the strength to complete. God bless your hearts eternally.

Over and beyond, thank you, God; it would not have been possible without you.

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LIST OF ACRONYMS

ALDEP	Arable Lands Development Project
ARAP	Accelerated Rainfed Arable Programme
BAMB	Botswana Agricultural Marketing Board
BCA	Botswana College od Agriculture
BERA	Botswana Energy Regulatory
BNWMP	Botswana National Master Plan
BPC	Botswana Power Corporation
CE	Circular Economy
CEDA	Citizen Entrepreneurial Development Agency
COP 21	2015 United Nations Climate Change Conference
CUM	Circular Urban Metabolism
DWA	department of water affairs
DPSIR	Driver-Pressure-State-Impact-Response
FAO	Food and Agriculture Organization
F-E-W	Food-Energy-Water
GHG	Greenhouse Gas Emissions
GWP	Global Water Partnership
GWP-SA	Global Water Partnership in Southern Africa
IEG	Integrative Environmental Governance
IRENA	International Renewable Energy Agency

ISPAAD	Integrated Support Programme for Arable Agriculture Development
IPPs	Independent Power Projects
ISS	The Institute for Security Studies
LIMCOM	Limpopo Watercourse Commission
LIMID	Livestock Management Infrastructure Development
MENA	Middle East and North Africa
MMGE	Ministry of Mineral Resources, Green Technology, and Energy Security
NDB	National Development Bank
NTS	National Transformation Strategy
OKACOM	Okavango River Basin Water Commission
ORASECOM	Orange-Senqu River Commission
SADC	Southern African Development Community
SAPP	Southern African Power Pool
SDG	Sustainable Development Goals
UM	Urban Metabolism
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
USAID	United States Agency for International Development
WEEN	Water-Energy-Environment
WEF	Water-Energy-Food
WEFEN	Water-Energy-Food-Ecosystem
WEFN	Water-Energy-Food
WELCN	Water-Energy-Land-Climate

WEN	Water-Energy
ZAMCOM	Zambezi Watercourse Commission
WUC	water utilities corporation

Chapter 1: Introduction

1.1 Introduction

Water is a crucial resource for both energy and food production. Simultaneously, energy is necessary for water extraction, distribution, and treatment, and food production needs both water and energy (Mabrey and Vittorio.,2018). Despite this, the approaches in managing the food, energy, and water (F-E-W) resources are siloed and fragmented, so the resource interdependencies are overlooked. It must be emphasised that in 2050, global energy demand is estimated to double, while the demand for water and food will escalate by 50%, yet an anticipated 9 billion inhabitants' needs must be met (Botai et al., 2021). In addition, rapid urbanization in urban communities increases the demand for Food-Energy-Water (F-E-W) resources. Nevertheless, the F-E-W resource supply is currently approached in silo sectors that are exclusive, reactive, and non-sustainable (Simpson and Jewitt., 2019). In this paper, I discuss the significance of recognising the nature of the F-E-W resource interdependencies for comprehensive planning and management of the F-E-W resources in the case of Botswana.

The urbanization wave, compounded with global climate change issues, has resulted in a rise in the demand for food, energy production, and water supply (Botai et al., 2021). Balancing resource availability with population increase can be attained through transformative approaches that will inform policy, decision-making, and systematic adaptation strategies. The transformative approaches are needed to enhance livelihoods and resilient communities (Nhamo et al., 2020a). Despite the F-E-W resource interdependencies and the shifting demand increase, Botswana's government pursues the F-E-W resource systems as separate components governed in the sectoral ministries. The individual ministries manage the respective resource sectors, as though they undergo individualistic challenges to be solved separately. In this sense, dealing with the resources in silos causes an intertwined network of challenges where solving problems in one domain can create problems in another (Botai et al., 2021). It is important to note that eliminating the silo governance of the F-E-W resources could foster sustainable resource planning and management (Biggs et al., 2015). As Schull et al., (2020) point out, eliminating the silo approach in addressing

the F-E-W resources, requires considering that their interconnected systems must be addressed holistically.

The food-energy-water (F-E-W) resource systems are intertwined with their challenges, making up complex relationships known as the F-E-W nexus (Nhamo et al., 2020b). Nhamo et al., (2020b) highlight that conceptualisation of the F-E-W nexus continues to become prominent in research agendas, global policy, and governance, considering many other elements. The nexus paradigm is proposed as a solutions-oriented strategy suitable for tackling the interlocked F-E-W challenges (Hezri, 2016). Therefore, the co-evolution of the F-E-W nexus is essential to mitigate the resource insecurities accompanying urban growth. The significance of this statement is that examining the F-E-W nexus across scales, and sectors creates a platform for designing inclusive policies, projects, and strategies, integrating energy, food, and water security challenges comprehensively (Martins, 2018).

1.2 Background

Botswana faces low food, energy, and security, and incurs high import rates to curb resource shortages (Gaborone City Development Plan, 1997-2021). This challenge is exacerbated by the country's arid climatic conditions and landlocked geographic setting (ibid). Despite these challenges, the conventional silo practice of addressing the resources in silos has been used in managing the F-E-W resources. The silo approach resulted in fragmented sectoral policies, decision-making, urban planning, and management, which is not sustainable. The nexus thinking is proposed as a critical way to understand the F-E-W resources' interconnectednesses, managing their trade-offs, and building their synergies (Nhamo et al., 2020a).

1.3 Problem Statement and rationale

Botswana relies on coal, a non-renewable source of energy, for most of its electrical power (Maswabi et al., 2021). As a result, the electrical power demand tends to exceed the supply to the increasing population. This causes electricity losses resulting in backup diesel power plants being utilised, and hence electrical imports from neighboring countries to supplement the shortages through the Southern African Power Pool (SAPP) ('Energy Sector – GET.invest', Accessed: 29

April 2021). Botswana's arid to semi-arid climate is characterized by low rainfall and high potential evapotranspiration rates (Batisani and Yarnal, 2010). The conditions result in low surface runoff rates and natural groundwater recharge (ibid). The water-stressed situation is exacerbated by climate change and a continuously increasing water demand (Lindhe et al., 2020). Gaborone capital city is subjected to rapid urbanization and expansion, which has resulted in the loss of productive agricultural land. In addition, the urban periphery settlements that practice agriculture have become engulfed by city growth, creating a decline in agricultural production.

Despite the intertwined complexities of the F-E-W nexus, the Botswana government addresses the F-E-W resource issues in silos. The silo-thinking is characterized by sectoral policy formulation, decision-making, urban planning, and management of the resources. The F-E-W resource systems are regulated and managed by separate ministry sectors that tend to overlook the interrelations between the resources. To break down the silos, the approach requires understanding the interconnectedness of the F-E-W resource flows within a determined spatial and temporal context (Roggema, 2021). This research context is Botswana, where I will examine the food-energy-water flows, status, and governance. In this respect, I highlight the need for the nexus approach, where the resource sector silos are integrated.

1.4 Research aims and objectives

It is imperative to initially comprehend the current status in terms of the challenges, opportunities, or potential applicability of the F-E-W nexus principles in the planning, management, or governance of the resources in Botswana. Therefore, the research aims to investigate how the F-E-W resources are addressed across scales from the African continent, and SADC region to national and local levels in Botswana. This will assist in unpacking the intertwined F-E-W resource issues affecting the countries through transboundary encounters, given that Botswana is landlocked and experiences semi-arid climatic conditions. Further, the intent is to examine what strategies could be employed to assist in achieving the F-E-W resource securitisation in Botswana. In addition, the study investigates modeling processes that can assist in developing a framework that can guide the implementation of the nexus in Botswana. Overall, the research aims to

understand how to fuel the F-E-W resources' interdependencies, and synergies and mitigate the trade-offs for informed policy formulation, decision-making, and planning in Botswana.

1.5 Research questions

1.5.1 Main research question

What is the current food, energy, water resources planning, and management status in Botswana? In terms of the current resource policies, do they practice silorisation, or are they guided by nexus approaches, and are they implemented on the ground? In comprehending this, what challenges and opportunities lie in operationalising the nexus practice in the country?

1.5.2 Sub questions

Secondly, what strategies could be employed to assist in achieving the F-E-W resource securitisation in Botswana? In examining these strategies, comprehensive modeling processes of frameworks that can assist in formulating integrated F-E-W policies, action plans, and programmes for practical implementation in Botswana could be targeted. In this sense, mitigating sustainable development and climate change could be achievable?

1.6 Expected findings

Historically and globally, the F-E-W resources have been addressed in the conventional sectoral silos. Hence the research report expects to find out that food, energy, and water (F-E-W) policy formulations, decision-making, planning, and management of resources in Botswana are conducted in sectoral silos. The intent is to assess how the F-E-W resources sector and ministries govern the resources in Botswana, resulting in an unequal representation of the F-E-W resources, exacerbating the F-E-W resource insecurities. The study expects to find that, instead of addressing the resources in silos, comprehensive and holistic approaches to dealing with the resources could break the sectoral silos. Furthermore, through comprehensive engagements across scales from local communities to national levels in the planning and managing the resources, inclusivity, equity, and resource security issues could be achieved.

1.7 Methods

1.7.1 Data Analysis and Collection

The qualitative approach is vouched for as suitable for examining the nexus because it allows for a descriptive analysis of the food, energy, and water interlinkages, which helps comprehend the F-E-W nexus system complexities (Endo et al., 2020). In addition, the qualitative approach's strengths of theoretical description nature are beneficial in assessing the resources' interlinkages which can be visualised. Hence, I opted for the nexus concept theoretical underpinnings instead of the qualitative approach focusing more on the F-E-W resource quantifications, which was beyond the research scope.

The qualitative approach further assists in investigating the interlinkages within distinct temporal, spatial, vertical, and horizontal dimensions(). For instance, assessing the cross-sectoral interlinkages across global to local scales to identify potential conflicts and synergies across national boundaries and sectors. In addition, the investigations focus on understanding the current status of the nexus across the scales to the Botswana national and local levels to identify areas to be prioritized towards implementing the nexus principles. After studies of the current scenario, the explorations also delve into studies of what strategic measures can inform integrated and holistic F-E-W resource planning and management to provide nexus-oriented investment projects. I opted for academic peer-reviewed publications that utilised the keywords food, energy, and water nexus.

In light of this, I carried out a desk study, where I further investigated the F-E-W linkages across the social, economic and environmental contexts of Botswana. Information on the current state of energy, food, and water security in Botswana, the SADC regional or transboundary relations, and its neighbouring countries was sourced. In terms of the current F-E-W nexus governance in Botswana, I studied the existing grey literature on policy reports and master plans online or from government departmental ministries dealing with F-E-W resources management. I aimed for the governance analysis to develop an understanding of the current strategies, policies, regulation framework, and the management of F-E-W resources.

In conducting the study, I examined the literature of peer-reviewed publications and articles, which explained the food, energy, and water nexus concept, including methods, at spatial and temporal scales and policy and governance implementation (Endo et al., 2020). In addition, I targeted articles that analysed the interlinkages of the F-E-W resources in terms of the trade-offs and synergies among resource systems. Investigations of how the resources are governed in their respective sectors I examined the impacts of the current conventional silo practices and progression towards shifting to the operationalisation of the concept. The important point is that expanding the studies to run across temporal and spatial scales of local sites, national, regional, and global scales expanding to the governance policy and implementation provides a comprehensive review. Studies at the varied scales were meant to draw lessons from other contexts' experiences to understand better the nexus concept applicability and how it can be contextualised to Botswana. The core idea of the nexus concept is anchored on integrative approaches, which have been developing over the years. Hence, to manage bias against focusing on literature reviews on the F-E-W nexus theories and current trends, I managed the bias by additionally reviewing publications that critiqued the concept, having been compared to other concepts centred around integration like the integrated water manage.

1.7.2 Selection of case study

During the study, I adopted a qualitative research approach, as my area of interest was more inclined to the nexus interpretations and implications for land-locked, developing countries subjected to harsh climatic conditions and rapid urbanisation, such as Botswana. Due to these factors, F-E-W resource insecurities are exacerbated, also triggered by the covid 19 pandemic in the country. COVID-19 revealed the vulnerabilities of F-E-W resource interconnections, which impacted livelihoods and the economy through disrupted supply chains and demand. Accordingly, I conducted studies of Botswana's national food, energy, and water, current status in terms of policy and strategy reports reviewing the challenges, problem aspects, and opportunities of implementing the nexus concept. In addition, I delved into case scenario analysis of the F-E-W resource governance across Botswana to the local context of the capital city Gaborone, assessing the potential for practical implementation. The methods are structured as illustrated below on (Fig 1).

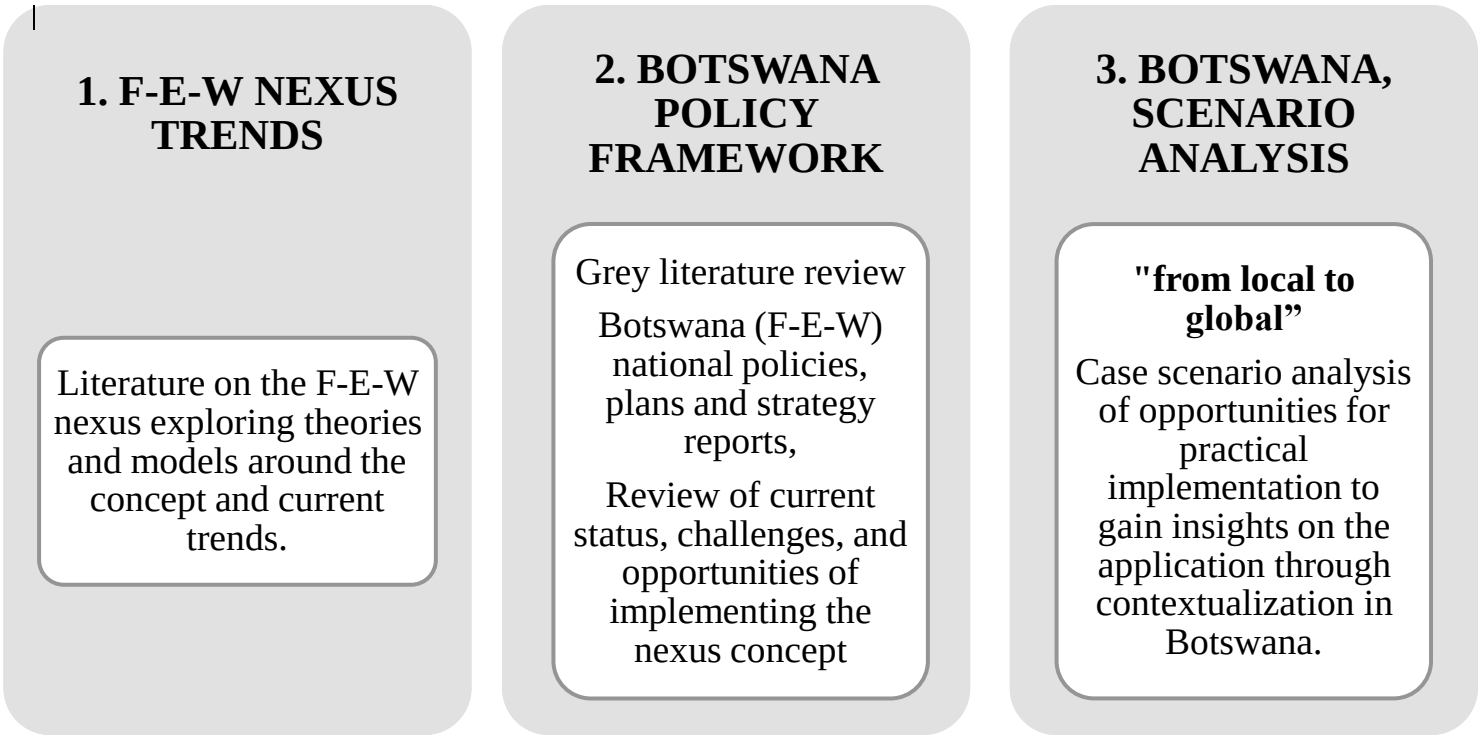


Figure 1:Methods structure (Source: Author's own elaboration of the research methods structure)

1.8 The Ethical considerations

I followed the University of the Witwatersrand ethics protocol which forms a critical research component, and received the ethics clearance prior to conducting the research. Provided with the clearance certificate, I accessed some of the F-E-W food, energy, and water sector departmental offices in Botswana to source some policy documents, and for those, I could not get, I searched online. To the availability of some of the policy documents online, I relied on literature that has analysed them before. I briefed all the food, energy and water departmental offices about my studies, providing my academic identity from the Witwatersrand University.

1.9 Scope and Limitation of the Research

During the data collection stage, the challenges I faced were the inability to access some of the publicized grey literature in the form of policies, strategies, and reports from specific government websites. The challenges were either that the documents were unavailable online or old and outdated. I had to access the ministry and department offices to mitigate this challenge, which was also a hurdle given the Covid 19 pandemic lockdowns. Furthermore, this study has certain limitations when attempting to inclusively grasp the current state of the F-E-W nexus in Botswana, because I mainly targeted to review articles underpinning the theory trends instead of quantifying the F-E-W resources which is outside the scope of this review. Moreover, several nexus case studies applying the nexus approach are still in the elemental stages of dialogues, investigations, and testing of the applicability of the concept.

1.10 The research report structure

This study is organised into five chapters. After the introduction chapter, the second chapter is the literature review of the nexus concept, providing the concept's multiple definitions; tracing the concept's development; conceptualisations; its relevance in the face of climate change; areas of focus for future research, and concluding with the proposed conceptual framework. The third chapter provides a contextualisation of Botswana's nexus concept by examining its current status and assements of the country’s engagements in nexus processes from Africa, and the SADC region, to the national and local levels in the country. The fourth chapter combines the findings and discussions of the research, delving into the F-E-W nexus challenges and applicability. The fifth and final recommendations and conclusion chapter summarises the research report findings.

Chapter 2: Theoretical and conceptual framework

2.1 Introduction

In this chapter, I draw on literature to discuss and review the varied theoretical views of the nexus concept as offered by other researchers and scholars. The intent is to establish the theoretical underpinning of the nexus concept, tracing its development, articulation, and linkages to grasp the

concept's core idea. I explore the purpose of the nexus concept, the food, energy, and water (F-E-W) systems' interactions across various context scales, over time. Assessments of the current status, challenges, and opportunities, and the concept's applicability will be captured by studying some cases where it has been implemented. It is essential to note the socio-economic and environmental implications of how policy formulations, decision-making, urban planning, and management respond to the implementation and operationalization of the concept.

2.2 Conventional Siloed Practices

The design of F-E-W resource systems has traditionally been independently done or only considered simple system interdependencies (GWP,.2022). Such approaches overlooked the valuable synergies among the resource sectors without considering the shared benefits between the sectors(ibid). Moreover, the conventional approach to managing the resources results in the development of rigid regulations approached in isolation, causing inequities (Chakrabarty., 2001). In this regard, it is significant to note that decision and policymakers ought to be aware that a problem solved individually, disregarding the impacts of intersecting with other issues, has a ripple effect.

Chakrabarty. (2001) argues that the principles of productivity, social responsiveness, and flexibility to uncertainties apply equally to urban management to overcome resource limitations. The principles can be improved to achieve integrated urban management (Chakrabarty., 2001). The current policies designed in siloes lack flexibility and navigational change, causing constraints. The policies are accepted as cemented and are not adaptable to change during unforeseen circumstances at points in time until more effective policies are evolved over long periods. It must be emphasised that from time to time, the policies must be reviewed incrementally to cope with uncertainties in urbanisation and development. Modifications of the conventional practice are significant to avoid failures in the planning and managing of resources affecting livelihoods. For instance, the traditional method of approaching master plans as rigid documents should be viewed as live development plans adaptable to people’s needs and subject to navigational change. This is in opposition to freezing their evolution for up to 20 years as per the usual master plan period.

2.3 Integrated Planning And Management Of F-E-W Sectors

It is important to note that eliminating the silo governance of the F-E-W resources could foster sustainable resource planning and management (Biggs et al., 2015). During planning, integrating strategies to operationalise the WEF nexus is imperative in order to manage resources in an integrated manner from a nexus planning perspective (ibid). Furthermore, integrated approaches for F-E-W security management are imperative to obtain maximum benefits and the optimum use of resources and simultaneously mitigate their competing demands (ZAMCOM).

If one sector has uncoordinated development and management, this practice can impact the other sectors. Comprehending the F-E-W nexus unlocks pathways for developments to be approached collaboratively and cooperatively. Engagement with all stakeholders allows for inclusivity and provides appropriate and adequate development programmes. Stakeholder institution establishments wherein all stakeholders are engaged in processes of shifting towards nexus-oriented practices provide inclusivity associated with the spirit of ownership and encourages them to adapt to the nexus approaches. Hence, experts, and decision-makers must explore links related to planning and management.

2.4 The F-E-W Nexus: A Contributory factor to Mitigating Climate Change and Sustainable Development?

To achieve sustainability and curb climate change, integrated and transformative solutions should be implemented (ZAMCOM). In efforts to achieve sustainable development, United Nations developed the 2030 Agenda for Sustainable Development Goals (SDGs) by balancing the dimensions of economy, society, and environment. Mabhaudhi et al.(2018) advocate for the F-E-W nexus as a framework that presents opportunities for directly achieving some of the SDGs, in particular goals 2(zero hunger), 6(clean water and sanitation), and 7(affordable and clean energy). In addition, indirectly, a potential to achieve SDGs 1(no poverty), 8(decent work and economic growth), and 9(industry, innovation, and infrastructure) is additionally provided, creating employment and innovations linked to F-E-W nexus planning. The SDGs have an interlinked nature that needs a holistic, multi-sectoral, and multi-dimensional approach to implement them.

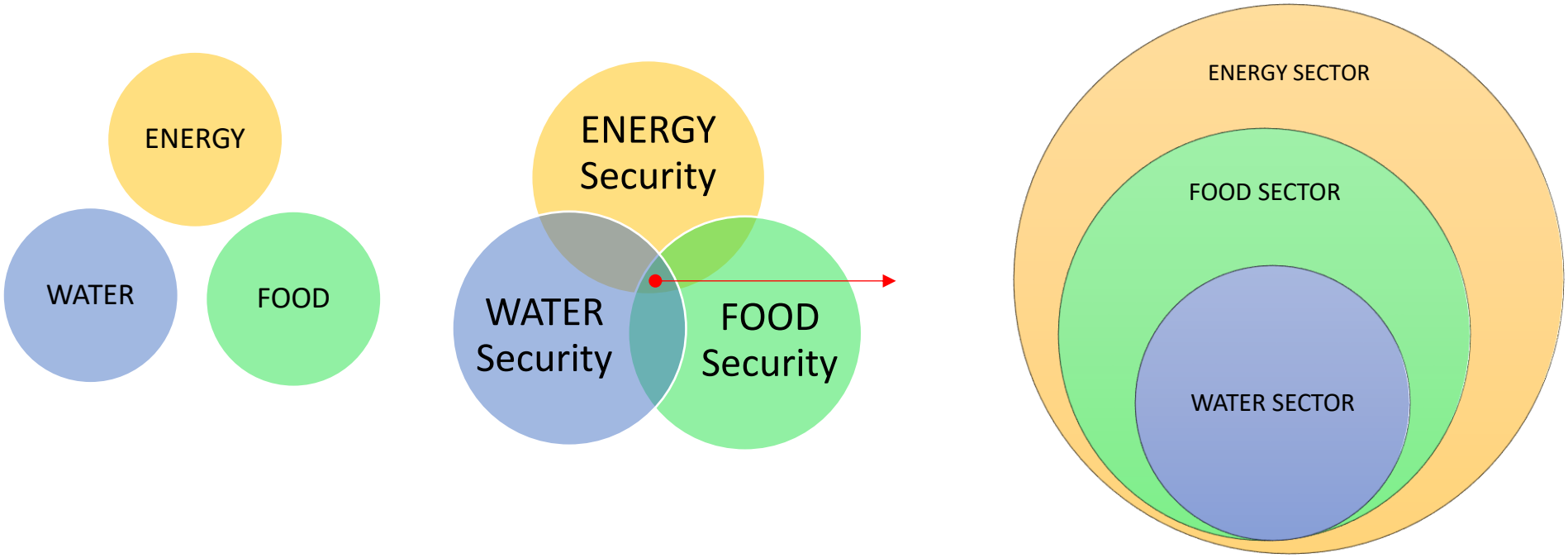
Similarly, the F-E-W nexus concept is concerned with the fact that the resource sectors are linked and should be managed in an intertwined nature. Therefore the nexus is well placed to nexus to inform integrated practices and policies toward the SDGs' achievements.

Similarly, climate change is linked to the F-E-W nexus in how it affects the nexus through temperature and precipitation. The critical point is that global warming and climate variability imply a necessity to combine the climatic dimension to the nexus. In this sense, further inter-sectoral responses are needed. To combat global climate change, The Paris Agreement was adopted by 196 parties at COP 21 in Paris on a course to achieve a climate-neutral world. Therefore, the nexus approach becomes valuable in combining climate change adaptation and mitigation strategies with the different SDG and Paris agreement targets.

2.5 Nexus Thinking 'Shifting paradigms'

Historically, conventional ways of addressing the food, energy, and water (F-E-W) scarcity challenges have overlooked the interconnectedness of the resources, with practitioners treating (F-E-W) as separate domains (Covarrubias et al.,2019). The isolated approaches to dealing with the resources have often caused friction where solving a single problem aggravates the others(ibid). Leck et al. (2015) place emphasis on the inextricable link between food, energy, and water resources. Mabrey and Vittorio (2018) also point out that the resources individually have their complexities, in addition to these interlinkages. As an example of a F-E-W linkage, water is required to produce energy; simultaneously, energy is necessary for water extraction, distribution, and treatment.

Moreover, food production needs both water and energy, hence the new way of thinking in the integrative approach (Mabrey and Vittorio.,2018). Many researchers have vouched for the nexus approach to dealing with the F-E-W resources, calling for a shift from silo thinking to nexus thinking. The illustration below demonstrates the current sectoral silos and the potential transition to the nexus approach composed of interconnected and interlinked F-E-W systems (Fig 2).



(A) Unconnected silos	(B) Interconnected linkages	(C) interdependent systems
F-E-W productions least supported individually	Integrated support to the F-E-W systems	comprehensive support of the interdependent systems
Food; Low Agric incomes, high food prices, least affordability & low nutrition	Balanced resource supply with increasing population	The interdependent Ministries of Food, energy, and water
Greenhouse gas emissions from transporting food are the highest		

Figure 2: Transitioning from the current unconnected silos to the interconnected and interdependent linkgaes (Source: Author's illustration)

2.6 F-E-W Nexus: Concept Definition

Various definitions and perspectives on the nexus concept have been presented in a quest to better understand the idea. Caputo et al. (2021) define the nexus as a system composed of feedback loops wherein the elements, food, energy, and water interact. In addition, understanding the elements' interactions requires simultaneous analysis of the resources together (ibid). In this sense, the description resonates more with the systems approach. On the other hand, Bizikova et al. (2014) defined it as an assessment approach that could inform water, energy, and food security policy development and implementation.

Taking an urban systems perspective, Ramaswami et al. (2017;1) describe the concept as below:

'The food-energy-water (F-E-W) nexus refers to intersections among food, energy, and water systems that have large impacts on natural resources (water, energy, nutrients), on pollution and greenhouse gas emissions (GHG), and on the security of F-E-W supplies essential to the well-being of the world's population.

The nexus concept has been used in various ways with overlapping ideologies, the core idea being the holistic approach to dealing with the F-E-W resources. Caputo et al. (2021)’s view that, of all nexus understandings, there is still no concrete perspective on the meaning of integration even though integration makes up the core of the idea. Dalton et al. (2019) indicate that the emergence of the nexus is a way forward to imparting alternative ways to mitigate stress on the resources caused by population increase, urbanisation, economic development, and climate change.

2.7 F-E-W Nexus: The Ripple Effect

As the definition suggests, the nexus displays a ripple effect in how risks in one resource sector correlate with risks in the other sectors (Covarrubias et al.,2019). The implication is that the resources are so interconnected that stressing one resource directly impacts the supply of the others. For example, growing more food implies that more water and energy will be used. Food production requires water for irrigation and energy for pumping and distribution. Energy production requires water for cooling simultaneously to produce water through desalination. For

biofuel production, energy crops are required to acquire biofuels such as biogas from food waste (Fan et al.,2019). Thus, withdrawing freshwater is not only a water-oriented issue but also energy and food security issue. Moreover, agricultural productivity is about attaining food security, water, and inclusive economic growth. For this reason, analysing the resource sector synergies and trade-offs through integrated approaches is necessary to maximise resource efficiency. Furthermore, it is crucial to understand how to use the resource synergies and mitigate the trade-offs as the close resource linkages present myriad opportunities. The (Fig 3) below illustrates above discussed interdependencies and interconnections of the F-E-W resources.

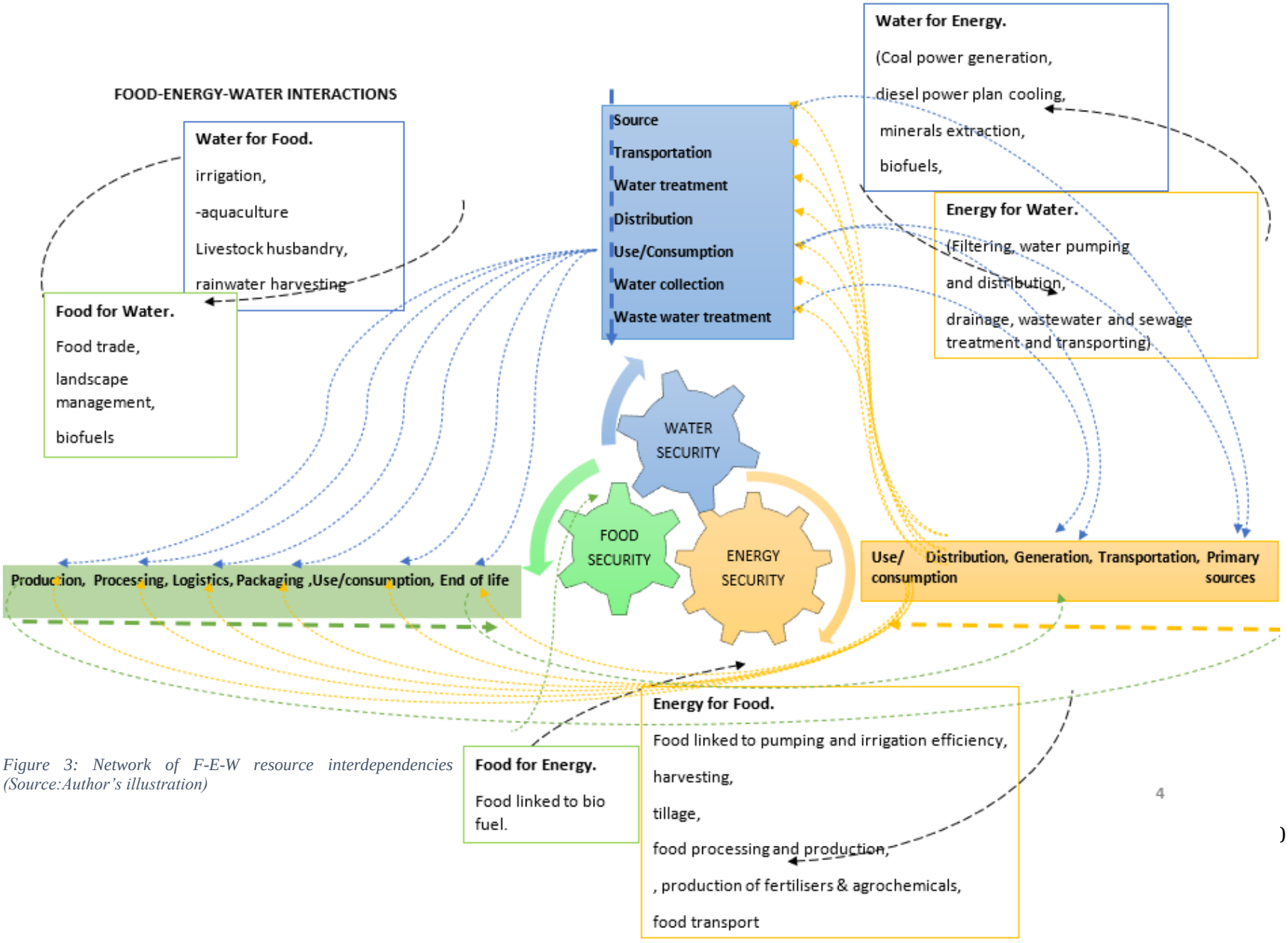


Figure 3: Network of F-E-W resource interdependencies (Source:Author's illustration)

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2.8 Tracing the Nexus: Concept development and articulation

The F-E-W nexus was initially conceived in the early 1980s, when the United Nations University developed food-energy (F-E) programmes (Al-Saidi and Elagib, 2017; Endo et al., 2017). However, in 2008 the nexus concept evolved to policy and industrial-level debates when the World Economic Forum presented the concept as a mechanism to examine the scarcity of resources and climate change to achieve global food security. As a result, the World Economic Forum's continuous discussions of the nexus in 2011 and Bonn (2011 and 2014) conferences focused on nexus policy implementation through effective decision-making processes (Daher and Mohtar, 2015; Caputo et al., 2021). The Bonn conference of 2011 was a significant catalyst. Post the conference, various actors undertook investigations and analyses of the F-E-W nexus from different perspectives under the science, social and political sectors (Mabhaudhi et al., 2018).

Following the catalytic conference, the period leading to the Rio+ 20 Summit in 2012 symbolised the emergence of 'nexus thinking', which Davis (2014:448) described as, 'a clarion call for a new approach to, or framing of, interdependent water, energy, and food problems.' Ramos et al. (2021) traced the pattern of development of the distinct nexus trend to have surfaced initially by highlighting the importance of the interdependence of systems before shifting to the design of analytical methodologies and system assessments of the interactions. The quantifying of the complexities followed, leading to the recent establishments in the planning approaches (Ramos et al., 2021).

The quest to find strategies to manage the food-energy-water (F-E-W) resources sustainably has since been promoted by the convergence of various ideas proposed in political events, academic literature works, and policy papers (Mabhaudhi et al., 2018). Since the conceptualization of the nexus, efforts have been to provide nexus solutions at policy and technical levels. Therefore, the research is anchored on exploring the theoretical footing of the nexus, analytical methods of the resource interactions with an intent to develop policy and technical level solutions contextualised to Botswana, Gaborone.

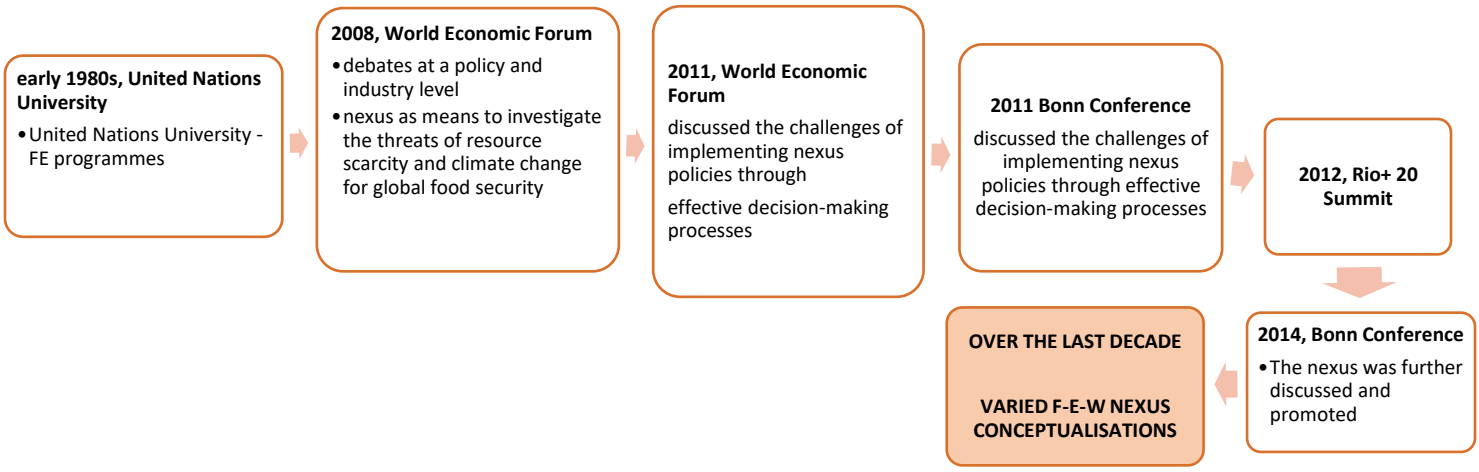


Figure 4: Tracing the Nexus concept development (Source: Author's timeline demonstration)

2.9 Nexus Conceptualisations

The continuous increase in demand for F-E-W resources has caused multiple compounded challenges that drive the development of more nexus conceptualisations. Newell et al. (2019) and Hoff (2011) pointed out that identifying one problem aspect often provides a simple model or conceptualisation. However, the increasing demand precipitates a call to continuous change through the nexus approach (Newell et al.,2019). In this regard, varied nexus types and conceptualisations have since evolved through various frameworks and models. The structure for each conceptualization model is guided by the boundaries of the nexus system (ibid). For instance, in a specific context, a typical framework could focus on a holistic approach to dealing with F-E-W resources considering other elements like ecology. The more elements accounted for in the context, the more the system complexity expands. In investigating various existing frameworks, Dai et al. (2018) discovered that seven elements (water, energy, food, land use, climate, economy, and ecosystems) make up the frameworks. In this sense, the frameworks take advantage of the resource elements' synergies and reveal the nexus's complexity. Caputo et al. (2021) outlined some of the variable framework structural compositions as water-energy (WEN), water-energy-environment (WEEN), water-energy-food (WEFN), water-energy-food-ecosystem (WEFEN), and water-energy-land-climate (WELCN).

Comprehensive approaches to dealing with the F-E-W resources, combined with other elements, foster sustainable resource management and create resilient systems. Chang et al. (2020) focused on water, energy, food, and ecology, describing the resources as an organic whole associated with and influential to each other. In addition, Wang et al. (2021) emphasise the relevance of studying the water, energy, food, and ecology resources as a whole in order to enhance the synergies and overall efficiency of the four. Only when this is the case can high-quality regional development be achieved. Likewise, Caputo et al. (2021) introduced another dimension exploring people's interactions with the elements, an that area has not yet been studied despite the overall impact of human activities.

Moreover, Caputo et al. (2021) explain that understanding humans' daily attitudes towards food production and the exploitation of resources is imperative for attaining a nexus systemic understanding. For instance, a tool developed for the Food and Agriculture Organization (FAO), accounted for social behaviours and processes. The tool addresses society as an element of the system; hence, the social variables, like food production and consumption patterns, are considered. In this sense, Caputo et al. (2021) conclude that F-E-W must become F-E-WP (Food-Energy-Water-People) to serve as a framework for assessing urban agriculture (UA).

Currently, the scope of the nexus elements continues to expand, which requires the capacity of analysis to improve so that relevant solutions that account for the interactions between the resources, environment, and people are formulated. In this respect, data demand increases as the nexus models become more complex (Caputo et al., 2021). Throughout the modeling process, it is essential to shift from theory-based models and steer towards designing practice-oriented models that better inform decision-making, urban management, planning, design, and policy formulation to be holistic. Ultimately, the F-E-W nexus must focus beyond the three resources and simultaneously consider people, climate, ecosystems, environment, economy, land use, and other elements. (Figure 5) below displays some of the frameworks formulated from varied elements or variables.

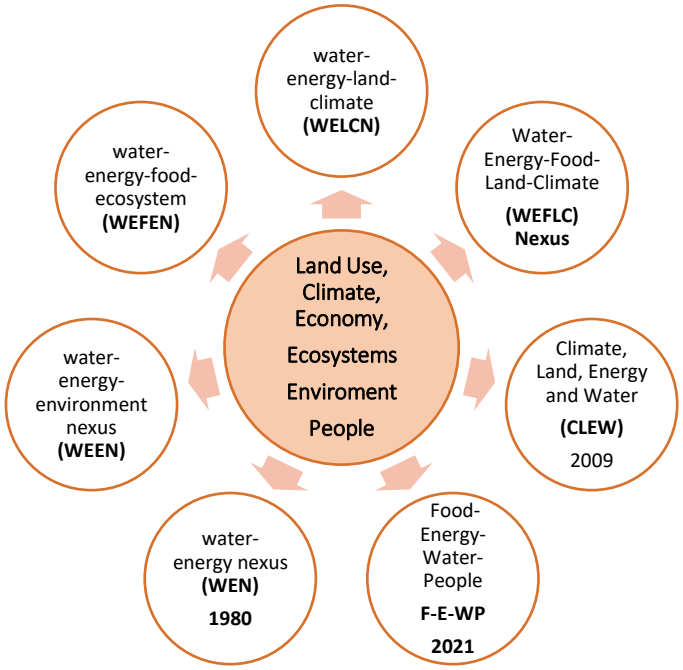


Figure 5: Nexus Frameworks formulated from varied elements (Source: Author;s illustration)

Associating the F-E-W sectors with the above discussed external variables has been demonstrated in different frameworks, tools, and models post the Bonn 2011 Conference, by various researchers, institutes, and international organisations (Purwanto et al.,2021). Fan et al. (2019) argue that in totality, the water and energy (WE) nexus is the starting point in the nexus approach before engaging other sets of broader interactions. The efforts to make comprehensive assessments and studies of the water, energy and other elements interactions, aimed at developing new methods and tools by most researchers, focus on the quantitative analysis of the nexus issues (Fan et al.,2019). During the investigations of some existing frameworks, Purwanto et al. (2021:6) observed overlapping and repetitive features. Most critically, they pointed out the importance of using the nexus concept in the policy and decision-making processes. Below is what Purwanto et al. (2021:6) outlined as the key missing features from the existing frameworks;

'(1) a focus on WEF resource security (i.e., availability, accessibility, quality of resources);

(2) appropriate and validated stages (of the WEF nexus modeling process, using a systems approach and critical analysis to understand nexus complexity better;

(3) promotion of innovation and knowledge mobilization;

(4) utilization of robust datasets from multiple sources; and

(5) participatory stakeholder involvement in framework development.'

The missing critical features by Purwanto et al. (2021:6) are relevant in delineating the nexus and directing towards the concept's applicability. By employing a nexus-oriented approach, the first key feature is concerned with achieving F-E-W resource security, where considerations of the resource linkages and interdependencies provide the ease with which to gauge the availability and control the resource depletion to avoid scarcity. It allows planning for the accessibility, decisions of use, and allocation of quality F-E-W resources to be approached holistically, accounting for all other elements. Given the existing myriad of F-E-W nexus models, tools and frameworks, they incorporate a diverse span of components that demonstrate beyond doubt that the idea is complex.

Critically, the models must be suitable and contextualised at varied scales, following critical analysis, as much as Purwanto et al. (2021:6) point out that the modeling process could be standardized and follow stages that could be validated. Practicing nexus-based management of the F-E-W resources from collected datasets that extensively embrace socio-economic, environmental, institutional, financial, and technological aspects can initiate innovative solutions. Ultimately, stakeholder engagement across all stages, from framework development to the operationalization of the nexus concept, is ideal.

2.10 Circular Urban Metabolism

To reduce the ever-increasing resource flows to cities and the corresponding environmental impacts, sophisticated management of the urban metabolism is required (Kalmykova and Rosado,2015). The circular urban metabolism (CUM) conceptualization is proposed as a framework that engages urban metabolism(UM) to speed up the shift towards circular economies. Fusing the two ideologies proves more beneficial in that regard. Hence it is necessary to comprehensively understand their value addition in operationalizing the concepts as a framework.

According to Lucertini and Musco (2020), CUM simplifies complexities by unpacking how flows interact in urban space over time, assisting with rethinking and sustainably redesigning cities.

Moreover, they conceptualise cities as living organisms that require resources (inputs) for activities to be carried out. After transformation, the resources are discarded as waste (outputs).In that way, Kalmykova and Rosado (2015) add that UM appraises resource consumption and the environmental impacts on urban areas in a systemic way. Sanches and Bento (2020) define CE as a systemic approach to designing waste and pollution in urban economic development. It is anchored on maintaining products and materials in use along with natural systems regeneration. Fundamentally, the core idea for CUM lies in employing a holistic, systemic approach, using UM as a tool for identifying opportunities for a CE in cities.

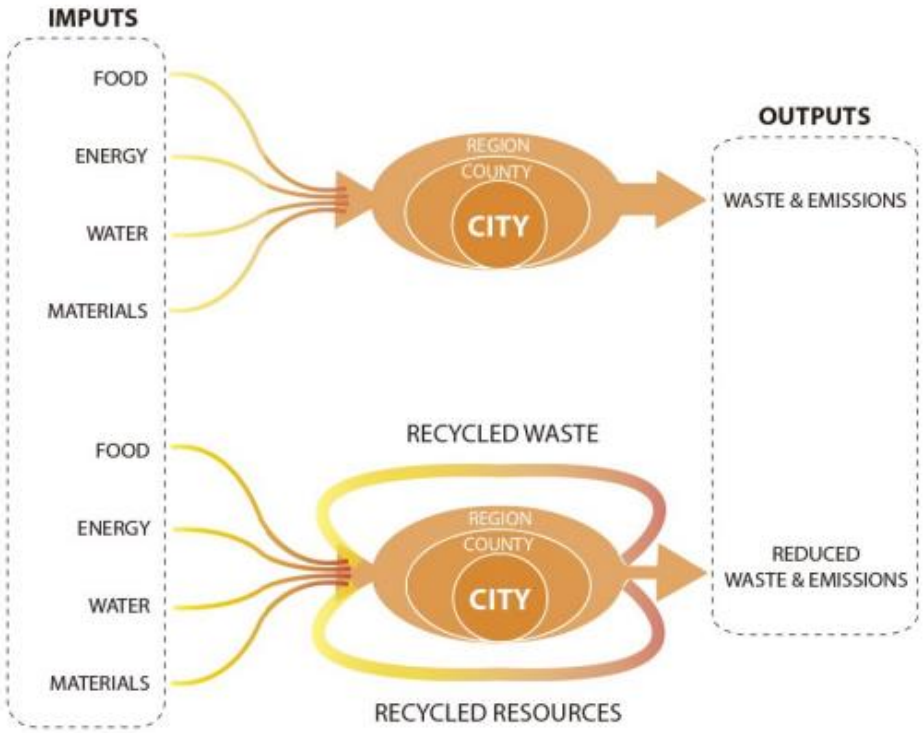


Figure 6: Urban metabolism,linear and circular (Source: Longato et al.,2019)

The UM and CE concepts are individually insufficient to achieve sustainability. Advantageously, they both recognise the significance of circularity. Therefore, the ideas are beneficial and can be simultaneously adopted and mutually complement one another. To illustrate, UM is essential for quantification and mapping urban resource flows that stakeholders would easily understand. By operating CE principles, the data could create more efficient supply chains and reduce waste (Lucertini and Musco, 2020). Longato et al.,2019 emphasise varied ways of how CE design will be more informed by UM analysis. For example, there will be quantified product and material level resource flows used in industries and other sectors. In addition, possible material and infrastructure links with suitable stakeholders will be identified. Further, multidimensional settings would be prioritized if the material flows are connected with life cycle impacts. Likewise, the driving forces of the material flow would be depicted. In a nutshell, the policy formulations will be modeled in alignment with the material flows. Although the inclusion of the concepts for appropriate decision-making, policy, and strategy design processes along with defined specific actions for resilience, still delayed behind. Prevailing UM research can provide an all-inclusive framework to explore routes to circularity at both urban and regional levels (Lucertini and Musco, 2020).

2.11 Delineating the Nexus: A buzzword? Criticisms and research gaps

The F-E-W nexus as a developing concept encounters some forms of criticism (Purwanto et al., 2021). As revealed on the multiple concept's definitions, there is no single way for delineating the nexus. The founding idea focuses on the integrative approach to managing resources to curb scarcity issues. Criticisms stress the nexus studies' apparent lack of focus and postulate that it is yet another buzzword and idea that is not practicable (Purwanto et al.,.2021). In addition, the idea has often been labeled ambiguous, with arguments that it is not new and further lacks common approaches to exploring nexus issues(ibid). A consolidated table exploring the F-E-W nexus concept's main criticisms, application, outcomes, and impacts from various literature works has been summarized below.

Table 1: F-E-W nexus concept's main criticisms (Source: Purwanto et al.,.2021)

MAIN CRITICISM		
THE WEF NEXUS CONCEPT	1. It is not really a new [11] and/or novel [12] particularly in low-level application or users such as farmers, fishers, etc. [7,29].	[11] Benson et al. (2015), [12] Bell et al. (2016), [7] Wichelns (2017), [29] Endo et al. (2017)
	2. Sometimes seen as a "nirvana" and narrative concept [34], "mercurial" concept that led to unpredictable changes in issues based on the context, location, and scale [12] without a means to address the challenges	[34] Middleton et al. (2015), [12] Bell et al. (2016
	3. Only "reframing resource scarcity as an existential threat" and "cling to a neoliberal economic agenda" [39].	[39] Leese and Meisch, (2015)
	4. It is not a clearly defined construct or an agreed-upon and tested framework [33], not a mature concept and needs further improvement [40]. It is promising but still faces significant conceptual and practical challenges [8,37].	[33] Wichelns (2017), [40] Reinhard et al. (2017), [8] Leck et al. (2015). [37] Albrecht et al. (2018)
	5. There is still no common definition, framework, and methodology for nexus research [5,8,11,31].	[5] Allouche et al. (2014). [8] Endo et al. (2015), [11] Benson et al. (2015). [31] Albrecht et al. (2018)
	6. It is not fully acknowledged on the ground and lacks publicity due to underrepresentation of private sectors and media in its activities [7].	[7] Endo et al. (2017)

	7. A buzzword derived from an ambiguous meaning and strong normative resonance. The usage of this term is plural, fragmented, and ambiguous in the UK natural resource debates [41,42].	[41,42]. Cairns and Krzywoszynska (2016)
	8. It is still an evolving concept that has remained largely in the conceptual realm [32] with high-level insights [37].	[32] (Smajgl et al., 2016) [37] (Galaitsi et al., 2018)
THE APPLICATION OF WEF NEXUS APPROACH	1. Policy processes may lead to delays [33], slowness, and inertia [36] in the policy-making process, especially in developing countries	[33] Wichelns (2017), [36] Mitchell et al. (2015)
	2. It not only involves technical issues but also political issues [34], while the nexus concept is often inconsistent in the politics of sustainability [39]. In addition, it is mostly depoliticized, neglecting historical, social, and political treatment [43].	[34] Middleton et al. (2015), [39] Leese and Meisch, (2015), [43] Foran (2015)
	3. In site-specific studies, the vertical integration of local nexus issues within national and global nexus issues was often missing [7] due to the complex nature of the nexus [35].	[7] Endo et al. (2017), [35] Allouche et al. (2014)
	4. Nexus analyses are insufficiently cross-sectoral, focusing mostly on water, which assigns unequal sectoral weighting [32].	[32] Smajgl et al. (2016)
	5. There are no clear boundaries to constrain the WEF nexus applications [37].	[37] Galaitsi et al. (2018)
	6. Some of existing models and frameworks failed to capture interconnections among variables	[22] Shannak et al. (2018)

	due to lack of data sharing and availability [22].	
OUTCOME AND IMPACT OF WEF NEXUS APPROACHES	1. The research on the nexus influence on the decision making by stakeholders is limited [33] and continues to fall short of expectations of its research-backed benefits [44].	[33] Wichelns (2017), [44] Dargin et al. (2019)
	2. The current WEF nexus discourse fails to adequately consider the politics inherent in the WEF sector [23].	[23] de Grenade et al. (2016)
	3. There is a lack of evidence from WEF nexus research that has produced an intellectual toolkit, including validated claims that showed the improvement of resource management and governance outcomes [37].	[37] Galaitsi et al. (2018)
	4. There is a dearth of WEF nexus adoption in national policies, programs and institutions. The gender aspects are also often overlooked in WEF nexus assessments [24].	[24] FAO (2018)
	5. Ignorance of the main democratic goal of sustainability concept through over-emphasizing resource security level at the expense of livelihoods [25].	[25] Biggs et al. (2015)
	6. Operationalizing the WEF nexus is suggested in many studies and is urgently needed to bring "nexus thinking" into "nexus doing" [38].	[38]Simpson and Jewitt (2019)

2.12 Future Research Key Areas for The Nexus Concept

Providing an empirical basis on what constitutes a nexus, from the past to the current and future research trajectories, Newell et al. (2020) identify four critical areas for future research of the nexus concept. Initially, Newell et al. (2020) draw on food production and ecosystem services, emphasising that research focuses on the capacity for urban agriculture to produce viable food amounts for given populations. However, to a lesser extent, quantifying the environmental footprint occupied by the production practices' lacks focus, exacerbating the local environment stresses. Although efforts to increase urban agriculture aim to achieve resource efficiency and mitigate pollution, other benefits of urban food systems, such as accessibility, employment creation, the substitution of food imports through food processing, and human well-being, are beneficial(ibid). Secondly, the urban F-E-W nexus resource recovery is necessary to curb edible food loss and waste and decrease packaging. Most is lost throughout the lifecycle of food during the production, transport, retail, and consumption phases.

Thirdly Newell et al. (2020) refer to social equity, for instance, the urban agricultural equity across the supply chain, multiple sectors, and scales also considering the human dimension, the inclusivity of the rural livelihoods, which currently presents a blind spot in the literature. Newell et al. (2020:4) point out the fourth key area as the food–energy–water–health nexus. The relevance of this is highlighted as a result of density settlement and the impacts that the urban F-E-W systems have on residents residing close to F-E-W infrastructures as, 'Fertilizer-related air pollution, pathogen risk in wastewater treatment and reuse, and the health effects of undernutrition, overnutrition, and food-related microbial contamination' Newell et al. (2020:4)

Conceptual Framework

2.13 The F-E-W Nexus And The DPSIR (Drivers, Pressures, State, Impact, Responses)

The DPSIR model can comprehensively account for the needs and threats of the F-E-W nexus (da Costa Silva, 2014). In the research, I intended to explore how to develop a comprehensive modeling process using the DPSIR model for the F-E-W nexus. The modeling process of the framework is meant to holistically take into consideration all components discussed in the literature review. For example, the DPSIR model explores the Drivers, Pressures, State, Impact, and Responses in addressing resources. When combined with the holistic approaches embedded in the nexus paradigm, like the systems approach, circular urban metabolism, life cycle approach, and opportunity cost, there is a high potential for more resource issues to be solved comprehensively.

The model determines the drivers, such as climate change and variability, along with population growth and economic development, which have escalated F-E-W resource demand (da Costa Silva, 2014). The pressures and impacts of the drivers are also considered along with the state of the F-E-W resources assessed in terms of quantities and quality to support livelihoods. In this case, the responses to these components will be presented as infrastructures that could foster the nexus. Therefore the responses to the pressures caused by the drivers are presented as infrastructures that could foster the F-E-W nexus. The responses are presented in aspects of F-E-W integrated policies that consider social, economic, and environmental issues to provide technological interventions that are nexus oriented. Therefore enlightened and informed action plans, programs, road maps could be developed for implementation. Hence examining how the DPSIR model (Drivers, Pressures, State, Impacts, Responses) could analyze the F-E-W resource interconnections in the case of Botswana. Insights on how policies, decision-making, planning, and investments will likely impact the securitization of the F-E-W resources shall be provided

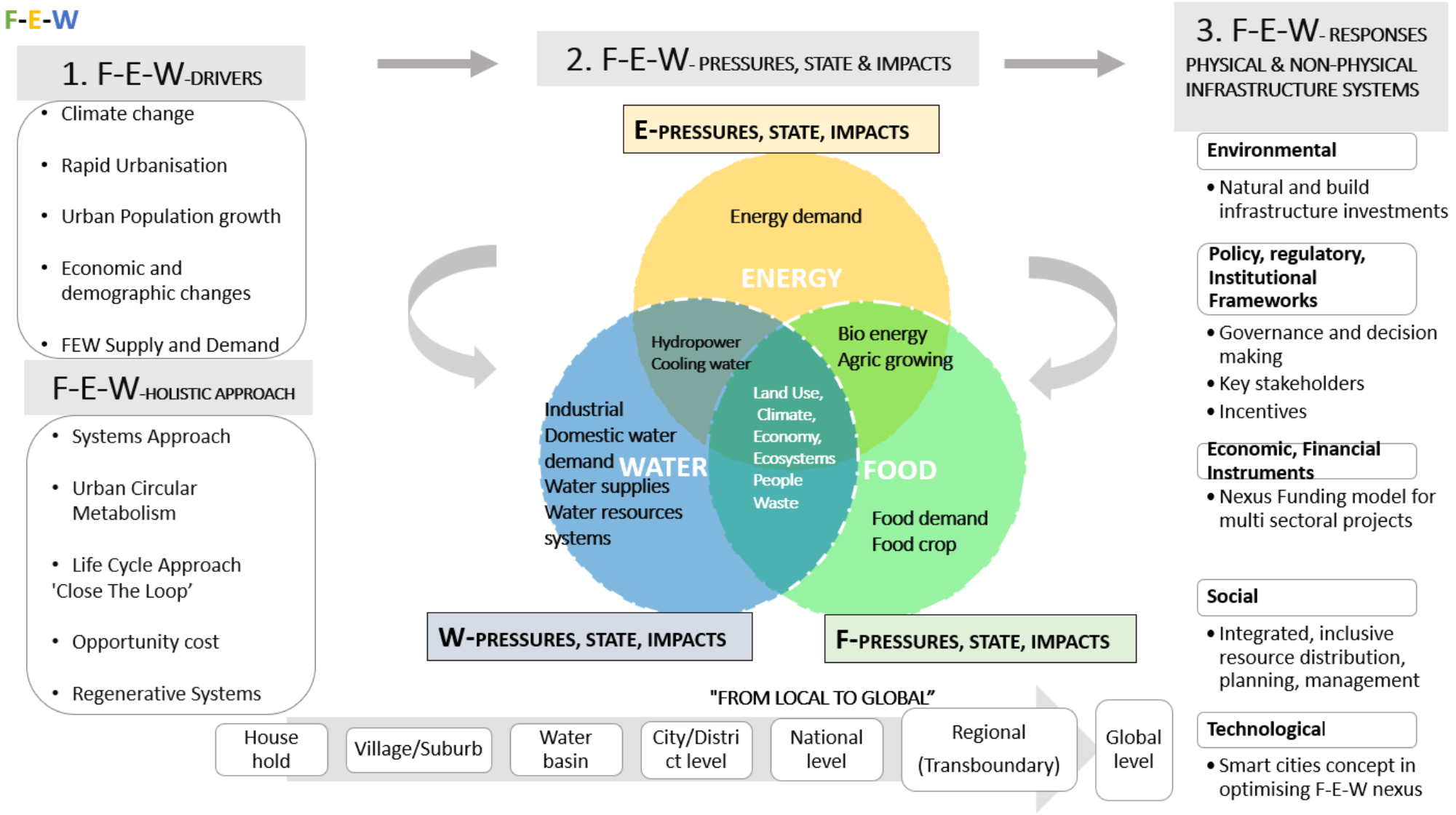


Figure 7: Conceptual Framework (Source: Author's illustration)

Chapter 3: F-E-W Nexus Current Status in Botswana

3.1 Introduction

The global imbalance between food-energy-water (F-E-W) resource availability and population growth continuously increases the demand for resources. Despite this, over decades, the implementation of urban growth models has overlooked the imbalanced supply and demand of the F-E-W resources (Nhamo et al., 2020b). Following the tracing of the F-E-W nexus development globally, it was imperative to interrogate its status across all scales, from Africa to the Southern African, SADC region. This is beneficial before examining its prevailing status in Botswana's national and local levels, with interest in Gaborone capital city.

The reasoning is that landlocked Botswana's F-E-W resources link across international borders. Botswana experiences F-E-W insecurities and hence depends on imports from neighbouring countries. Hence, I drew my analysis of Botswana's food, water, and energy to the transboundary connections. In a sense, an apprehension of the F-E-W interactions at the various scales, in this case, offers a comprehensive understanding of the complex resource connections between landlocked Botswana and neighbouring countries. Finally, I explored the present governance systems of the F-E-W resources to trace the applicability, opportunities, and challenges of employing the nexus approach in Botswana.

3.2 Contextualising The F-E-W Nexus in Africa

The F-E-W nexus scholarship in Africa is dispersed but has expanded since 2013. Therefore, there is an acknowledgment of its urgency in research and planning (Botai et al., 2021). Regarding planning, the land use set of problems requires managing the landscape footprint to get sustainable F-E-W systems. There is progress in implementing the nexus approach through integrated management of resources in a F-E-W countries in the MENA (the Middle East and North Africa) region, like Jodan, Lebanon, and Morocco (Hoff et al., 2019). For instance, the Sahara Forest Project is an integrated technology-intensive project targeting F-E-W production in desert areas. The project utilizes desert saltwater, carbon dioxide, and sunlight to sustainably produce more food, water, and clean energy (Botai et al., 2021). Pilot facilities are

implemented, the first one in Qatar and a more significant launch in Jordan (Hoff et al., 2019). The project also combats desertification through revegetation of the desert lands.

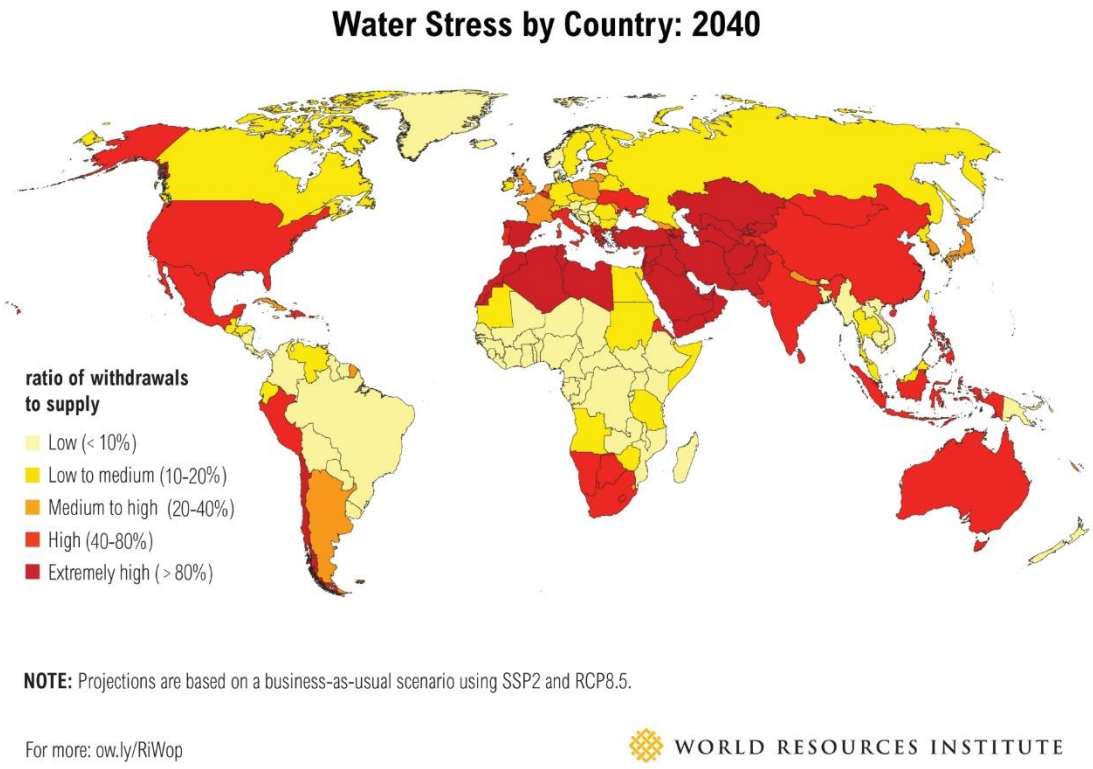


Figure 8: Water Stress by country-2040(Source: World Resources Institute)

Botswana could learn from such projects as the harsh hot and dry conditions experienced in the Sahara and the country, as illustrated in (Fig.8) showing the water stresses by 2040. Water security in developed countries has been achieved through policy changes, effective water governance, financial investments in water infrastructure, human capacity, and technological solutions to water supply (UNDP,2006). On the contrary, regarding developing countries, Africa and South Asia remain behind other regions in achieving SDG 6(ibid). Developing countries have not managed to devise strategies that similarly enhance water security as developed countries (ibid)

The research in Africa has grown in all conceptual, intellectual, and social structuring aspects, which are prevalent in emerging topics focused on climate change and variability, sustainability in enviro-ecosystem services, development, livelihoods, and modeling(Botai et al., 2021).

Moreover, Botai et al. (2021) express that the evolving nexus research development spans various disciplines. It targets a shift from unconnected silo paradigms in addressing the F-E-W security to interconnected, interdependent, and nested linkages or systems(ibid). Therefore, incorporating the subfields of environmental, social, economic, and political drivers becomes critical to contribute to the achievement of the SDG across Africa holistically (ibid). Another case example of the dam construction on the transboundary Nile basin demonstrated a need to consider the needs of both Ethiopia, Sudan, and Egypt. In Ethiopia, the dam construction targeted energy production while, on the other side, there will be an impact on agricultural production due to the affected water amount and resources in Sudan and Egypt (Mbaku, 2020).

In reviewing the statute of the F-E-W nexus in Morocco and South Africa, El Youssfi et al., (2020) conveyed that F-E-W nexus policies are formulated in isolation, disregarding the interdependencies of the resources. As a result, it becomes challenging and impractical to undertake valuable comparisons and direct risk analysis of the F-E-W components. El Youssfi et al. (2020) proposed that F-E-W nexus frameworks be assisted by technology for collecting data and modeling the complex interconnections. Furthermore, El Youssfi et al. (2020) further recommended that the F-E-W nexus evaluation models be adopted as test approaches for policymakers in Morocco and South Africa.

3.3 Regional/ Transboundary level: SADC Region

The Southern African Development Community (SADC) region is the principal institution that focuses on integrating shared resources at the regional level in Southern Africa (Nhamo et al., 2018). The fifteen member states that constitute the SADC region in southern Africa are Angola, Botswana, Democratic Republic of Congo, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe (Mabhaudhi et al.,2019). The United Nations estimates that by 2050, the SADC population is projected to be 712 million (United Nations., 2019). As a result, F-E-W resources demand will escalate over the years, worsening the F-E-W securities. Hence it was vital to examine some of the F-E-W interlinkages in the context of some countries in relation to Botswana. The focus is on the interaction process of policies, institutions, and the resources governance and management, especially in response to climate change.

The region is actively involved in the development of F-E-W nexus research. The F-E-W nexus is conceived as a pathway to sustainable resource management, suggesting an acknowledgment of the critical F-E-W resource interlinkages in the SADC region. Collaborative, practical steps between the SADC member states have been taken towards the nexus through various workshops, dialogues, consultations, and presentations on the significance of the F-E-W nexus in the SADC region(ibid). In addition, attention has been drawn to discussions of socio-economic and political, environmental issues affecting the implementation of the F-E-W nexus (Mabhaudhi et al.,2018). As a result, the region developed a F-E-W nexus plan that acknowledges the nexus role in resolving population growth, climate change, and variability issues and optimizes resource use to achieve regional goals (Mpandeli et al., 2018). Furthermore, the F-E-W nexus plan requires assessment studies to direct the policy recommendations and strategic actions informed by research (Mpandeli et al., 2018).

3.4 SADC Food Sector Perspective

In the Southern African region, an increase of 60% (116 million) of the population, which surpasses the growth of the agricultural sector, is expected in two decades (The Institute for Security Studies (ISS)., 2017). Furthermore, 3.5 % of all required food is imported, with almost 29% expected to increase by 2040(ibid). Despite this, nearly 12.5% of the region's arable land is cultivated, mainly concentrated in countries in the eastern (Mabhaudhi et al., 2019). In contrast, countries like Botswana and Namibia have the least cultivated land due to arid conditions (Fig 9,left). As a result, states like Botswana, Lesotho, and Seychelles are expected to increase their food importation by more than 60% of the total food demand (Fig 9,right). Given this scenario, Botswana will most likely undergo exacerbated food insecurity due to the food insecurity in South Africa and neighboring countries (Mabhaudhi et al., 2019; The Institute for Security Studies (ISS)., 2017)

Despite fluctuations and failure to meet the regional demand, cereal production is the major SADC regional contributor to food security (The Institute for Security Studies (ISS)., 2017). Moreover, the region is a net importer of livestock products indicating that growth has failed to meet the demand (ibid). However, due to high input prices, prevailing floods, drought, pests, and diseases, there is a reduction in food production in SADC countries(ibid). Therefore, the regional food and nutrition security status remains unstable and unpredictable. For an alarming scenario like this, the limited multi-sectoral approach and integration with other resource

sectors become risky (Mabhaudhi et al., 2019). This signifies a need for SADC countries to enhance food production, industrial development, and the enhancement of the r linkages with water and energy supply (SADC Food and Nutrition Strategy, 2014).

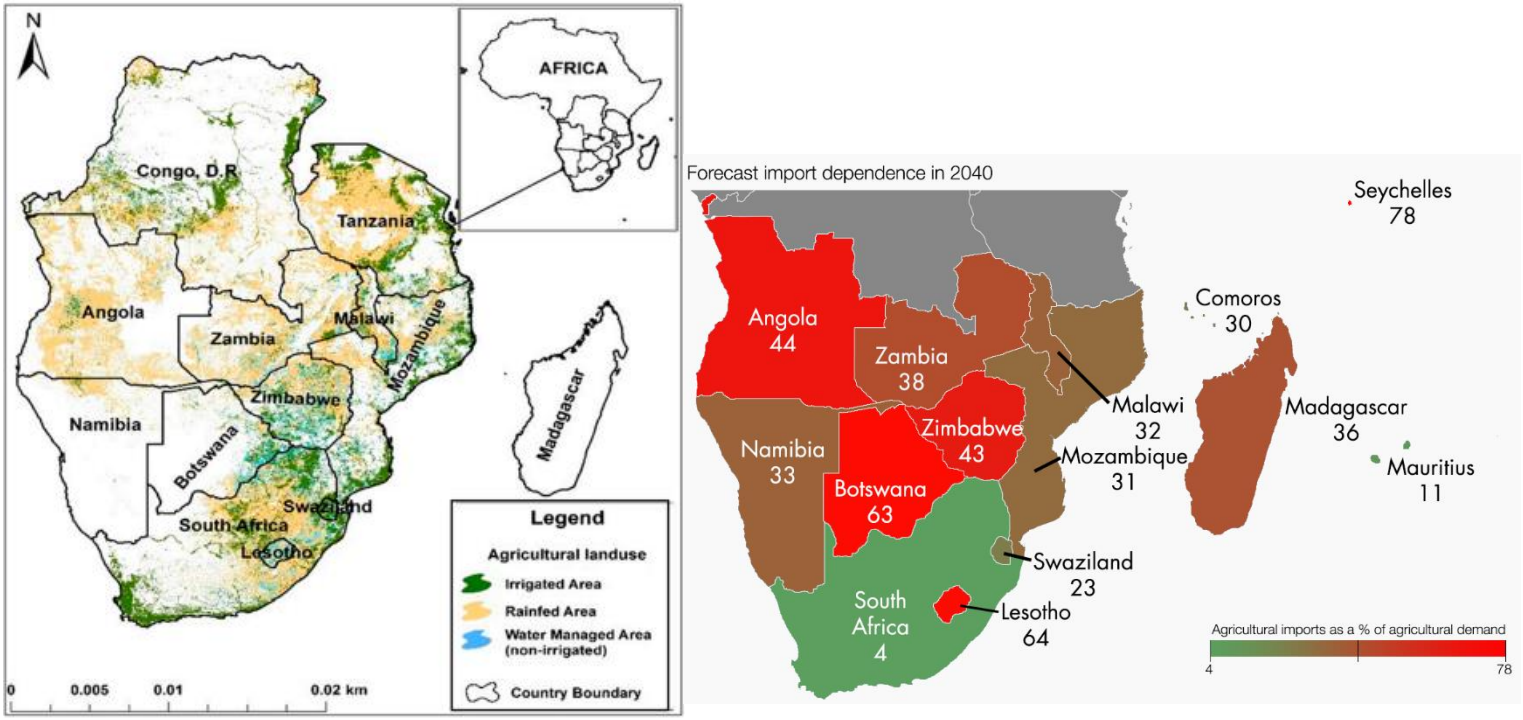


Figure 9: Map of Southern Africa showing the agricultural landuse(left) (Source:International Water Management Institute (IWMI) irrigated area mapping); Forecast import dependence in 2040, agricultural imports as a percentage of agricultural demand)(right) (Source: https://www.dailymaverick.co.za/)

3.5 SADC Energy Sector Perspective

Significant strides have been made at the regional level to establish regional infrastructure to support the electricity sub-sector. The map below (Fig 10) captures the SADC countries' interconnections to the regional power pool, the Southern African Power Pool (SAPP) (Regional Infrastructure Development Master Plan, Executive Summary, 2012). The SADC region experiences an energy shortage, with most member states depending on hydropower, for example, Congo, Mozambique, and Zambia, whereas Botswana and South Africa are coal-dependent (ibid). A trade-off between water and energy production prevails due to the extreme pressure posed by water allocation for hydropower generation(ibid).

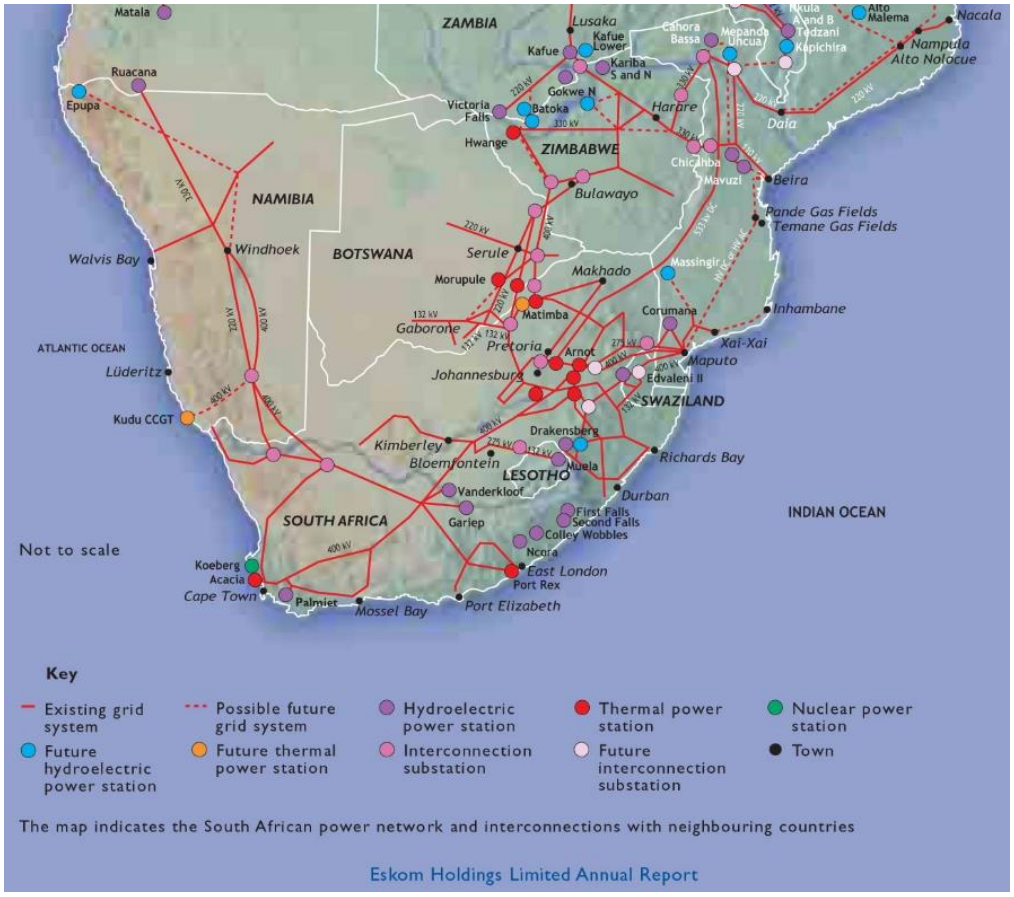


Figure 10: Southern African Power networks and interconnections(Source: Eskom Holdings Limited Annual Repor,2016)

3.6 SADC Water Sector Perspective

Botswana is part of the protocol on major transboundary river systems' shared watercourses with neighbouring countries (Fig 11). The watershed commissions (Table 2) have been formulated to resolve conflicts between countries surrounding rivers and efficiently use and develop water resources (Botswana National Water Master Plan Update based on Smart Water Management System, 2018).In addition, the commissions are responsible for the formulations of policies governing transboundary river basins (Mabhaudhi et al.,2018). An example is the Zambezi water basin region, ZAMCOM's principal role in promoting interaction and coordinating emergent preparation and responses during a crisis like flooding. Moreover, the commission is responsible for Member states' policy and legislation governance, management, and ensuring harmonization with required activities for strengthened cooperation and

communication capacity(ZAMCOM,2019). The watershed commissions have initiated various projects by designing comprehensive Water Management (IWRM) plans according to water resources and topography characteristics (Botswana National Water Master Plan Update based on Smart Water Management System, 2018).



Figure 11: The transboundary river basin shared by Botswana and neighbouring SADC region countries(Source: (Source: https://www.sadc.int/, 2020))

Table 2:SADC Transboudary Commisions(Source: Botswana National Water Master Plan,2017)

Watercourses	Commissions	Countries
Okavango	OKACOM	Botswana, Angola, Namibia
Orange-Senqu	ORASECOM	Botswana, South Africa, Lesotho, Namibia
Limpopo	LIMCOM	Botswana, Mozambique, South Africa, Zimbabwe
Zambezi	ZAMCOM	Botswana, Angola, Malawi, Mozambique, Namibia, Tanzania, Zambia, Zimbabwe

3.7 Botswana National level

3.7.1 Food Insecurity In Botswana

Botswana's agriculture sector comprises livestock, with cattle dominating, and small stock farming as sheep and goats, and arable crop production (BCA Consult,2012). Agricultural practices like herding cattle make up 85% of agricultural output, as illustrated in (Fig 12). Regardless, livestock productivity is reducing because water pumping systems are manually operated, indicating a need to consider solar for pumping water and other electricity uses to reduce sector volatility (ibid).

In terms of crop production, farms are sparsely located in remote areas, making grid electricity connections costly and exacerbating transmission losses(ibid). It must be emphasised that this causes a heavy reliance on commercial imports of most agricultural products, except beef and its by-products(ibid). Hence Botswana is subjected to high food insecurity, with about 90% of the national supply being imported to feed the population (Legwegoh and Hovorka, 2016). In addition, there is a heavy dependence on neighbouring countries like South Africa, catering to the importation of primary food commodities except for beef (ibid).

Botswana's landscape comprises 70% of poor soils and the desert with low and variable annual rainfall, which negatively impacts arable production and subsistence scale farmers, who also

lack capacity-building assistance to commercialise agriculture(Legwegoh and Hovorka, 2016). As a result, there have been large annual deficits in cereals and other foods. The significant contribution to the low production in the subsistence farming sector is the recurring droughts. Attributes towards this failure could be the costs incurred by importing most of the agricultural inputs (ibid).

In Botswana, the agricultural sector is regulated by the Ministry of Agriculture Development and Food Security (gov. bw, 2021). Over the past decades, the ministry has provided substantial funding to support agricultural programmes such as ARAP, ALDEP,LIMID, BAMB and ISPAAD. Still, they have not succeeded in improving the food security situation in the country (Seleka and Mmopelwa, 2018). The silo thinking, that disregards the resource interlinkages in designing the programs seems to contribute to the challenges continuously. Moreover, limited integration and coordination between the institutions potentially lead to duplication in the mandates of the institutions and conflicting policies. Furthermore, some economic incentive schemes, such as Citizen Entrepreneurial Development Agency (CEDA), provided grants and subsidized loans to farmers. However, the downside is, those who are well connected are favoured by the personal surety required by CEDA, which disadvantages most vulnerable people unable to provide and smallholders(ibid).

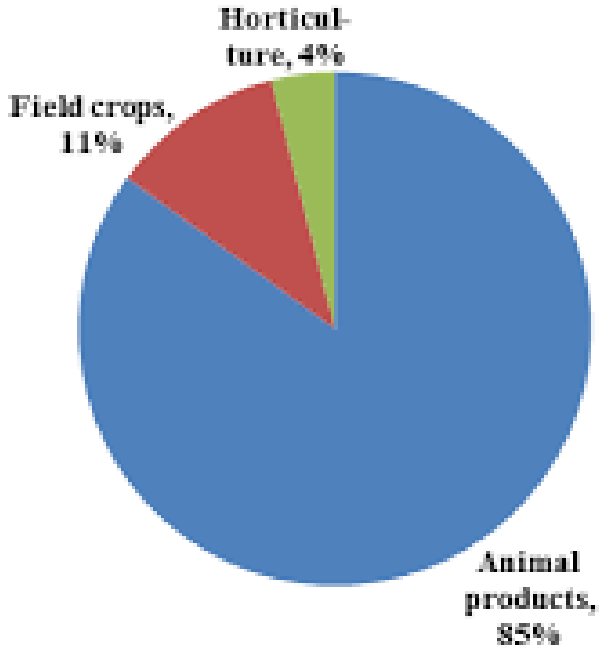


Figure 12: Agricultural output in Botswana (Source:https://borgenproject.org/tag/hunger-in-botswana/, 2020)

Additionally, to promote food security, the Accelerated Rainfed Arable Program (ARAP) and the Integrated Support Program for Arable Agriculture Development (ISPAAD) provided funds for expanding cultivation and subsidized inputs like fertilizers and seeds to promote more output (Seleka and Mmopelwa, 2018). For instance, ISPPAD's assistance components to the local struggling arable farmers include cluster fencing, provision of potable water seats and fertilizers, facilitation of access to credit, and establishment of agricultural service centers. Moreover, the government injected funds into the NDB seasonally to loan farmers at reduced interest and finance arable farming projects.

The incentive schemes appear to focus more on food security, but they could offer more integrated solutions if designed to consider water and energy security. In addition, improving the inclusivity and transparency of the incentives is imperative for the benefit of the community of farmers. A lack of transparency and ineffective government institutions hinders the government from achieving the securitization of the F-E-W resources (Al-Zu'bi and Keough, 2018). Irrespective of the government interventions to invest in production inputs, the sector is still challenged by efficiency and production inputs(ibid). Furthermore, a lack of infrastructure and support services hampers production, especially since productive farms are sparsely located, causing difficulties in service provision like water, electricity, telecommunication, and access roads.

3.7.2 Energy Insecurity In Botswana

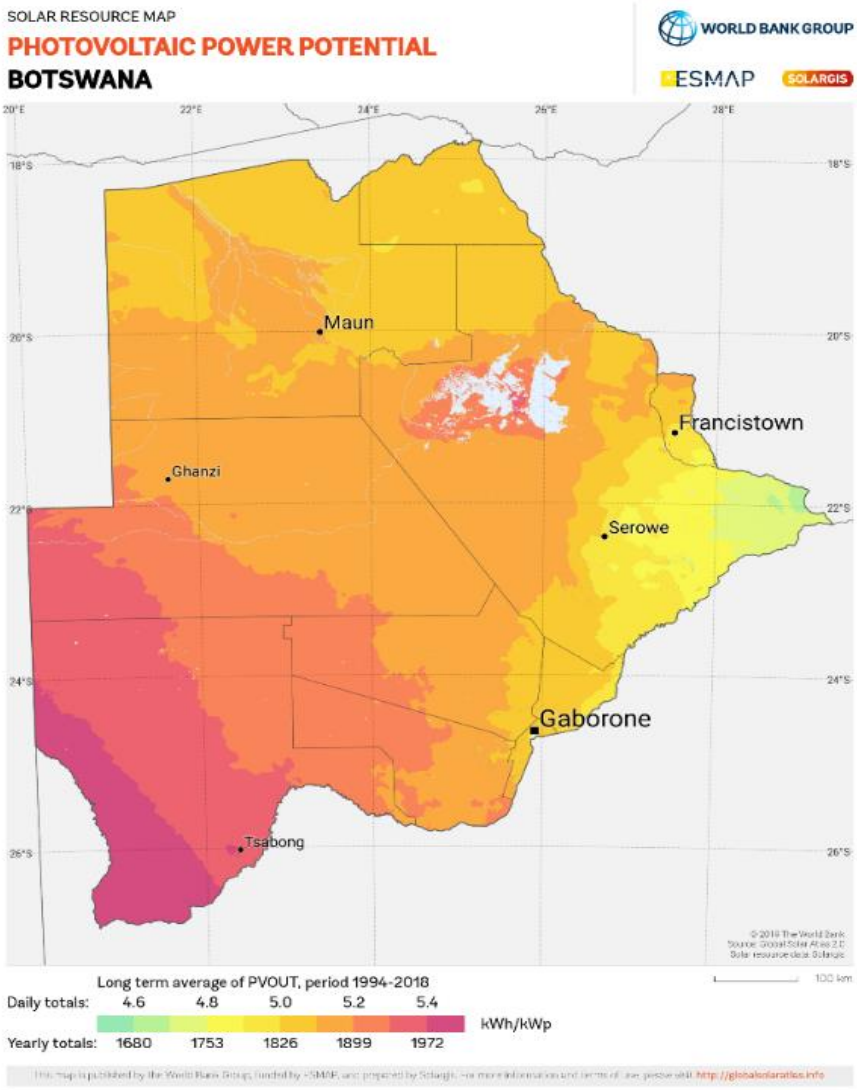
The Ministry of Mineral Resources, Green Technology, and Energy Security(MMGE) regulates the energy sector (USAID Land Tenure Botswana Profile, 2010). The Ministry directs the electricity sector through the Department of Energy while ensuring the sector is regulated by the Botswana Energy Regulatory Authority (BERA) to secure a competitive environment (IRENA, 2021). Established in 1970, Botswana Power Corporation (BPC) is the state-owned utility company responsible for electricity generation, transmission, distribution and retail (Botswana Power Corporation, undated).

Botswana heavily relies on fossil fuels for electrical power generation (IRENA, 2021). The country has been prone to sporadic power cuts, especially in the city. Imports through the Southern African Power Pool (SAPP) have been done to curb the shortage of electrical power(ibid). Botswana is exposed to 3,371.0 hours of sunlight per year, with an average of

solar radiation of at least 5 kWh per day . The map below as illustrated on (Fig 13) depicts the country's photovoltaic power potential, implying that solar energy expansion offers enormous potential. South African utility provider, ESKOM, has exported to Botswana since 2017 to complement national production, especially during peak periods.

Botswana government intends to become a net exporter of electricity to curb its domestic and regional power shortages. In addition to its energy mix, it plans to add solar power and coalbed methane(). A F-E-W renewable energy projects have been initiated, with the private sector involved in the bidding. However, no projects in the form of IPPs(independent power projects) have materialised in Botswana because there is a lack of an enabling environment (Eberhard et al.,2016). The government signed a memorandum of intent with the United States, Namibian and developing banks in April 2021 to initiate a 2-5 gigawatt mega solar project that will run

Figure 13: Annual solar radiation in Botswana. (Source;world bank group,2011)



for 20 years. Situated in both Botswana and Namibia, the intent is to make the countries both net exporters of solar power, adding 300-500 MW to Botswana's energy mixes.

3.7.3 Water Insecurity In Botswana

Botswana is subjected to water stress, due to low and erratic rainfall of 200mm to 500mm annually, with an estimated annual average of 1400mm and frost (Davies et al.,2017). Since the 1950s, the harsh climatic conditions of Botswana have resulted in successive, multi-year droughts that have hit the country, leaving the Gaborone Dam, the capital city's main water supply, dry for years (ibid). To curb the water insecurity, the country imports water from the Northwest Province of South Africa. Still, on the endeavor to curb the water insecurities, a new contract to draw Water from Lesotho via the Orange-Sengu River Commission has been signed

(ORASE.COM,2018). The governance of F-E-W resource supply must ensure improved infrastructures provides the resources on a reliable and sustainable basis, which is ineffective in developing countries like Botswana.

The Ministry of Land Management, Water and Sanitation Services governs the water sector in Botswana. Its mandate is to manage and service land administration to facilitate socio-economic development and simultaneously deliver water (Minister for Land Management, Water & Sanitation Services,2021). This implies progress in practicing integrated approaches to managing land, water, and sanitation services. However, the water master plan presently promotes two large-scale water transfer schemes as a core strategy for the security of water resources in Botswana. The Chobe-Zambezi transfer scheme was designed in 2014 for irrigated agriculture in the Chobe area(Fig 14). The Lesotho highlands transfer has been underway through funding. The projects will supply water to three countries, from Lesotho across South Africa to Botswana. The scheme will collect water from the Makhaleng dam, which forms part of the Lesotho Lowlands. Through a water conveyance pipeline of approximately 700 km, the water will be transferred from Lesotho, South Africa, to Botswana (ORASECOM,2018). This is a demonstration of good transboundary relations between the three countries at the regional level.

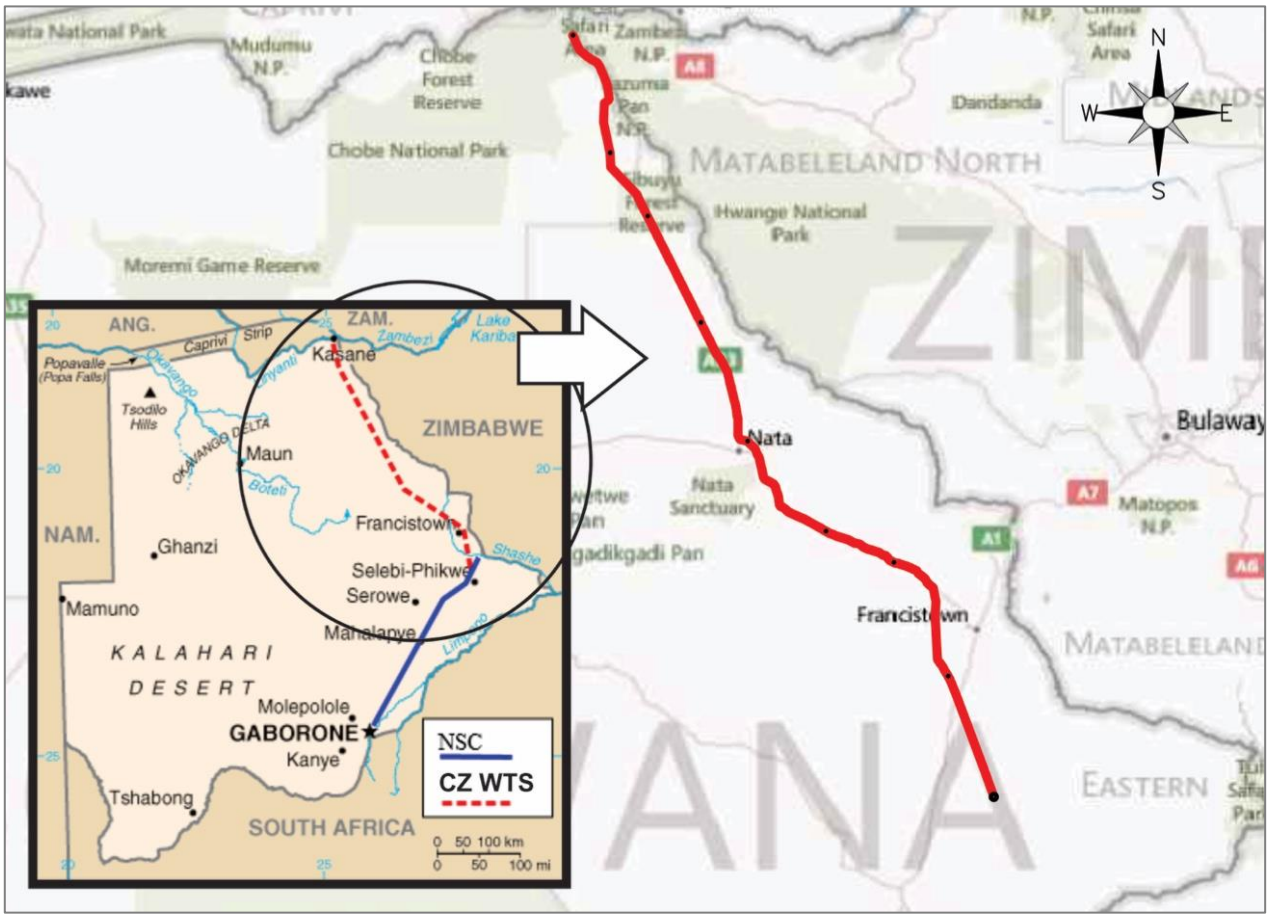


Figure 14: Botswana N/S Water carrier project(Source: Botswana National Water Master Plan)

According to Magole and Kgomotso (2018), the Botswana policy does not provide water supply services to ungazetted settlements, exacerbating water insecurity and human security challenges. Despite this social exclusion in ungazetted areas, Botswana has made improvements in water infrastructure investments that have allowed all households in gazetted settlements access to improved water sources. In addition, the government policy has ensured that all gazetted settlements have access to safe water for equitable domestic purposes from better sources within 400m. Hence there is 97% coverage (Magole and Kgomotso,2018). Although this is the case, more services are still required because households continue to experience water insecurity despite having access to improved water sources. While there is good progress, some ungazetted settlements in Okavango still access water from untreated sources like rivers and streams. However, the majority of gazetted settlements have good water sources, and despite this, frequent water shortages are experienced dating (Ibid).

Ngamiland Region households experience water insecurity, which negatively impacts human security(Kujinga, et al., 2018; Hambira, et al., 2011). The community members have access to water unsuitable for drinking which puts individuals at health risk. For instance, the diarrhea outbreak claimed 18 babies' lives in June 2012 due to poor water quality. The gazetted settlements have improved water sources but lack access to sufficient good quality water, while ungazetted villages receive no water supply services, which compels them to access untreated water.This indicates that it is not always the case that improved sources like in the urban and gazette settlements, guarantee access to water all the time. It is a management failure. When service providers fail to provide water supply demonstrates when infrastructure is present. Despite these challenges, there is an acknowledgment of the importance of approaching resource management integratively.

Magole and Kgomotso (2018) placed emphasis on a comprehensive, integrated management plan that is developed for the conservation and sustainable use of the Okavango delta. The plan was developed using the ecosystem approach, which promotes stakeholder involvement in managing natural resources. However, it appears that, theoretically, what is written in the plans is not practically implemented in these settlements. Not recognizing the ungazetted settlements clearly indicates policy shortcomings, mainly because the settlements play a significant role in the country's social-political and economic development. Especially given that ungazetted settlements are essential, as livestock farming is practiced primarily in these areas.

It is undisputed that water resources are essential for food and energy security and vise versa; the resources display causal links or feedback loops. I explored the significant links among the resource interactions in Botswana from a nexus perspective. The intent was to understand the current status of the F-E-W interconnections, which entailed unpacking the complex structures of the resource interlinkages. The F-E-W links are either coupled in pairs, linear chains, or in nested interactions of feedback loops. This insight will emphasise the intimate interrelations of the linkages within F-E-W sectors. Essentially, this demonstrates how strategic decisions in any sector greatly influence others (Al-Zu'bi and Keough, 2018). Indicated in the table below(Table 3) are the pairs, chains and loops as the causal links in the context of Botswana demonstrating the interactions in the microclimate of Botswana.

Table 3: F-E-W Interlinkages(Source: Authors illustration, adapted from Webber et al., 2018)

Nexus	**Interlinkages**
PAIRS	
W - E	Water allocated to coal energy production e.g. for cooling and plant facility operation at the coal mine, Morupule
W - F	Water allocated to irrigated agriculture, like the Glenn Valley Irrigation Scheme in Gaborone which uses secondary treated wastewater
CHAINS	
W - F - E	Water allocation for food increases the energy required for pumping during irrigation
	Water allocated to coal energy production reduces the river flow diverted to agricultural production land
	Income earned from coal energy is allocated to agricultural development
	Water allocated to biofuel crops means less land for food crops production
	Dams constructed for coal energy production and consumption disrupt aquatic fish life ecosystem
LOOPS	
W -E -W - F	Water diverted for irrigation reduces the quality of flow for aquatic and wetland ecosystems important to fisheries
	Water allocated to coal energy production reduces river flow to aquatic and wetland ecosystems reducing fisheries
	Water allocated to coal energy production reduces irrigation during dry season
	Water allocated to coal energy production reduces suitability of flow to agricultural lands with impacts on soil salinization and ground water that impacts crop production

3.8 Local Context: Profiling the F-E-W Nexus in Gaborone Capital City

Cities are the center of economic, social, and political activities (Webber et al., 2018). Moreover, they are considered a means to manage natural resources effectively(ibid). Therefore, understanding the complex urban F-E-W systems provides opportunities for interventions of innovative technology and integrated policy implementation. Moreover, given the population densities in cities and that cities are concentrated centers experiencing growing economies, they hold the potential to impact vast populations(ibid). The F-E-W linkages in Gaborone are complicated as the city faces multiple overwhelming challenges in achieving its development priorities.

Botswana encounters the most rapid urbanization and comes second after South Africa in the Southern African region. Projections suggest that by 2025, the country will be 69% urbanized (Acquah and Kapunda, 2016). The economic hub of Botswana, Gaborone capital city, is undergoing social changes of rapid urbanization and population growth (Legwegoh, 2012) as illustrated in (Fig 15). Due to the social changes caused by the rapidly growing population in Gaborone's context, there is a need to analyse the F-E-W nexus concept and its potential applicability. This particularly impacts the Planning Area of Gaborone which is bordered by Tribal Land and freehold farms towards the south (Figs 16 and 17), signaling limited room for expansion. Hence, the city encounters constrained spatial growth due to the bordered city limits (Sebego and Gwebu, 2013).

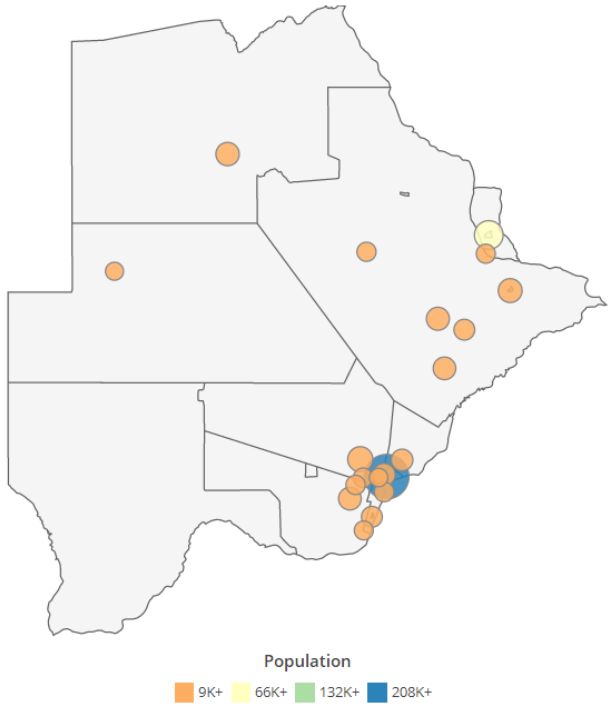


Figure 15: Botswana Population Density Map (Source: Census, 2011)

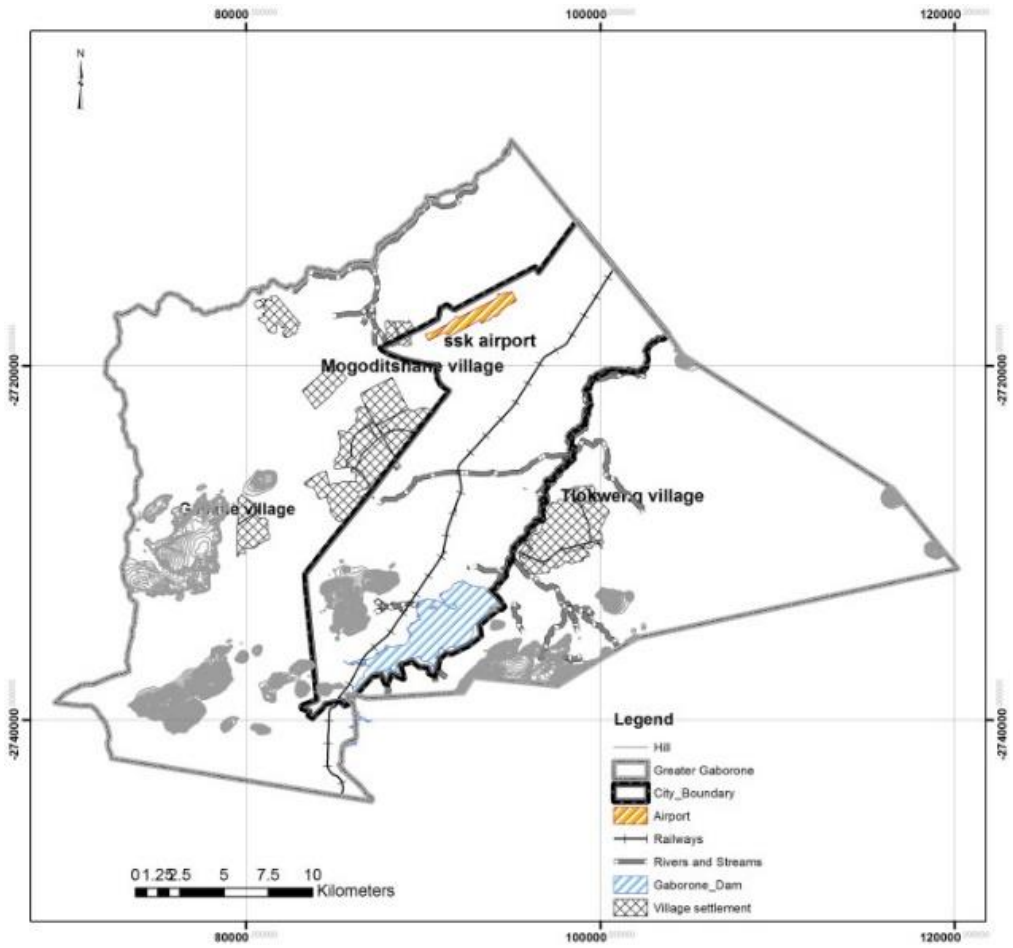


Figure 16: Gaborone planning Area located in relation to other satellite settlements (Source: Gaborone city Development Plan, 1997-2021)

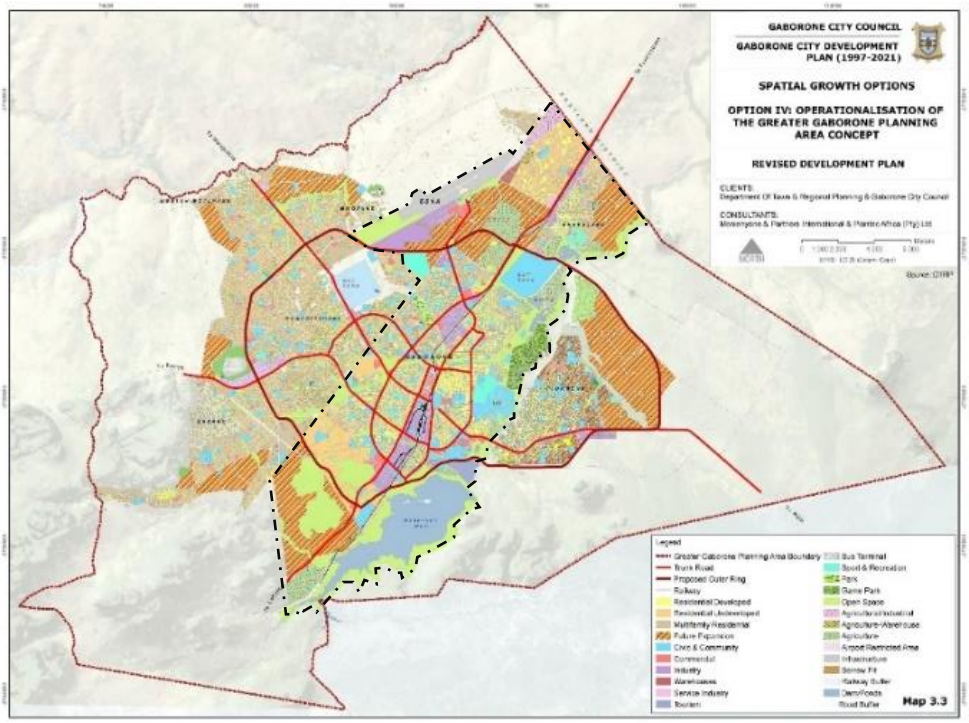


Figure 17: Loss of productive agricultural land, and agriculture practicing urban periphery settlements engulfed by city growth (Source: Gaborone city Development Plan, 1997-2021)

The rapid urbanization and population increase in Gaborone is characterized by centripetal (rural-urban migrants) and centrifugal (urban-rural migrants) movements (Sebego and Gwebu, 2013). The centrifugal movements are from rural satellite settlements within its commuting radius (ibid). The high migrations are stimulated by the pursuit to access services in the economically vibrant Gaborone. On the other hand, uncontrolled and unplanned growth and expansion of the urban edges of the city have engulfed the satellite settlements with uneven development patterns. As a result, the rural satellite settlements including Tlokweng, Mogoditshane, Gabane, Gaborone North, Kopong, Metsimotlhabe, Mmopane, and Phakalane, became dormitory suburbs. Thus, the gradual process of the satellite settlements adopting the structure of Gaborone's social, economic, and commercial attributes is prevalent. Sebego, and Gwebu (2013) reiterate that the satellite settlements still relied on crop farming and livestock agriculture. However, the reliance on agricultural production has declined, causing food insecurity challenges.

Gaborone's rapidly growing population, continued urbanization, high unemployment, and F-E-W resource insecurities result in reliance on imported resources to curb the scarcity posing immense challenges to the city's development(Gaborone development plan, 2011). In addition, misunderstandings of the complex processes of urban metabolism and ecology have caused a gap in urban growth models (Chang et al., 2020). For instance, Gaborone's rapid urban growth and population increase resulted in the loss of farmland for agricultural production, increasing the water demand (Sebego and Gwebu, 2013). The city's population and economic growth cause a growing demand for resources transferred over long distances across borders. Moreover, the Gaborone dam is challenged to meet the city's population demand (Fig 19). The pie chart (Fig 18) shows the population distribution in the city at 53% of the nation's population. The dam receives its water along with the North-South water carrier project, transferring over a long distance across the country, which is economically costly (Legwegoh, 2012).

Gaborone's urban and peri-urban agriculture is still minimal because producing food in harsh climatic conditions without irrigation is challenging (Legwegoh, 2012). Furthermore, as illustrated in (Fig 18 and 19), the Gaborone map shows the limited urban agriculture being practiced in the city. In addition, the Gaborone energy demand is met by state-owned coal-fired plants and imports primarily from South Africa and Mozambique (IRENA, 2021). The city must assess the F-E-W nexus security to track the resource flows, mitigate their tradeoff, and

fuel their synergies. The F-E-W interactions are overlooked, which has decreased the impact of initiatives in the food sector that have been implemented. The reasoning is that the initiatives are not coordinated.

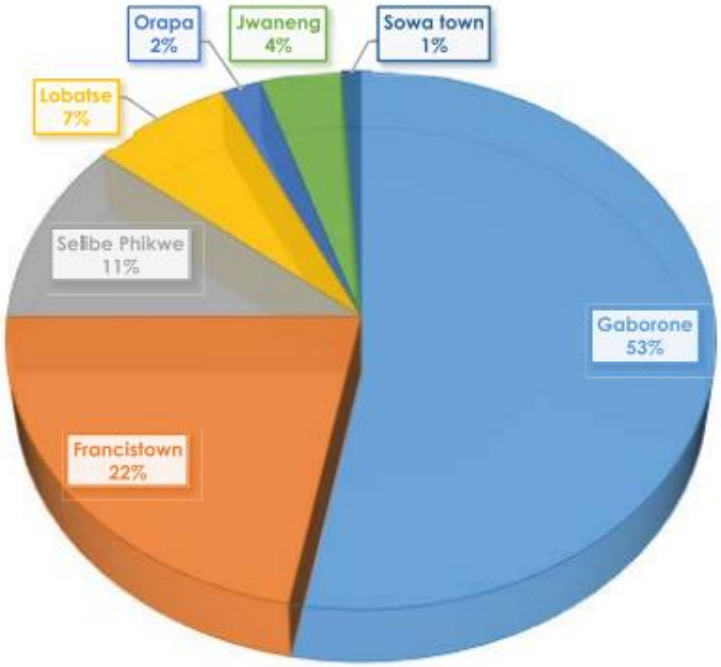


Figure 19: Agricultural production in Botswana urban areas (Source: Legwegoh, 2012)

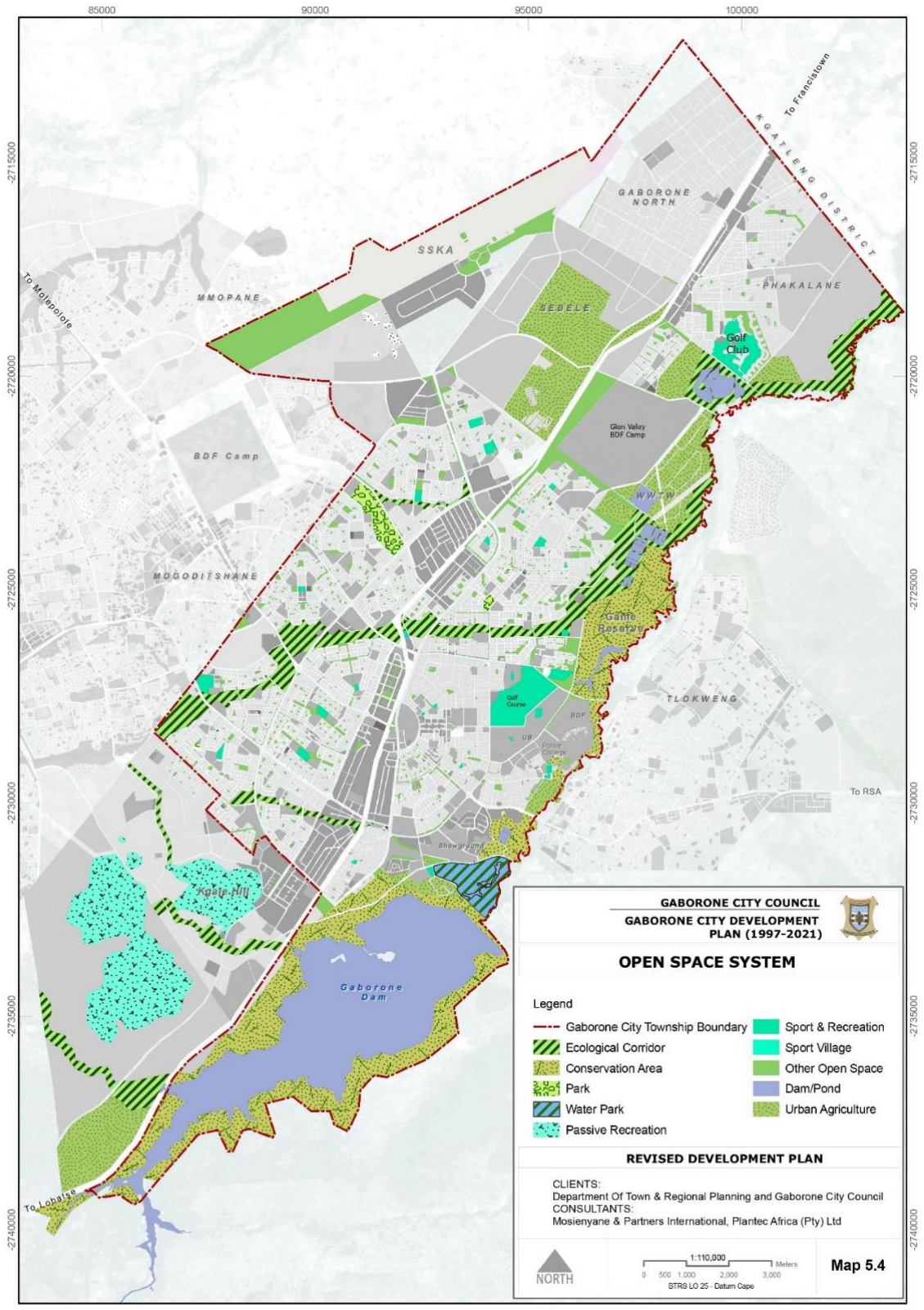


Figure 19: Map of Gaborone (Source:Gaborone City Development Plan ,1997-2021)

3.9 Botswana's Challenges in Aligning with The F-E-W Nexus

3.9.1 Climate Change and Variability

To a great degree, in arid and semi-arid regions, F-E-W nexus systems encounter challenges in supporting humans' well-being (Yada et al., 2021). Within the nexus, water is the most vulnerable element affected by climate change and exerts a knock-on effect on other sectors(ibid). For example, in semi-arid Botswana, climate change significantly impacts the insufficient F-E-W resources (Mugari et al., 2020), creating compounded socio-environmental challenges that must be addressed holistically.

In acknowledging the need to promote the nexus in Botswana, the National Water Master Plan reports that resource management through the nexus can be used to assess changes in resource demand or supply management. This is due to climate change impacts and the impact of individual resource management policies on other resources (BNWMP,2017). Therefore, in the face of climate change, ecosystem services must be considered during decision-making, policy formulation, planning, and resource management to achieve the F-E-W nexus (Swatuk and Cash, 2018). For instance, besides the efforts towards the securitisation of the resources, scarcity issues caused by climate change and variability impacts are experienced unevenly in specific geographical areas, especially ungazetted settlements in Botswana. The fact of the matter is, it is crucial to improve Botswana's national regulatory and legislative framework to align with the F-E-W nexus approaches.

3.9.2 Silo or Sectoral Approach

According to the Water Master Plan of Botswana, there is an understanding that it is critical to promote the nexus in various ways that consider policy reforms, economic value and technological improvements (BNWMP.,2017). However, in reviewing the Botswana food, energy, and water policies and decision-making processes, I have observed a continued lack of application regarding the nexus application. As a result, approaching the food, energy, and water resources as interconnected systems instead of the traditional silo approaches in the planning and managing of resources still falls short. In addition, policies and regulations developed at the national level do not consider local conditions, making F-E-W implementation difficult. Moreover, the sectoral approach to managing resources is still reflected in Botswana's

F-E-W policies, regulatory, institutional framework, and investments. As a result, the Governance issues of the resources are resolved in siloes.

Theoretically, the National Water Master Plan recognises the F-E-W nexus. Still, with no practical plans for implementation, it has not been made an official policy in Botswana, with the sectoral policies governing resources still operating in silos. The nexus governance is fragmented in Botswana, as seen in the limited cross-sectoral engagements. Any action addressing the F-E-W resource issues is reactive to scarcity stresses, for instance, drought. Although there are indications of acknowledgment of the significance of the resource links, actions are mostly reactive after pressure from the communities. Decision-making and responsibility attribution processes are opaque and display transparency and exclusion issues, as seen in how ungazetted settlements do not acquire F-E-W services from the government. There is unsatisfactory coordination between the ministries governing the food, energy, and water resources, which is seen in the silo mentality practiced. In the case of Gaborone, the City Development Plan is not detailed enough to effectively guide the design of F-E-W infrastructure projects and decisions on how they will operate. Thus, the complexities of the F-E-W links structure in Botswana are composed in a way that makes adressing the governance problems difficult.

Policies theoretically acknowledge the significance of the other sectors. For instance, the water policy stresses the importance of efficiently using water to cater to energy and food production. However, negligence persists in providing equal weight to food, water, and energy security. Despite the high insecurities encountered in Botswana, the resources' socio-economic, political, and governance issues are resolved in siloes. Despite the growing economy, the government prioritises unemployment, which is one of the country's significant challenges (Hope, 1996). On most occasions, the high unemployment rates drive decision-making, causing the government to overlook the other compounded issues of the integrated F-E-W resources. In this way, the silo mentality results in missed innovative intervention opportunities for nexus-oriented projects, creating jobs.

3.9.3 Conclusion

After examining the current status of the nexus in Botswana, it is prevalent that the ministries govern the F-E-W resources in silos. This implies that the departments that operate under the

ministries also operate separately. It would be ideal for the sectoral ministries to engage in research investigating factors that lead to the failure to supply the resource services in the varied settlements across the country. For instance, the water utilities corporation(WUC) needs to interrogate what caused the department of water affairs (DWA) to fail to supply water to households (Magole and Kgomotso, 2018). This will help understand the challenges faced and provide integrated solutions to the governance of the resources, management, and planning. — Vision 2036 proposed water accessibility to all households (Moroka, 2017: Vision, 2036). According to the vision, there is a need to enhance social inclusion; hence, all the settlements, both gazetted and ungazetted, require quality F-E-W resource service. Integrated policies that recognize that all settlements must be prioritized for quality resource provision and supply services.

Chapter 4: Findings, Analysis and Discussion

4.1 Introduction

Advancing the F-E-W nexus in Botswana presents challenges that could hinder its implementation. This chapter explores the challenges and opportunities in transitioning from the conventional silo approach to the nexus approach in the context of Botswana. The country encounters challenges due to the harsh climatic conditions, rapid urbanization, mainly experienced in Gaborone's capital city, and the geographic challenge of being landlocked. In addition, there is limited education and awareness of the resource interlinkages regarding the nexus. Thus, societies approach food, energy, and water management challenges in isolation to satisfy short-term needs. I explored the sectoral policy formulation and ways of planning toward achieving nexus-oriented solutions for implementation and management in Botswana.

4.2 Ineffective F-E-W Nexus Governance, Policy incoherence, and fragmented institutions

According to the World Bank, what encapsulates good governance is open policy-making (World Bank, 1994). The governance must be informed and predictable with a bureaucracy that is instilled with a professional attitude, a government executive arm responsible for its actions; a strong civil society engaged in public affairs, and all behaving under the rule of law. Botswana still governs the F-E-W resource sectors in islands, as much as the F-E-W nexus

concept has been briefly captured in the National Water Master Plan. Undoubtedly with poor governance of the resources, Botswana will face challenges in addressing issues of all socio-economic and environmental aspects, which essentially hinders sustainable development. There will be development challenges if there is poor resource management (Al-Zu'bi and Keough, 2018).

Transitioning from a sectoral to a cross-sectoral approach in policy formulations is fundamental (Al-Zu'bi and Keough, 2018). The Botswana governance issues and decision-making are resolved in sectoral siloes, although the policies theoretically acknowledge the significance of the other sectors. For example, the strategies of the water policy are anchored on serving the food and energy sectors. The government still operates according to the conventional approach where a single ministry plans and manages a single resource sector with limited or no participation and communication with the other ministries. This proves less beneficial, given the persistent F-E-W resource insecurities and the silo practices overlooking the interactions between food, power, and water infrastructure. Despite this, town planners and physical planners at planning stages tend to ignore the resource linkages and miss the opportunities during planning stages (Gaborone City Development Plan.,1997 – 2021). This implies that proposals by Gaborone City Development Plan are not necessarily those under consideration by different infrastructure service providers. Overall, there is a need for synergy in planning F-E-W infrastructure provisions.

Furthermore, interlinkages between all aspects of the F-E-W-Nexus are disconnected from the Gaborone spatial planning transformations (Magole and Kgomotso, 2018). Seleka and Mmopelwa, (2018) acknowledge the severe need for policy initiatives to promote peri-urban agriculture in Gaborone's surrounding settlements. There are no implementation plans and programs, that have been developed yet, that demonstrate plans to integratively address the resource insecurities in these ares. Recognition that the continued increase in power demand requires a more holistic and integrated approach to manage the demand, action steps towards integration are not elaborated.

The government of Botswana monopolises the F-E-W resource sectors. It overwhelms the government especially in the face of climate change, population growth, rapid urbanisation, high unemployment, and increasing F-E-W resource demands. For instance, to curb the reliance on coal for energy production, which is a significant hurdle in achieving SDGs the

central government could co-manage the resources with the local government. Moreover, it could distribute some of its responsibilities by engaging investors who could drive the renewable energy infrastructural development to assist the government in transitioning to the use of solar power.

As previously alluded to in the context chapter, due to the dispersed spatial distribution of the resources across the country, the inclusion of the needs of affected remote and ungazetted settlement communities is still limited (Magole and Kgomotso, 2018). The challenge is significant especially given the efforts of the government to control the resource insecurities through initiatives in the nation's Vision 2036 and other National Development Plans(Moroka, 2017; Mogomotsi et al., 2018).

The vision 2036 (https://vision2036.org.bw/) reports delivering the country's vision through:

'A comprehensive National Transformation Strategy (NTS) that will be developed and act as the single strategy reference document, subject to periodic reviews to reflect changing global and local emerging trends. The NTS will provide a framework for fully coordinated, articulated and aligned sectoral and enterprise strategies in the public and private sectors at national and local levels'

A scenario where all the ministries, NGOs, and stakeholders collaborate across scales from local to high-level regional commissions from the planning stages to project implementation would be a more practical step towards operating the nexus principles. In that case, the F-E-W infrastructure development projects at the regional level would involve other neighboring countries affected, resulting in enlightened nexus-oriented projects. Given the poor progress, the Botswana National Water Master Plan, a proposal for a government-led F-E-W management system integration, and an implementation plan needs to be developed for the country (BNWMP.,2017). Enhancing the system mechanism, institutional processes and supporting individuals' capacity to engage in the development of their society can ensure responsibility and transparency in managing the natural resources and simultaneously address the current policy shortfalls (Al-Zu'bi and Keough, 2018). For example, ineffective coordination among the energy, water, and agricultural sectors could result in conflicting policies. For instance, much focus is placed on food security, encouraging agricultural

development through subsidies, and ignoring energy security. Therefore, it would be beneficial to design subsidies and programs that promote solar energy.

Policy coherence systematically reduces policy conflict and promotes synergies to achieve integrated F-E-W policies formulated cooperatively. Decentralization of F-E-W resource governance is critical. Botswana is characterized by top-down governance (Sharma, 2010). The planning and policy formulation process is centralized, where the local government councils in rural and urban areas derive authority and perform functions allocated from statutes (ibid). The central government plays a dominant role in developing policies and development plans and their implementation. Due to limited capacity, local governments still struggle to perform other roles. Therefore, decentralization will not be fully achieved if the capacities of local government are not further developed through financial autonomy. The district administration office acts as an instrument of decentralization, representing the district's central government, coordinating rural development activities. A lot of opportunities of practically implementing the nexus lie in decentralising, and further growing the capacities of the local government in Botswana. Moreover, moving decision-making and responsibilities from the central government to the lower local level as the central government is distanced from people's actual experiences and provides practical solutions to the compounded problems (Saito, 2008).

Top-down approaches are inefficient in enhancing the supply of F-E-W resource services, posing political implications. The potential lies in centralized planning and managing of the F-E-W resource systems. Hence decentralization and distribution of responsibilities are essential to address F-E-W. The co-management process serves as a process of cooperation and partnership amongst central governments and local stakeholders in environmental resources and management. The approach is an underlying process in distributing authority where central government authority shares responsibility with local communities. It advocates for fairness, transparency, and equity in enviro planning and decision-making.

Regarding institutional synergies, coordinating water, energy, and food security at every local government level is needed, instead of only food security (Purwanto, 2021) as in the case of Botswana. This is to assist the government in collaborative planning and actions and synchronizing the target achievements between national targets and local government targets in F-E-W security. In addition, intergovernmental cooperation between local regions through coordinating agencies can help the local region fulfill the F-E-W demands in accordance with

each region's potential. According to Swatuk and Cash, (2018) an obvious fact is that those in power acquire the best resource services using motivating political forces.

A holistic approach to implementing these pillars could foster Botswana's operationalisation of the nexus. As provided, socio-environmental systems' resilience can be enhanced through the efficient use of F-E-W resources, advanced comprehension of F-E-W system components interlinkages, and improved adaptable management strategies (Yada et al., 2021). Strategically managing these complex interconnections of the F-E-W systems in an improved manner should be the target in Botswana.

4.3 Opportunities For The F-E-W Nexus in Botswana

4.3.1 Participatory approaches: Private-Public Sectors, Civil Society, And Stake Holder Consultations

Botswana has opportunities to integrate the F-E-W sectors to avoid intensifying the F-E-W insecurities. The F-E-W nexus opportunities lie where current F-E-W challenges are faced (Mabhaudhi et al., 2018). To ensure that vulnerable populations like the ungazetted settlements in Botswana or the disabled, women, and youth are included in the decision-making and benefits, investigations must be conducted even in the design and adaptation of the systems (ibid). Moreover addressing inequalities, to enhance the rural poor and smallholder farmers' access to resources, it's important to interrogate and test which tools and services could be used (ibid). In the case of urbanising and expanding cities, encountering stress on the food, energy, and water resources, varied ways of alleviating the stress must be discovered (ibid).

To leverage private sector and multi-stakeholder investments, strategic ways to attract the private sector to engage in food, energy and water systems investments must be explored (Mabhaudhi et al., 2018). Investigations of effective platforms to coordinate and organize multiple stakeholders become imperative. In the case of Botswana incentives on the food sector, the funding schemes would be more relevant if aligned with the market signals, especially regarding food prices and fuel costs on the transportation of food over long distances across borders. To create resilient F-E-W infrastructure systems tha are resilient, the suited approaches to public financial management must be explored (Mabhaudhi et al., 2018).

4.3.2 DPSIR Model For F-E-W Nexus: Model Development Process for Botswana

The socio-economic and environmental relations of particular national or regional communities can be demonstrated in formulating and modeling frameworks to inform policy and practice (Swatuk, and Cash, 2018). For instance, the DPSIR model can successfully unpack these relations and account for the F-E-W nexus, especially in urban areas. (da Costa Silva, G., 2014). Furthermore, it could address changes in the F-E-W resources by examining the drivers, pressures, and state of F-E-W resource insecurities. Hence the responses will account for significant and direct impacts on the production and consumption of the resources (ibid). For instance, applying the response actions to climate change allows examining the risks and associating them with opportunities presented to private-public collaborations toward building resilient cities (Hunt and Watkiss, 2011).

According to Nhamo et al. (2020), for the F-E-W nexus to function, it requires a decision support tool that will analyze the three sectors simultaneously. The DPSIR model is a holistic tool that has the capacity to assess the resources together comprehensively. The comprehensive analysis will allow for the cross-sectoral linkages to be quantified, the balance of the synergies to be visualized, and assessments of the resource development and use to be holistic (Nhamo et al., 2020). In this sense, such an analytical framework will provide decision-makers with information on the state of the F-E-W resources over the short-medium and long term. This will provide the means to comprehensively tackle all planning, governance, and technological development aspects to enhance livelihoods in a sustainable and balanced manner.

Furthermore, the parameters of the analytical model could expand to indicate environmental, social, and economic systems. Hence, it will be beneficial as the SDG's progress assessment will be simultaneously achieved. Thus, the modeling process provides an inclusive multi-spatial and scale analytical framework that can quantify and define the interconnectedness of the F-E-W sectors. Moreover, understanding the F-E-W links will be provided to promote coherent policy-making and sustainable development. In addition, it will direct the cross-sectoral collaborative and participatory approaches. All scales, from local to global, must be accounted for along with all of these components to be considered in the modeling process. The perspective of "from local to global" where the locally-based F-E-W resource management

strategies are prioritised to ensure that F-E-W security can be achieved sustainably in local communities so that they will help towards national and global targets (Purwanto et al.,2021). Below (Fig 20), I attempted to illustrate a simplistic way of considering all components integratively in modeling an intergrative framework.

Using the analytical framework will provide decision-makers with information on the state of the F-E-W resources over temporal (short and long-term) and spatial scales (local to global) (Nhamo et al., 2020). The framework aligns with the “5 Is” framework of nexus solutions developed by the United Nations Economic Commission for Europe (UNECE). The UNECE derived the five categories of solutions considered success factors in implementing the nexus to tackle transboundary challenges.

The “5 Is” framework of nexus solutions derived by (UNECE,.2020) comprise of:

Institutions (inter-sectoral, multiple-level governance, engaging resource users, responsibilities etc.); Information (multi-sector information to support policy, assessing impacts across sectors, guidelines); Instruments (mixes of regulatory, economic, and information instruments); Infrastructure - built and natural (investments, operation, multiple use designs); International coordination and cooperation (sharing information, plans, good practices)

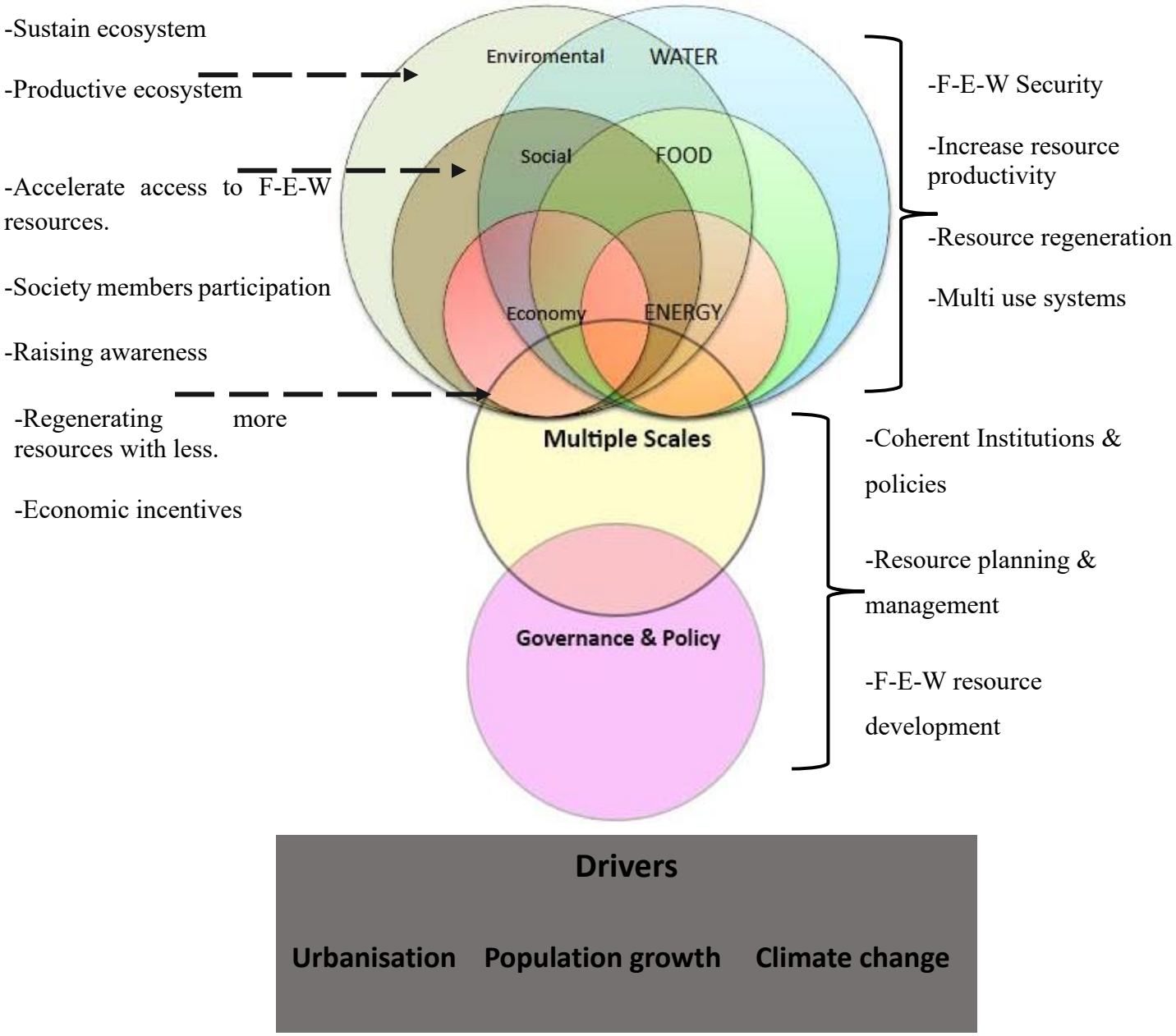


Figure 20: Illustration model of intergration of varied aspects (Source: Author's Illustration)

As I previously alluded to, studying the F-E-W nexus across all scales, from the local to global levels, provides lessons to be learned to countries still in their elemental stages of operationalising the concept. Accordingly, this entails consultations to source indigenous knowledge from community members operating on the ground. By gaining an understanding of practical examples of how the nexus is applied in other settings, stakeholders could quickly adapt the lessons gained to their unique contexts. In this sense, multi-purpose investments

considering the F-E-W resource linkages could be better planned for. In turn, that approach could assist in supporting socio-environmental developments across localities. Using case studies, sharing knowledge acquired across countries, and transboundary and regional basins fosters nexus adaptation. Undertaking scenario analysis could allow reconciliation and navigation of the competing interests among the F-E-W resources and the environment (Dalton, et al., 2019). National stakeholders coordination also must be established. Both the commetees of local and national levels need to align to incorporate community based activities, and facilitate a work plan implementation, frameoweks through national thinking.

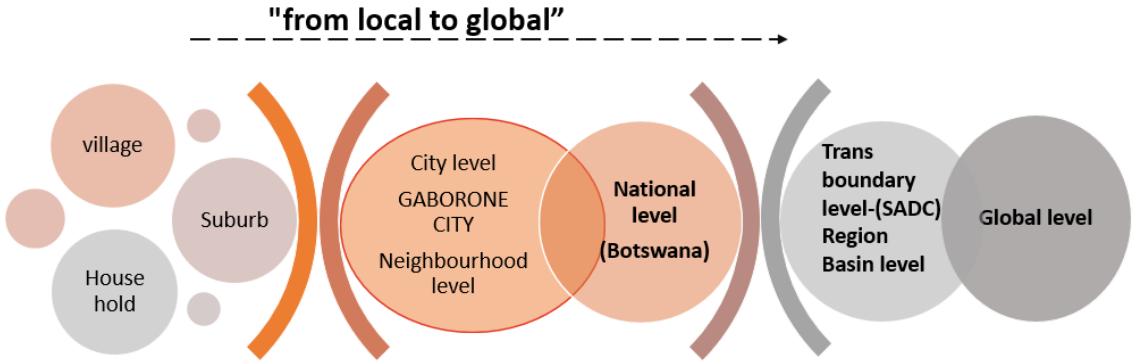


Figure 21: Demonstration of holistic components to be considered in the process of modeling(Source: Author's illustration)

4.3.3 Limited Education on The F-E-W Nexus

Developing countries could benefit from research on the securitisation of F-E-W resources to secure livelihoods. However, in Botswana, the idea is still new in the National Water Master Plan and has not been tested (BNWMP.,2017). For this reason, it continues to cause communities to approach F-E-W management in isolation to gain immediate needs. Therefore, analyzing and understanding the F-E-W resources is crucial to make informed decisions regarding their access, use, and allocation issues in communities. In addition, it is essential to comprehend the F-E-W resource interconnections and how they interact across the socio-political and environmental landscape, as it will assist in formulating enlightened decisions and policies. Therefore, future research needs to focus on integrated F-E-W governance to ensure the sustainable provision of resources and vulnerabilities like increasing variability in the context of climate change. Given the apparent expansion in the research agenda in Africa, Botai et al. (2021) state that an aspect not covered in the literature is the Integrative Environmental

Governance (IEG) theory which is suitable to bridge the disconnect between the F-E-W nexus output and the governance process. In this manner, Botswana's future research could be guided by such findings and proposals.

4.3.4 F-E-W Innovative Interventions

In this research report, I found that, Botswana needs to consider technologies and innovations that can strengthen and securitize F-E-W systems (Mabhaudhi et al., 2018). The government tends to prioritise unemployment, which drives decision-making on most occasions. The operationalisation of the F-E-W nexus is crucial, and if overlooked, it could result in missed opportunities for innovative interventions of nexus-oriented projects. An important factor is the capacity to measure and prove the resilience of the F-E-W system quantitively. Despite the continued and growing interest in Botswana's F-E-W nexus, technical interventions and recommendations remain vividly opaque from the socio-political perspective. In the national water master plan's action plan, a 'Nexus Element Technology and ICT-based Link Technology' is proposed to develop technology that will improve the F-E-W linkages, efficiency, and optimization to operate on an integrated decision support system. However, it still appears vague and opaque and not detailed to demonstrate how the technology will operate to achieve the nexus. It is essential to factor in ways to scale them up cost-effectively in applying technological solutions. Essentially, the extent of the adaptability of the digital solutions locally must accommodate even the remote rural areas. Hence, there is a need for a new national policy that integrates innovative technologies that can increase one resource without depleting the other (BNWMP.,2017).

4.3.5 Connecting The Dots: Integration of Social, Environmental, Economic, Perspectives for F-E-W Implementation

To achieve a holistic approach to addressing the F-E-W resources in Botswana, all aspects of the environment, society, and economy must be considered in implementing the nexus to achieve sustainable development. The elements comprise the three pillars of sustainability because they are not mutually exclusive but mutually reinforcing (Munasinghe., 2003). Therefore, the F-E-W nexus is instrumental to developing and monitoring the SDGs (Biggs et al., 2015). The insinuation is that all the social, environmental, and economic benefits are significant and justify the relevance of nexus-oriented technological projects (Mabhaudhi et al., 2018). The use of F-E-W resources reflects the nature of our social systems (Swatuk and

Cash, 2018). For instance, farmers encountering harsh and unpredictable circumstances may opt for a response that jeopardises the environment to satisfy their needs. To control such situations, holistic outcomes would be achieved if the policy formulation process utilizes the optimizing approach that considers all the socio-economic and environmental elements. Hence employing a nexus sensibility is vital, but without appropriate socio-political and socio-economic conditions, it will not function (Swatuk and Cash, 2018). Therefore, Botswana's Vision 2036 does reflect a direction towards achieving sustainable development by considering the sustainability elements.

Chapter 5: Recommendations and Conclusion

5.1 Introduction

This research report has discussed the implications of the conventional ways of managing and governing the food, energy, and water resources in silos, especially given that the three

resources are the most significant to human livelihoods. The traditional way of dealing with the resource sectors as separate entities creates a network of challenges where solving problems in one resource sector creates more problems in another. Regarding this, the F-E-W nexus has been proposed in most literature papers as a concept that can comprehensively address the resources to curb insecurities. Hence, in the concluding chapter, I summarise from the study the main aspects to be considered to implement the nexus concept in Botswana successfully. The research is not to solve the silo approach but rather to explore ways of transitioning from the conventional silos to a nexus approach which holistically deals with challenges of resource insecurities.

5.2 Recommendations

5.2.1 Structuring Nexus Framework Development in Botswana

The F-E-W nexus requires a decision support tool to analyze the F-E-W resources together (Nhamo et al., 2020). Botswana is still in its elemental stages of examining the nexus, given that the concept has only been briefly captured theoretically with no tests on the national water master plan. In the study, I investigated ways the DPSIR model can holistically and comprehensively assess the F-E-W resources to identify cross-sectoral linkages. Therefore from the DPSIR model, the responses to the pressures caused by the drivers are presented as components that could foster the F-E-W nexus(da Costa Silva, 2014). From the model, I discovered that the response components need to holistically consider nexus interactions coupled with environmental, political, economic, social, and technological aspects.

Considerations of the environmental, political, economic, social, and technological aspects are in alignment with the “5 Is” framework of five categories of nexus solutions developed by UNECE. The categories of solutions that account for Institutions, Instruments, Infrastructure, International coordination, and cooperation provide consolidated action steps of implementation on the ground. Therefore, comprehensively accounting for all these aspects and solution categories could inform the development of the nexus implementation in Botswana. Comprehensive nexus planning and management become manageable in this manner.

5.3 Bringing the F-E-W nexus to fruition in Botswana

5.3.1 Nexus Institutionalisation

Provided with the guidance of the framework development process, I delve into case scenarios of Botswana in bringing the nexus to fruition. In the country, the institutionalisation of organisations to facilitate the planning and management of F-E-W resources need to be established, as the existing ones are fragmented, still solving problems in siloes. As alluded to, a ripple effect of challenges is caused due to competing demands and trade-offs, exacerbating resource insecurities. It is important to place emphasis on the fact that in formulating and structuring F-E-W institutions, they have to be intersectoral, inclusive of all the vertical multiple levels of governance and engage all the mustiple stakeholders. For instance, institutions in Botswana, like the innovation hub, must be restructured to investigate nexus innovations and interventions.

5.3.2 Nexus Information and Knowledge Creation

As alluded to analysis of the status of the F-E-W resources in Botswana needs to be undertaken across all scales to understand their linkages. This entails that detailed resource data must be collected and shared with all stakeholders for improved assessments of trade-offs and identification of synergies in the country. In addition, the comprehensive data collection across multiple sectors could support integrated policy formulation and facilitate concrete implementation of the nexus on the ground. Knowledge creation opportunities also lie with the incorporation of academia in education facilities especially given that Botswana provides free education; nexus specialists could be capacitated.

5.3.3 Nexus Instruments

In Botswana, regulatory framework instruments are designed to be single entities, missing the value of integrating policies that govern F-E-W sectors. Investigations of ways to employ integrated approaches in the design and formulation of integrated F-E-W regulations need to be undertaken. Given that the Botswana is landlocked, and the national water master plan has only theoretically attempted to investigate the nexus concept, further investigations and tests must be conducted in local, national, and regional contexts. From the investigations, I have learned that at SADC regional level, has engaged in various consultations, workshops, and

dialogues held by SADC Water Division, SADC River Basin Organisation and Global Water Partnership in Southern Africa.

5.3.4 Nexus Oriented Investments

Investments from the government of Botswana must account for the impacts on both the built infrastructure on the natural infrastructure for sustainable operations. For instance, through the ISPAAD programme, the Botswana Ministry of Agriculture provides free seeds, fertilisers, and herbicides to farmers due to poor soils and the desert. Environmental impacts must be considered in terms of soil and water pollution. In contrast, investments in irrigation are still minimal, given the low annual rainfall. Water pumping systems for livestock and crop irrigation are still manually operated. This indicates a need to consider solar for pumping water. In addition, the government incurs costs in investments on grid electricity to supply power to the remote and sparsely located farms.

On a good note, progress in energy investments is seen in collaboration with Namibia to initiate a 2-5 gigawatt mega solar project to make the countries both net exporters of solar power. Moreover, the public-private biogas project needs to be scaled to contribute to the country's renewable energy. This scenario of infrastructure investments in Botswana indicates misalignments with tendencies to invest in the sectors separately. Moreover, it is significant to point out that the current practice of solely depending on the government’s support for budgets to operate the F-E-W resources limits economic growth. F-E-W nexus considerations provide business and local communities with development opportunities for the private sector.

5.3.5 International Coordination, And Cooperation

In efforts to achieve sustainability and mitigate climate change challenges, Botswana has committed to achieving the SDG and the Paris Agreement targets. The literature review has revealed that evaluating these goals in relation to the food, energy, and water nexus assists in establishing holistic approaches towards achieving sustainability and combating climate change. Therefore, it is important to place emphasis on the significance of Botswana engaging in these international coordination and cooperation efforts. Sharing lessons learnt, plans, and successful practices benefits the country.

5.3.6 Paving The Way Forward Towards The F-E-W Nexus in Botswana

An enabling environment must be created through a phased approach to initiate nexus thinking and practice (Meyer, 2019). To begin the process in Botswana, the relevant stakeholders, from public to private, across multi-sectors, need to be identified with the constraints affecting them. All the identified stakeholders, policy, and decision-makers must be exposed to learn and understand the usefulness of F-E-W nexus security for Botswana. It empowers and builds their capacity to gain skills and knowledge (ibid). With the acquired skillsets, the stakeholder and decision-makers should conduct local to global assessments using the bottom-up approach to draw lessons applicable to Botswana's context.

Contextualising the nexus is crucial because it varies how it applies to different contexts. Afterward analysing the sectoral policies currently governing the sectors is essential to depict cross-sector conflicts and benefits and inform ways to adapt them to be flexible and integrated with options to design context-relevant integrated policy frameworks (Meyer, 2019). Following the creation of such an enabling environment, mapping relevant nexus investment opportunities informed by findings from the investigations follows. Finally, action plans and programmes with clear timeframes over short, medium, and long term need to be developed to guide the stakeholders in formulating nexus solutions and projects.

Conclusion:

5.4 Taking the Unorthodox Journey towards Nexus Thinking in Botswana

Throughout conducting the research, I realised that the study could have expanded to quantifying the nexus resources to investigate their interactions in detail through qualitative methods. Having opted for the qualitative method, I utilized illustrations to visualize and demonstrate the theoretical descriptions of the qualitative approach selected for the study to advance my arguments. Further, limited research on the nexus pertaining to the context of Botswana is available. Additionally, due to covid 19 lockdowns, accessing policy documents was a hurdle, which made my investigations over-reliance on a F-E-W sector policies to source findings. However, beyond the limitations, below I discuss the conclusions drawn from the study and the future research agendas.

From the research, across all scales from local communities, national, and regional to the globe, the F-E-W resources are stressed and reaching their limits in time. At this instance, it is no longer news that the global population is continuously increasing, and the capacity to supply the extra population with F-E-W resource services is at stake. Moreover, it is beyond doubt that the nexus of food, energy, and water resources is complex and yet essential, given its capability to solve the numerous challenges people encounter. The nexus paradigm, having been advocated as an instrument that has the capacity to curb resource insecurities through holistic and comprehensive measures, requires a lot to be implemented. Moreover, the nexus as an academic construct will naturally expand as our understanding of the world's dynamic problem aspects increases. Still, it is unlikely that we will ever be able to draw its boundaries fully (Howarth and Monasterolo, 2017). Flexibility and change navigation become critical in this sense, for ease of adaptation in response to uncertainties.

In the context of Botswana, holistic scenario-based approaches conducting integrated analysis of the food, energy, and water policy frameworks are required. In addition, exploring integrated ways of governing and managing the resources in the face of climate change is essential. There is a need to develop a nexus road map for Botswana that will guide policymakers, private-public sectors, and stakeholders. The road map will direct them through a structured process towards the practical implementation of the nexus in the country. Identifying the current challenges and opportunities of implementing the nexus in the country is essential as initial assessments that will inform policymakers.

Subsequently designing, integrated analytical frameworks that will function as assessment tools to provide information about the current nexus status and interdependencies. The modeling process must be holistic and comprehensive in examining the nexus issues so that relevant data is collected to formulate informed and coherent policies. In the road map, detailed programmes of the practical implementation must be developed to implement relevant F-E-W nexus-oriented projects. Through collaborative approaches, stakeholders and investors could provide financial support that needs to be targeted toward these F-E-W nexus projects being implemented.

Overall, this study explored some aspects of the planning and governance of the F-E-W resources across scales to gain insight into how it can be implemented in Botswana. Given the complex scenario in Botswana, there is a need for an all-rounded comprehensive approach that

displays a hybrid character in addressing F-E-W resource challenges. The approach would be relevant if it is analytical and diagnostic of the F-E-W resource issues in the country's various dimensions and scales. Drawing towards a system thinking dynamic to deal with the F-E-W resources as systems interlinked with multiple systems can allow for a shift towards achieving sustainability in Botswana, provided a detailed and holistic analysis is carried out. In essence, the hybrid approach of utilising the systems thinking would offer more benefits for sustainable development. By way of scenario-based approaches to understanding various contexts in the country, conducting an integrated analysis of Botswana's food, energy, and water policy frameworks to explore how they are addressed could in consideration of climate change effects is an important requirement.

5.4.1 The research agenda

Due to the policy data collection shortfalls, the research does not discuss in detail issues of planning and management of the F-E-W resources in the context of Botswana. Despite this, the intent is to initiate future research agendas to set a platform to begin the nexus processes. Because nexus studies in Botswana are still minimal, and their elemental stages within the SADC region, detailed studies investigating a diverse nexus issue across scales are required. Studies concerning the linkages of the nexus concept to SDGs, and the Paris Agreement to achieve sustainable development and combat climate change are needed. This is particularly important because lessons could be drawn from the international engagements to guide integrated policy formulations in the context of Botswana.

Botswana needs to develop an enabling environment to operationalise the nexus successfully. Designing the integrated policy frameworks could be informed by nexus contextualisation to local settings, engaging with stakeholders operating on the ground. To build the capacity for implementing the nexus, there is a need for policy reforms, enhancement of institutional frameworks, and empowerment of key stakeholders and decision-makers through the provision of required knowledge and skills to advance along with the road map for the country.

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