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Understanding the Effects of Water and Energy Crises on Small-Scale Urban Food Systems' Resilience in Cape Town

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Abstract
This research examines the impacts of recent water and energy crises on small-scale food systems' resilience in Cape Town, South Africa. Small-scale food system activities are argued to be highly vulnerable to disturbances. However, there is limited research on how the sector is affected by interrelated water and energy crises, how resilient the diverse food systems activities are in response to such crises, and how crises can induce 'transformative' change across sectors. Through in-depth interviews with small-scale food actors in Cape Town, this research finds that underlying social vulnerabilities exacerbate vulnerabilities to water and energy crises and hinder the implementation of resilience strategies. The research also finds that the small-scale sector inhibits moderate transformative capacities in the form of innovations in farming practices. However, financial and institutional barriers hinder the successful implementation of more technological innovations. In order to increase small-scale food system resilience to water and energy crises, this research suggests that water, energy and food resources should be coordinated by local authorities, who can pay better attention to place-based attributes. Moreover, providing access to non-networked water and energy sources to small-scale actors is seen as a solution to current vulnerabilities. The research furthermore suggests that new conceptualisations of resilience would benefit from including nexus thinking to minimise trade-offs of sectoral resilience strategies.

Keywords: food system resilience; water-energy-food nexus; Cape Town; food security; transformation; innovation.

1. Introduction

Worldwide, crises in water and energy sectors are becoming more habitual, which has raised concerns over their potential impact on food security (Ruwanza et al., 2022). Water and energy are vital resources in the food system, and energy and water infrastructures supply every step of the agri-value chain (Gulati et al., 2013). Given the increase in disturbances of these interconnected resources, resilience has become an essential concept in finding solutions to more sustainable and crisis-proof food systems (Storm & Rahimifard, 2018).

Food system resilience can be defined as the "capacity over time of a food system and its units at multiple levels, to provide sufficient, appropriate and accessible food to all, in the face of various and even unforeseen disturbances" (Tendall et al., 2015, p. 19). Most resilience literature examines how systems can absorb negative consequences from disturbances and adapt to changing conditions (Meerow & Newell, 2019; Pelling et al., 2014). The focus is often on preserving the 'system' to ensure stable food supply. Little research has been conducted on the capacity of diverse actors in the food sector to enable systemic change, sometimes referred to as 'transformative capacity'. Moreover, food systems are often viewed internally, with little consideration of the transformative capacities of food actors to alter water and energy systems.

Food systems are globalised and highly interconnected, yet place-specific characteristics are important to consider in resilience assessments. Cape Town is an interesting case study, as it has not only faced endemic food insecurity, but it has also experienced perpetual water crises such as in 2017/2018; and is facing an ongoing energy crisis (Millington & Scheba, 2020; Ting & Byrne, 2020). Furthermore, Cape Town's food system is dualistic: it consists of a diverse (often informal) small-scale sector and a consolidated large-scale industrial sector, which rely on different infrastructures and differ in their scale and organisation (Du Preez et al., 2019). Cape Town's high levels of food insecurity are primarily driven by lack of access to food (Crush et al., 2018). Poorer Capetonians are most likely to be food insecure, and they rely on the informal small-scale sector to access affordable food (Battersby, 2011). It is thus crucial to understand and assess the differing vulnerabilities of different actors within such dualistic food systems - the relation to water and energy crises and how different actors adapt to them.

For example, agricultural and residential water use was severely restricted during the 2017/18 water crisis in Cape Town, caused by a prolonged period of drought and other interrelated issues (Millington & Scheba, 2020). As water levels dropped, the city projected a 'Day Zero' on 13 May 2018, on which all water taps were to run dry (ibid.). 'Day Zero' was ultimately avoided; nevertheless, the fear of running out of water again in the future lingers as impacts of climate change strain the nation's water reserves. Since 2007, Cape Town has also been experiencing a major energy crisis (DW, 2019). Power outages ('load-shedding') occur regularly, as the monopolistic state-owned energy provider Eskom has failed to meet increasing demand for electricity (Ward & Walsh, 2010).

The effects of water and energy sector crises on the food sector appear to be significant and highlight the interdependency between the three sectors. Such interdependencies have been a common concern in debates surrounding the water-energy-food (WEF) nexus (Gulati et al., 2013; Mabhaudhi et al., 2018). For example, disturbances in one sector can negatively - or potentially positively - affect other sectors, and thus some have called for more integrated forms of resource governance. However, to date, closer examinations of how water and energy crises impact the small-scale food sector in Cape

Town, particularly concerning the infrastructure systems that support food production and distribution, has not been sufficiently explored in empirical research. A crucial question of this paper is therefor to what extent the food sector depends on water and energy, and how resilient the diverse food systems activities are in response to crises.

'Crises' can offer unique snapshots into resilience, as responses to such threats and shocks often embody transformative capacity while simultaneously exposing critical vulnerabilities. Hence, due to the interconnectedness of the sectors, research on food system resilience intuitively requires also addressing water and energy resilience. The Western Cape Government has recognised this need and has implemented the *SmartAgri* framework in 2016, a roadmap to combat the impact of extreme weather events on the regions' agricultural sector (Western Cape DoA, 2016). It focuses on adaptation strategies and innovation, highlighting the 'resource nexus' as particularly important in improving food security. However, a 2020 evaluation report criticises its lack of understanding of climate-induced response strategies implemented by farmers on the ground (Farrell, 2020). The report argues that farm-level innovations need to be studied, as they represent learning opportunities for the sector at large.

Therefore, this research aims to understand the effects of recent water and energy crises in Cape Town on small-scale food systems and assess the response of different food actors to them. The central concern is identification of system vulnerabilities and analysis of barriers and opportunities to transformative capacities. This will give an implicit understanding of certain features of resilience, which impact food security in the city. The research aims to answer the following question: How resilient is the small-scale food sector to disturbances in the water and energy sector?

The paper is outlined as follows. The first section reviews literature relevant to this research, followed by the research design. The final section consists of the discussion of findings and the conclusion.

2. Literature Review

The following section elucidates the underlying theoretical perspectives of this research. First, a general overview of food system resilience debates is given, to then focus more in-depth on underlying vulnerabilities and capacities. Finally, debates surrounding the WEF nexus are combined with resilience thinking.

2.1. Food system resilience

Resilience thinking, which focuses on the capacity of social-ecological systems to deal with disruptive change, has gained prominence in recent academic debates and across various scientific disciplines (Meerow et al., 2016; Huck & Monstadt, 2019). Given the increasing intensity and severity of disruptions in the food system, food system resilience has emerged as a new sub-topic (Tendall et al., 2015).

In traditional resilience thinking, a resilient system is defined as one that can withstand disturbances and 'bounce back' to equilibrium (Folke, 2006). Holling (1973) divided resilience into engineering resilience and ecological resilience, two distinct categorisations that are commonly used today. The engineering definition emphasises the speed of 'bouncing back' to the state of equilibrium (Holling, 1973). The ecological definition on the other hand acknowledges multiple different equilibriums that the system can bounce back to (ibid.). Recent notions of resilience, also termed 'adaptive' resilience, emphasise the capacity of underlying systems, people and communities to learn from a disturbance and innovate to come back stronger than they were before (Tendall, et al., 2015).

Most resilience literature distinguishes between three capacities that need to be enhanced to achieve resilience outcomes, namely *absorptive*, *adaptive,* and *transformative* capacity (Meerow & Newell, 2019). Absorptive capacity is the ability of a system to buffer negative consequences of a disturbance while maintaining its function and 'bouncing back' to a pre-crisis state (Folke, 2006). In other words, absorptive capacity provides stability to the system (Brown, 2015). Adaptive capacity is the capability to proactively adjust or respond to changes to create more flexibility in the future (Pelling et al., 2014). Transformative capacity is the scope for providing an enabling environment to create systemic change when "ecological, economic, or social conditions make the existing system untenable" (Walker et al., 2004, p. 4).

Several scholars have applied resilience thinking to food systems, which are considered complex socio-ecological systems whose dynamics are determined by "a combination of physical, biological and socio-economic processes" (Godfray, et al., 2010, p. 2775). Food system activities can be categorised as production, processing, retail, distribution, and consumption (Ericksen, 2008). Tendall et al. (2015) define food system resilience as the "capacity over time of a food system and its units at multiple levels, to provide sufficient, appropriate and accessible food to all, in the face of various and even unforeseen disturbances" (p. 19). This definition adds a social goal to resilience: food security.

Food security is commonly defined as existing "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996). While there are many reasons for food insecurity, Battersby (2020) claims that it is primarily an outcome of failures or inefficiencies in the food system, rather than a shortfall in productive capacities. This draws attention to the underlying infrastructures that support food systems. The importance of the small and informal food sector in providing food security is often not accounted for (Battersby et al., 2016). Battersby (2020) argues that this is particularly problematic as those most vulnerable households and prone to food insecurity depend on precisely these small-scale food system activities. Incorporating food security in a food system resilience definition thus means it goes beyond preserving the existing system, to rather changing it to become more equitable.

Tendall et al. (2015) apply the three resilience capacities to the food system; however, compared to conventional definitions of resilience, they emphasise the importance of systems transformation. Such transformation is enacted through innovations (McClements et al., 2021), defined as new methods to solve existing problems in the form of technology, user practices, services, or business models (Smith et al., 2014).

The literature identifies several principles that may increase food system resilience. De Steenhuijsen et al. (2021), highlights diversity, agency, redundancy and connectivity as crucial. Diversity is understood as the ability of a system to compensate for a shortage with a surplus elsewhere, implying that more diverse farming systems have greater capacity to absorb disturbances, which stabilises food supply (ibid.). Agency refers to the ability of people along the food value chain to respond to shocks, which allows for anticipation and prevention (Ziervogel et al., 2016). 'Buffering', or redundancy, in food systems can mean relying on a variety of suppliers instead of just one, having spare land available when needed, or the creation of national food stocks (Bajželj et al., 2020). Connectivity refers to the "interconnection of and communication between actors and market segments" (De Steenhuijsen et al., 2021, p. 2). Mackay et al. (2020) add that flexibility, defined as the ability "to restructure existing capabilities and assume a different position or configuration towards mitigating the magnitude of disruptions" (p. 1550), is key to achieving resilience.

2.1.1. Underlying capacities and vulnerabilities

Resilience capacities depend on the underlying social conditions (income levels, access to other resources, etc.) and capacity to innovate (ibid.). Following Dolata's (2009) research, exogenous changes can also influence the transformative capacity of sectoral structures. Moreover, there are often multiple food chains and scales of farming that serve diverse populations, for which the level of transformative capacity may not always be the same.

De Steenhuijsen et al. (2021) furthermore underline the often-overlooked adverse effects of socio-political differentiation and economic inequality on food system resilience. They contend that "monopolies by big private sector players, at the expense of a multitude of smaller players, have a potentially negative impact on the overall resilience of food systems." (p. 3). Big corporations can thus "shape markets, shape technology and innovation agendas, and shape policy and governance frameworks" (p.3). A case in point is the dualistic food system in South Africa.

Due to deregulation and liberalisation, the South African agricultural sector is becoming increasingly centralised, and a small number of large-scale farms dominate the farming landscape (Greenberg, 2019). Legislation tends to favour corporate interests and capital-intensive production models, and the concentration of power is largely enjoyed by a few private actors of approximately 37,000 large-scale farms and a small number of processors and retailers (Boermann, 2019). This has led to what Greenberg (2017) calls the 'era of a corporate-led food regime', in which large corporations and farmers with high annual turnover have concentrated political and economic power.

Parallel to this is a fragmented 'broad periphery' of small-scale farmers (more than 2 million) who rely on informal infrastructures such as township markets, street vendors and informal seed trading schemes (ibid.). Their power is rather dispersed and weak, and despite this sector's critical importance for food accessibility (especially in low-income areas), it has been widely neglected in agricultural policies as it is deemed in need of modernisation (Charman et al., 2019). The informal food sector is also crucial for generating employment, as it is usually labour-intensive and does not benefit from the same degree of mechanisation as the large-scale sector (Cousins et al., 2018). Furthermore, small-scale producers face difficulties accessing the formal market, as they often cannot meet the high production standards and because large corporations are actively hindering their access (Battersby et al., 2016).

The unequal access to land, infrastructures, and markets in the food system translates into actors' ability to access other resources, such as water and energy. According to some researchers, large-scale producers in the food system have a tighter connection with the government and can leverage their influence, evidenced in water allocation strategies, for example (Greenberg, 2019). With the small-scale sector mainly operating in the informal sphere, little is known about the transformative capacities of the small-scale food system to cope with interrelated WEF crises.

Linked to the diversity of underlying social conditions and the dualistic nature of the South African food system is the issue of 'vulnerability'. An important concept in resilience debates, vulnerability is commonly defined as the degree to which a system, community, or person, is susceptible to shocks and stressors (Proag, 2014). It implies the possibility of risk occurrence and the uneven severity and intensity of how such risks are experienced. Proag (2014) argues vulnerability is dependent on the availability of resources, and the capacity to use them.

Regarding the food system, this characterisation implies that the large-scale sector is less vulnerable to disturbances. However, some research suggests that consolidated and concentrated food systems are more vulnerable to stressors such as droughts. Tibesigwa et al. (2017), for example, find that despite the favourable political and economic position of large-scale farms in South Africa, they are "equally vulnerable to climate change" (p. 607) compared to their small-scale counterpart. This is especially due to this sector mainly growing profitable monocultures instead of practising mixed farming (Thow, et al., 2018). However, when it comes to disturbances or uncertainties in the food value chain, the large-scale sector has more resources to invest in alternative infrastructures and create redundancy, for example by storing large amounts of water or investing in renewable energy such as biogas (Makwela, 2017). Conversely, small-scale farmers tend to rely on mixed-farming methods, which have less long-term vulnerabilities to changing environmental conditions, but they typically have limited resources to invest in innovative alternative infrastructures (Tibesigwa et al., 2017). Thus, some scholars argue that the monopolisation of the food system and the predominance of crop monocultures disturbs the system's capacity to withstand shocks and build resilience in the long-run (Bormann, 2019; Cousins, 2013).

As the above review shows, system vulnerabilities are mainly researched in terms of internal shocks and stressors, whereas vulnerabilities to shocks and stressors in external sectors (such as water and energy) are rarely considered. Furthermore, while a large body of literature discusses the negative effects of shocks on systems, there is limited literature on positive effects and how they induce 'transformative' change across sectors. It is therefore crucial to consider transformations in other sectors for the resilience of a given sector.

2.2. Water-Energy-Food (WEF) Nexus

To achieve food security, WEF nexus literature argues that water and energy security must be achieved simultaneously. WEF resources are highly interlinked: water is needed for irrigation and energy extraction and consumption, while energy is needed to irrigate land, extract water, produce fertilisers, and fuel transportation, packaging, processing and disposal, and biomass is used for energy production (Gulati et al., 2013) (Figure 1). Scholars argue that the management of the WEF resources has been historically characterised by sectoral approaches and isolated policy responses, which undermine the complex relationships between sectors and resource systems and lead to inefficiency in their uses (Hoff, 2011). Thus, nexus literature advocates for an integrated approach in which the systems are considered interdependent (Mabhaudhi et al., 2018).

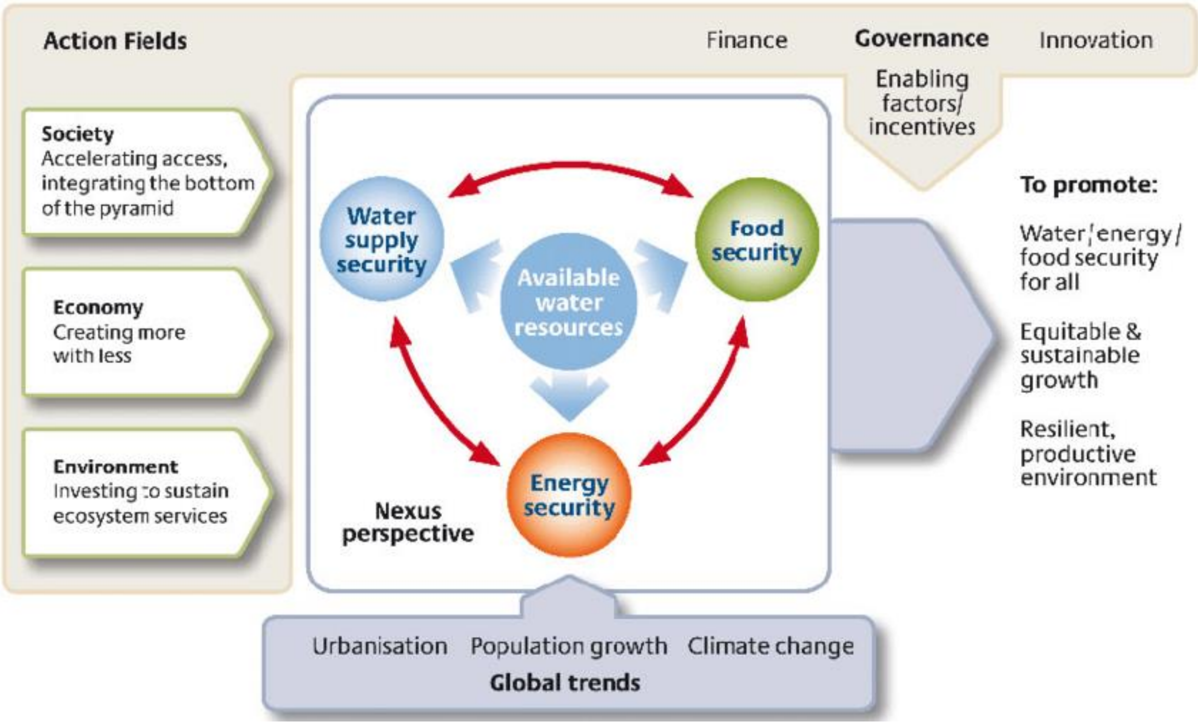

Figure 1 The Water-Energy-Food Nexus framework by Hoff (2011)

There are urgent challenges for WEF resource management such as meeting conflicting objectives without compromising the resource base of any sector. Adopting a WEF nexus approach may mitigate trade-offs and unintended consequences by maximising synergies, increasing resource use efficiency, and improving governance mechanisms (Bazilian et al., 2011). Considerable policy focus is placed on WEF security as a desirable outcome, wherein security encompasses supply and stability of and access to WEF resources (Stringer et al., 2014). Thus, WEF nexus framings have considerable overlap with resilience thinking, as both draw on systems thinking for conceptualising interlinkages across socio-ecological systems (Leck et al., 2015).

While there are no universally agreed-on indicators or measurements for successful WEF nexus implementation, some authors have used case studies to identify context-specific nexus links. Case studies are typically framed from the perspective of one of the three resources, and some use qualitative evaluation methods (Hoff et al., 2019; Leck et al., 2015), while others adopt quantitative or mixed methods (Seeliger et al., 2018; Ding et al., 2019; Ozturk, 2017).

Ding et al. (2019) conducted empirical research on WEF nexus management in Cape Town. The authors test different WEF approaches to the 2017-2018 water crisis by comparing a business-as-usual (BAU) scenario with a holistic-adaptive management (HAM) scenario. The BAU scenario means no action is taken to confront the water crisis, whereas the HAM scenario means raising water tariffs in case of dripping water storage levels. They conclude that implementing increased water tariffs can be a successful adaptive strategy to combat loss in agriculture. They also conclude that implementing water tariffs will hit poor and lower-middle-class residents the hardest, while more affluent residents can afford increasing prices (ibid.). This solution does not consider equitable access to water under conditions of scarcity.

Technological innovation, next to integrated governance, is a recurring concept in nexus literature and is frequently suggested as a key tool to achieve WEF nexus implementation, leading to positive resilience and sustainability outcomes (Mabhaudhi et al. 2018). Applying this to food systems, Botai et al. (2021) argue that a lack of innovation may even hinder the implementation of WEF nexus agendas that would allow the production of more food with less energy and water resources. Thus, innovation is said to moderate food insecurity impacts. Scholars have identified the importance of stakeholder involvement in implementing technological innovation, as the measures may otherwise fail to address the issues that local people consider most urgent (Rasul & Shamra, 2016). Hoolohan et al. (2018) argue that innovation tends to be localised, which is why it is essential to understand how agency among actors is distributed and exercised.

There are different schools of thought on how this can be achieved when it comes to implementing nexus approaches. While one focuses more on integrated governance (Weitz et al., 2017; Bielicki et al., 2019), another one is focused on synergistic technologies and systems (Govidna & Al-Ansari, 2019; Núnez-López et al., 2021). However, what role differentiated actors across complex food systems can play in water and energy innovations is poorly understood.

While WEF nexus literature is still growing and evolving, some scholars have identified gaps and shortcomings. The most common critique is that it is too theoretical and lacks practical application (Leck et al., 2015). Research on the interconnectedness of the food sector with the water sector is more advanced as compared to the energy sector, a research gap that has also been identified by Purwanto et al. (2021). Another potential limitation is that most WEF nexus literature does not explicitly mention resilience. However, the two concepts have been acknowledged as overlapping and complementary (Stringer et al., 2014). The following section therefore elaborates on the connections between resilience (specifically that of food systems) and the WEF nexus, particularly how transformative capacities are crucial in both agendas. This discussion is used as a basis to develop a conceptual framework that will be applied in this research.

2.3. Combining food system resilience and WEF nexus thinking

While the nexus approach is mostly normative, resilience thinking focuses on the ability of systems to learn from the past (Stringer et al., 2014). A resilient system could therefore be described as the desired outcome of successful WEF nexus implementation. Combining the strengths of nexus and resilience approaches enables assessments of how resilience is affected by cross-sector interdependencies (such as 'synergies' or 'trade-offs'). Stringer et al. (2014), however, contend that both perspectives must also consider questions of justice and equity. This perspective provides key insights into issues of cross-sectoral power and agency to actually build resilience, such as the ability of actors to make choices for more resilience outcomes. This is particularly important considering the dualistic South African food system, where power is not distributed equally among actors.

Furthermore, nexus frameworks are focussed on the interdependencies between sectors whereas resilience often focus on single challenges in 'complex' systems. By examining the impact of stressors and shocks originating in energy and water sectors on food systems, we can help to unpack the nature of such interdependencies, and the unevenness of underlying vulnerabilities in relation to those connections. Nationally, the impact of stressors and shocks in water and energy on food security is widely discussed. However, there is a gap in the literature concerning 'transformative' capacities in complex food systems at urban scales and how urban actors in food chains can innovate in water and energy systems.

In both resilience and WEF literature, resource security is a key concern. From a resilience perspective, availability and access to all three resources is considered crucial, even in the face of disturbances (ibid.). The WEF nexus approach adds a potentially valuable perspective on how transformative action to increase resilience in one sector, may alter system dynamics of other sectors (Dolata, 2009). As Rasul & Sharma (2016) put it, “sectoral adaptation strategies can increase vulnerability or undermine net resilience by decreasing capacity or increasing risks in another place or sector, resulting in maladaptation” (p. 683). Building innovations/technologies that have mutual benefits for all sectors is key to avoid trade-offs and unsustainable sectoral practices. Thus, a focus on infrastructural innovations is crucial as it enables an assessment of how food systems can transform and strengthen the systems’ capacity to withstand further disturbances.

3. Research Design

3.1. Conceptual Model

Following from the above discussion, I developed a conceptual model (Figure 2) which demonstrates the practice and conceptual interlinkages between the food, energy and water sectors in terms of resilience.

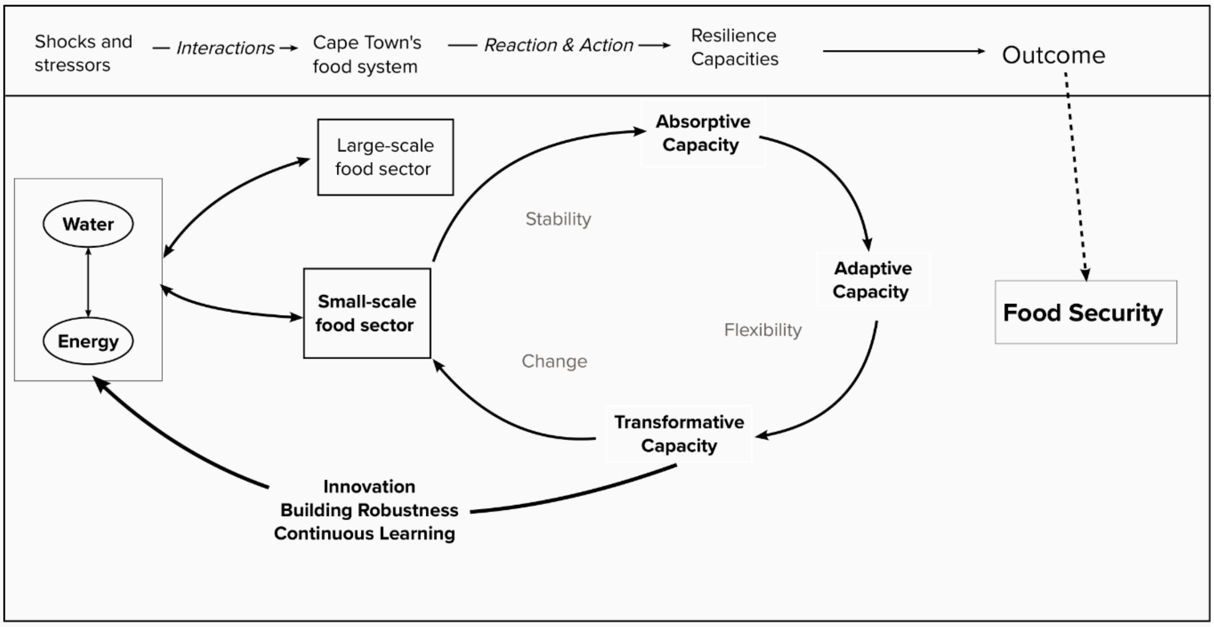

Figure 2 Conceptual Model

The model illustrates that water, energy and food sectors in Cape Town interact with each other; hence shocks and stressors in water and energy are assumed to affect the food system. The food system is divided into large-scale and small-scale sectors, which are assumed to be affected differently and have different underlying vulnerabilities and resilience challenges. How actors in the food system react and act to disturbances depends on their resilience capacities. Reacting thereby refers to the capacity to absorb negative consequences of shocks, which provides stability (Brown, 2015). How actors act is, in turn, determined by their adaptive and transformative capacities, which provide flexibility to the system and enable change (Pelling et al., 2014; Walker et al., 2004). The resilience capacities, specifically transformative ones, thus determine the ability of the small-scale food sector to innovate in water and energy sectors, build robustness and learn from disturbances. Consequently, due to the sectors' interdependencies, future food (in-) security depends on the food sector's resilience to crises in the water and energy sectors.

3.2. Methodology and Case Study Selection

The research used qualitative research methods. Following a review of the academic literature and literature on water, energy and food in Cape Town, the first major methodological step was to conduct a 'grey' literature review (newspaper articles, reports). This review was specifically conducted to identify the impacts of the recent water and energy crises on food systems activities. The second step was to map the activities and flows of Cape Town's food system to identify food flows and key stakeholders, who were subsequently contacted. This stakeholder mapping exercise was conducted in collaboration with Western Cape Economic Development Partnership (WCEDP), an important civil society organisation in Cape Town linking many food initiatives. The third step was to conduct 17 key-informant interviews with farmers, practitioners, civil society organisations and academics involved in Cape Town's food system (Appendix I). The interviews were conducted online via Zoom or Microsoft Teams using semi-structured interview guides. The guides are based on the output of previous research steps and were continuously adjusted to new findings. The limitations of the methodology mainly relate to the global COVID-19 pandemic. Travel restrictions meant that participant recruitment and interviews had to be conducted online. This has impeded the research process, as not being able to recruit participants in person decreases the degree of randomization of the study population.

3.3. Case study selection

I chose to focus on the small-scale food production and distribution activities as a case study. From the mapping exercise described above, three case study sites were identified for deeper investigation: the Philippi Horticultural Area (PHA), Khayelitsha, and the Cape Town Fresh Produce Market (CTFPM). The PHA, a large agricultural area, is an interesting case study as it produces more than half of all vegetables consumed in the city every day (PEDI, 2016). Medium-scale farmers mainly farm the PHA, but there are also significant informal small-scale farming activities (PEDI, 2016). Khayelitsha, an impoverished township where various informal small-scale farmers and distributors operate, adds valuable insights into the realities of urban food systems and makes for more representative case studies. The PHA and Khayelitsha were chosen based on their crucial role in small-scale production activities and providing food security to poorer households. The CTFPM, a large distribution centre, was chosen because it is an important interaction node between small-scale and large-scale production and distribution activities. While the majority of its activities include large-scale producers and distributors, 40% of the markets' clientele are small-scale distributors, spaza shops and street vendors (Haysom et al., 2017). It must be noted that the case studies solely deal with the production and distribution of fresh produce, which excludes other agricultural value chains.
The aim of this research is to examine the impacts of the water and energy crises on food systems resilience. Concerning how those crises were defined, the '*water crisis'* is considered as the period between 2017 and 2018, in which water levels in Cape Towns' dams dropped to critical levels (close to 10%) due to a prolonged drought (Millington & Scheba, 2020). As this led to fears of running out of water, the city introduced high water tariffs, restrictions and rationing for its residents, also affecting agricultural use (Ibid.). The water crisis is rooted in the meteorological drought that started in 2015 and a long history of failures in water governance of post-apartheid South Africa (ibid.).

The energy crisis is considered the period from 2007 until the present, as this is when widespread and regular power outages, commonly called load-shedding, started (Ting & Byrne, 2020). The monopolistic state-owned energy provider Eskom, which generates approximately 90% of South Africa's electricity (mainly from coal), has failed to meet increasing demand for electricity (ibid.). A combination of mismanagement of existing power plants, skills shortages, lack of critical infrastructure repairs and investment, and political unwillingness have led to the current energy crisis (ibid.). Given these interrelated challenges on the case study locations, several aims and objectives for this research were developed, which are outlines in the following section.

3.4. Aims and objectives

The subsequent analysis is guided by the conceptual model and the following research objectives:

- To offer insights into the Cape Town food system and identify resilience challenges;
- To assess the impacts of the water and energy crises on the small-scale food sector in Cape Town;
- To identify the adaptive capacity of food actors in response to the energy and water crises;
- To identify the water/energy infrastructures innovations in food systems and barriers to uptake in the small-scale food sector.

4. Results and Discussion

The following sections outline the findings of this research. First, the nature of the Cape Town food system is described, particularly the dependence of small- and large-scale food supply chains on water and energy infrastructures, to understand in which ways resilience challenges materialise. Second, the impact of water and energy crises on small-scale food production and distribution is outlined. Third, the resilience capacities of the small-scale sector are assessed.

4.1. The Cape Town food system, resilience challenges, and interdependencies between water, energy and food

Based on reviewed literature and stakeholder mapping, the following section describes both large-scale and small-scale food systems and their dependence on water and energy infrastructures, which enables the identification of resilience challenges across the dualistic food system. Subsequently, I focus on the interactions between WEF resources in the small-scale sector, an analysis which is currently lacking in the literature.

4.1.1. Mapping Cape Town's dualistic food system

The Cape Town food system relies on various infrastructures along its supply chain, including but not limited to electricity, water, roads and rails. Electricity is used for cold storage, water pumps and machinery; water is also needed for the cold chain, watering crops and cleaning. Roads and rails are important infrastructures for the transportation of agricultural produce. Figure 3 presents a simplified depiction of the city's food system, as conducted with WCEDP. This diagram shows that production is mainly carried out by three types of farmers: subsistence, small-scale and large-scale commercial. Concerning the large-scale sector, a small number of large-scale producers dominate the market, who are highly industrialised and resource-intensive, are geared towards processing and exporting. Produce that is not exported goes to wholesale and distribution centres such as the Cape Town Fresh Produce Market (CTFPM). Large-scale farms are mainly situated on the fringes of Cape Town, and surrounding regions, where they have access to a sophisticated logistics network and infrastructures along major roads and agri-processing plants (WCEDP, 2021). Most large-scale producers do not rely on the municipal water supply system, rather they have private dams or boreholes (Greenberg, 2019). Given the optimised value chains and large quantities of products handled in the large-scale sector, it is energy intensive. It is furthermore highly consolidated and represented by powerful farming organisations, who are reported to influence government decisions (ibid.). Furthermore, due to its crucial role in job creation, food supply and economic growth, it benefits from governmental support (WCEDP, 2021).

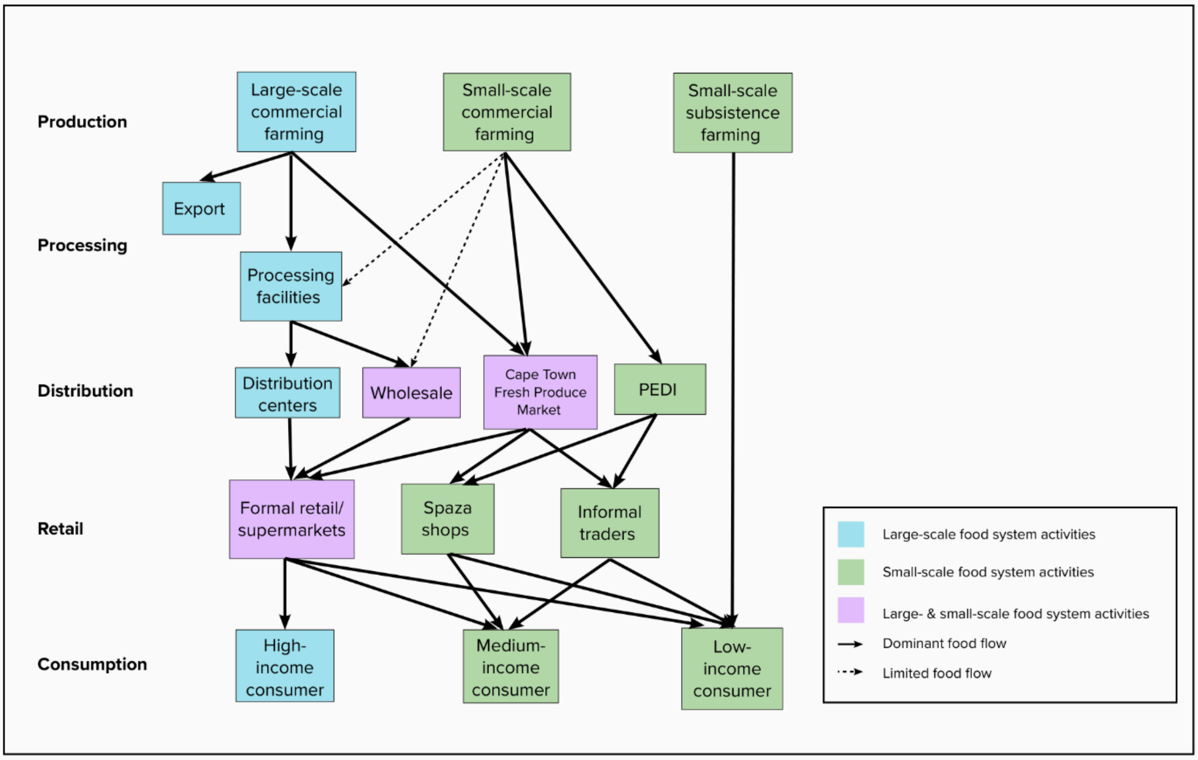

Figure 3 Simplified Cape Town food system

The small-scale agricultural sector in Cape Town on the other hand consists of many smaller producers who supply both informal and formal markets. Small-scale producers in Cape Town are not uniform, rather they differ in size, locality, output and access to key infrastructures (Battersby-Lennard & Haysom, 2012). Small-scale farming activities occur all over the city, however, they are concentrated in certain special zones, most noticeably the PHA. Farmers on this large agricultural area of 3,600 hectares, also nicknamed the 'breadbasket' of Cape Town, sell approximately 80% of their produce to retailers, 12% to the CTFPM and the rest is being sold to informal traders or consumed directly (Battersby, 2020). The PHA is situated on top of the Cape Flats Aquifer, a critical water resource and natural habitat for the city. The PHA is also said to depress food prices in Cape Town due to its central location and low transportation costs (Haysom et al., 2017). Such areas are found to mainly source water from municipal water supply or groundwater resources. Most producers in these areas do not have access to electricity, and those who do get it from Eskom.

Located in the Philippi area is the Philippi Economic Development Initiative (PEDI), an organisation that aims to become an agri-processing hub for small-scale farming activities in and around the PHA (PEDI, 2016). The organisation, which is supported by the CoCT, buys produce from farmers, processes some of it and sells it at affordable prices. Despite supermarkets being the most commonly used source of food; small-scale food systems activities are key for food security of especially poorer Capetonians, who often cannot afford the large quantities sold at formal markets (Charman et al., 2019). Informal distributors, who are largely unregistered, have more accessible opening hours, and give low-income consumers the chance to buy on credit (WCEDP, 2021).

4.1.2. Resilience challenges

The mix of formal and informal food flows is argued to provide flexibility to the system which is important for mitigating the magnitude of disruptions (Mackay et al., 2020). Consumers can buy from a range of formal and informal food retailers and thereby maximise their potential of food security through exercising agency with their purchasing power. However, many poorer Capetonians are excluded from buying from the formal market, which is why the corporate consolidation of the food system and proliferation of supermarkets are likely to present critical resilience challenges: diversity and flexibility decrease; and inequality across the food value chain increases (Charman et al., 2019). Extreme income inequality means that some are more vulnerable to shocks; and those more vulnerable are highly dependent on the small-scale informal food sector.

The large-scale retail sector inhibits the critical feature of redundancy as it sources from multiple producers and distributors (even outside of Cape Town), meaning that it holds additional resources in reserve to deal with disruptions (Greenberg, 2017). The small-scale sector, on the other hand, predominantly relies on local production and distribution. Thus, understanding how the small-scale sector is affected by disruptions in water and energy supply is key to increasing resilience in the long-term and providing food accessibility for disadvantaged Capetonians.

4.1.3. Interactions of Cape Town's small-scale food systems with water and energy sectors

Based on the review of grey literature, water was found to be the most important resource for farming. Water is used for irrigating crops, which must be done during relatively cool times of the day (morning or evening) – as it otherwise evaporates before entering the soil. Additionally, based on interviews with farmers and agricultural organisations I found that depending on their location, farms rely on different types of water sources. In Khayelitsha, for example, farmers were found to have boreholes to access groundwater, which are often shared with other farmers in the community. Conversely, despite being situated on the aquifer, smallholder farmers at the PHA reported that they did not have access to boreholes. Rather, as one interviewee described, "*in order to get water into these communities, the City of Cape Town runs water supplies to where people can go and fill buckets with water*" (Interview 16). Interviewees in the PHA expressed interest in acquiring boreholes; however, they face financial barriers. Furthermore, boreholes require electricity to pump water, and most small-scale farmers at the PHA are not connected to the energy grid. In Khayelitsha, farmers have access to electricity from Eskom, however, it is expensive and thus used sparingly.

The CTFPM is highly dependent on both water and energy for conducting its daily operations. The market "*utilises upwards of 100.000 litres of water per day to operate its cold room facilities alone, which does not include cleaning and public use*" (Interview 15). Electricity is needed to operate computers, cold rooms, lights and machines. Conversely, small-scale distribution activities at the CTFPM are less dependent on water and electricity, as they do not have storage capacity or cold rooms, but rather buy and sell produce on the same day.

4.2. Understanding the impacts of the water and energy crises on food systems

Based on the review of published news articles and reports, as well as interviews with key food actors, the following section assesses the impacts of the water and energy crises on small-scale production and distribution activities. This provides insights into WEF interactions and critical vulnerabilities of the system.

4.2.1. Categorising energy and water impacts on food

Besides directly affecting water and electricity availability, the crises were found to affect the small-scale food sector in many other – often interlinked – ways. Concerning the severity of impacts, interviewees at the case study locations indicated that this depended largely on the source of energy/water connection. Smallholder farmers in the PHA, for example, reported that they were not affected significantly by the water crisis in 2018 in terms of production loss. This is because the municipal water they rely on was not restricted – contrary to other areas in Cape Town. And since the municipal water was ultimately not restricted, farmers did not lack water supply at any given time. However, it was also found that the low humidity and lack of rain caused damage to some crops and increased working hours, as crops had to be watered more often (Interview 5, 7).

Interviewees in Khayelitsha with farmers using boreholes revealed that they had to stop farming for up to two months in 2018 during the crisis, as their boreholes broke down or ran dry due to low groundwater levels. In terms of energy, smallholder farmers at the PHA reported that they did not directly feel the impacts of load-shedding because they are not connected to the grid, whereas farmers in Khayelitsha were affected due to their connectivity to those systems. Food retailers and distribution centres also reported that they were affected by the energy crisis. Triangulating data from news reports, grey literature and interview responses, the individual 'impacts' were categorised into six key themes, namely 'economic, 'infrastructural/technological availability', 'daily farming practices', 'product quality/food safety', 'environmental' and 'social impacts'. An overview is provided in

Table 1.

Impact	Water Crisis	Energy Crisis
Economic	○ Decimated yields, leading to long-term loss-making (Johnston, 2018) ○ High water tariffs, quotas (Walker, 2018) ○ Farmers facing foreclosure (Chutel, 2018) ○ Increased expenditure on irrigation management and feed (NDMC, n.d.) ○ Farmers have to buy produce from elsewhere instead of producing it for own consumption, impacts livelihood (Interview 9)	○ Farmers can only use electricity during certain times, if they use it during peak times, they face high penalty tariffs. Peak times often coincide with usual watering times in the morning and late afternoon (Tom, 2020). This leads to disturbed irrigation schedules (Smith, 2019) ○ Farmers must invest in diesel-powered generators, and as diesel prices are higher than average electricity costs, this increases production costs (Deign, 2020; Tom, 2020) ○ Inferior products with lower prices and margins (WWF, 2015) ○ Food Waste (Interview 10) ○ Businesses cannot operate during load-shedding and lose customers (Interview 16)
Infrastructure/technological availability	○ Low water levels in boreholes, shallow boreholes emptied quickly (Interview 10)	○ Damaged equipment and machinery (especially if farmers do not receive advanced warnings) (CBN, 2019) ○ Disrupted cool chain (refrigerators etc) leads to food waste (WWF, 2015)

		○ Cable theft during load-shedding (Interview 5, 10) ○ During load-shedding, water pumps do not work (for those who have boreholes) (Interview 8-10) ○ Solar panels often do not work when load-shedding occurs, as the meter requires electricity from an external source (Interview 16)
Daily farming practices	○ Water restrictions of up to 85% for agricultural use (Goudriaan, 2019) mean farmers have to adapt their watering schedule ○ Farmers prioritise crops with higher profit margins and choose to abandon vegetables and other crops (WWF, 2018) ○ Farmers cut production, irrigate only small parcels of land (Walker, 2018) ○ Interruption of farming practices for several months (Interview 8-10)	○ Altered watering schedule due to electricity availability (Interview 8-10) ○ Absence of electricity can put farmers behind harvesting schedule (Smith, 2019) ○ Petrol stations cannot pump fuel during load shedding, delays transport (City of Cape Town, 2021) ○ Lost trading hours (Hedley, 2015) ○ Uncertainty and unpredictability of load-shedding makes planning daily farming practices difficult (Interview 8-10) ○ Filling up water tanks outside of load-shedding hours is time-consuming (Interview 8-10)
Product quality/food safety	○ Low product quality, sunburned or smaller (Walker, 2018) ○ Food processing facilities and distribution/retail centres must find alternatives to sanitize surfaces and hands (Smith, 2019)	○ Crop damage ○ Decreased shelf life of products due to interrupted cool chain (Interview 5,7,8)
Environmental	○ Poor soil quality due to elongated drought and low humidity (Johnston, 2018) ○ Pests and diseases (Enca, 2018; Interview 6, 8)	
Social	○ Unequal access to water, water allocation (Chutel, 2018) ○ Large-scale unemployment and social unrest (Johnston, 2018; Parks et al., 2019) ○ Inflation, rise in food prices is exacerbated by weaker Rand as prices of imported commodities increase (PMA, 2017).	○ No streetlights mean less safety for farmers when they go water their crops at night (Interview 5-10) ○ Safety concerns when people use open fire in their shacks during load-shedding, many have burnt down in the past (Interview 5-10)

Table 1 Impact of Water and Energy Crises on Farming Activities in Cape Town

The following examines each categorised impact in further detail. Reduced water and energy availability was found to have *financial and economic impacts* on some actors in the small-scale food sector. For example, water shortages lead to decimated crop yields, meaning affected farmers sold less produce and thus had a reduced income. As one farmer from Khayelitsha explained:

"Income was reduced. Because we now didn't have the extra income to maintain our livelihoods. And our lives also got affected because for me, I always eat from my farm. So now I had to go out and find food, had to spend money to buy food where before I just didn't spend money on vegetables, I would get them from my farm." (Interview 8).

For the CTFPM, the lack of fresh water, high water tariffs and quotas have also caused significant financial losses. Large producers preferred selling their best quality produce to large retailers directly *"who could handle their produce more efficiently and have more modern infrastructure that requires less water"* (Interview 17). Consequently, small-scale distributors who buy and sell at the market received lower quality produce with lower profit margins, which led to financial losses (Interview 15).

Due to increasing energy prices, farmers faced high penalty tariffs if they used electricity during peak times, which often coincided with usual watering schedules (and the pumping required for such irrigation) in the morning and late afternoon (Tom, 2020). The interviewee from the CTFPM noticed that reduced buying power from small-scale businesses has affected the market:

"The main impact of the energy crisis on the market is perhaps that […] 40 percent of our clientele, small distributors, struggle when there is load-shedding which in the end affects their buying power at the market." *(Interview 15).*

Infrastructures and technological availability are also a major impact. This refers to all supporting networks, systems, equipment, and technologies needed to perform agricultural practices (Hecht et al., 2019). In particular, water pumps were found to not work during load-shedding, disrupting water supply.

There was also found to be negative effects of the water and energy crises on *daily farming practices.* Restricted water use, together with load-shedding, meant that farmers were often forced to adapt their watering schedules to times when the resources are available. Farmers stated that they often water in the middle of the night when electricity is cheap and available; and temperatures are low enough for crops to be irrigated.

Both the water and energy crises also affected *product quality and food safety.* Crops became degraded and lower quality due to sunburn, for example (Walker, 2018). Load-shedding was reported to have interrupted cool/cold chains, which led to decreased shelf life, and food safety was no longer guaranteed (Interview 15).

The water crisis furthermore was found to have had *environmental impacts*. The elongated drought and low humidity caused poor soil quality (Johnston, 2018). As a result, soil was less productive, and an increase in pests and diseases was noticed (Interview 6). This is expected to have long-term consequences for farming in Cape Town (Enca, 2018).

Other knock-on effects are of *social* nature, including *safety* concerns. Lower crop production means that fewer workers are needed, which is said to lead to large-scale unemployment and subsequent social unrest in agricultural areas (Parks et al., 2019). Furthermore, crime rates are reportedly higher when streetlights are out at night, which means less safety for street vendors and farmers who have to water their crops at night. One farmer explained:

"It's also not safe in our community during this load-shedding when we don't see people sitting in the corners. You don't know who's coming next to you in front of you. And then they take chances. Because it's dark, you can't see them." (Interview 8)

The multiplicity and severity of impacts of the water and energy crises on the small-scale food system show how highly interdependent these systems are in Cape Town. Interactions between water and food were found to be considered the most important for interviewees, as crops do not grow without water. Given the limited connectivity to energy infrastructures across the small-scale food system, fewer information was found concerning food-energy interactions. For those who have access to electricity, it was reported to almost exclusively be used for powering water pumps, as other energy-intensive technologies were not used on the case study locations. Financial constraints and insecure land rights were reported as reasons for lack of access to energy infrastructures (Interview 12).

Summarising the above findings, impacts can be broadly distinguished as either into primary (direct) or secondary (indirect) impacts. Primary impacts are more predictable, events that directly disrupt the functioning of food systems. Low water levels in boreholes, high water tariffs, disturbed irrigation schedules and disrupted cool chains are all examples of primary impacts that affect food system actors independently of their socio-economic background. However, these direct impacts materialise differently across the food system, depending on how connected the activities are to the respective systems.

Secondary impacts, however, are indirect effects of the crises exacerbated through marginalisation, socio-economic inequality, and lack of access to markets and infrastructures. This exposes underlying vulnerabilities of small-scale food system actors. For instance, small-scale farmers' livelihood depends on their farms' output, and when crises in water or energy interrupt production, they do not have the flexibility to access alternative food sources (such as the formal market). Their household income is thus vulnerable to water and energy crises. Heightened safety concerns and crime rates during load-shedding are other secondary impacts that occur due to precarious living situations in marginalised areas such as the PHA and Khayelitsha.

This shows that not only are the WEF resources highly interlinked, but they are also connected to social, economic, and environmental systems, a finding that needs to be considered in their governance. Given this interconnectedness, there is a need for more coordination across the sectors and within different government levels. Overall, interviews have revealed a concern about the effects of future crises on the food system, and how they will be able to cope with them. Thus, the following section looks at whether and how actors learn from the crises to increase resilience.

4.3. Resilience capacities in response to the water and energy crises

The following section assesses the absorptive, adaptive, and transformative capacities of small-scale production and distribution activities in Cape Town in response to the water and energy crises, summarised in Table 2.

Resilience Capacity	Resilience strategies and innovations	Food system activities	Supporting infrastructures	Type of innovation	Description and challenges
Absorptive	Re-using and preserving water (dishes, showers etc.)	Small-scale production	Water	Farm practices	Time-consuming, can cause contamination and lead to low food safety.

	Shift in watering schedules to avoid loss from load-shedding	Small-scale production	Energy	Farm practices	When load-shedding is anticipated, farmers water their plants before/after load-shedding, or they fill water tanks at night in anticipation of load-shedding in the morning
Adaptive	Planting of drought-resistant crops	Small-scale production	Water	Infrastructural	Important for food security during water shortages. May reduce diversity of produce consumed. Pests and diseases more likely to spread.
	Rainwater collection system	Small-scale production	Water & Energy	Infrastructural	Cannot be used in long periods of drought. Some of the donated tanks do not come with gutters and can thus not be used to full extent. Advantage: can be filled with water from somewhere else and used during load-shedding.
	Rainwater collection system	Large-scale distribution (CTFPM)	Water	Infrastructural	Municipality was threatening the market with fines, market installed large water tanks to catch rainwater, and a borehole tank for ground water. Does not cover daily needs.
	Watering plants directly	Small-scale production	Water	Farm practices	Farmers fill up cans and water the plants directly (Manual drip-irrigation). Time-consuming.
	Borehole for cleaning purposes	Large-scale distribution (CTFPM)	Water	Infrastructural	Water is too salty to use it for cooling operations or human consumption, has reduced water consumption from municipal water system significantly.
	Generators (diesel)	Large-scale distribution (CTFPM)	Energy	Technological	The market had one generator from the beginning, added another one when load-shedding began so that the market can function 100% during load-shedding.
Transformative	Mulching/trench beds/composting	Small-scale production	Water	Infrastructural	These methods retain water in the soil, keep the soil healthy and reduce food waste. Type of agroecological practice that does not exhaust soil (reduced need for fertilisers) and improves quality of soil.
	Participatory Guarantee System (PGS)	Small-scale production	Water	Institutional	Peer-review system where small-scale farmers collaborate with each other to guarantee that standards of organic farming are being met.
	Solar Panels	Agri-hub (eventually for small-	Energy	Technological	Big investment, when load-shedding occurs, solar panels cannot be used to produce

		scale distribution)			electricity (meters need electricity from national energy grid). Connecting small-scale farmers is challenging.

Table 2 Resilience strategies and innovations in the small-scale food sector

4.3.1. Absorptive capacities

Absorptive capacities relate to how actors prepared for and reacted to the crises and whether they were able to buffer negative consequences. The assessment of absorptive capacities is based on three aspects commonly found in resilience literature, namely diversity, redundancy, and agency (De Steenhuijsen et al., 2021)

It was found that during the water crisis, farmers in Khayelitsha employed various strategies to mitigate some of the immediate effects. These include *reusing and preserving water* from household use and *shifting watering schedules* to times when water was available. Additionally, some farmers were found to shift production to *cultivating only small plots of land*, which meant that some crops were salvaged, and inputs could be concentrated. As a result, farmers were able to maintain production for their own consumption; however, it was reported by some respondents that this did not sufficiently cover daily needs. Community and social ties were mentioned as an important buffer in responding to the crises, as produce, knowledge and information were shared (Interview 8, 10). Farmers at Khayelitsha showed an understanding about the gravity of the situation of low water levels and did not want to contribute to the crisis by drawing water from the municipal supply system.

To absorb the immediate impacts of load-shedding, I found farmers shifted watering schedules to times outside of power-cuts, which only works when it is cool enough to water the crops. This also meant, however, that load-shedding during the water crisis was especially problematic when it occurred during the limited times when water was available and that there was a lack of absorptive capacity to deal with such situations. This showcases the connectivity of the WEF resources.

Concerning production, such findings suggest that small-scale farming initiatives and areas that depended on non-networked water sources such as Khayelitsha have a relatively low absorptive capacity to address the water crisis, as the negative consequences of the drought could not be buffered sufficiently to avoid an increase in food insecurity.

Conversely, because farmers at the PHA were able to continuously source municipal water, the need to 'absorb' the crises was extremely low. However, farmers in the PHA did express concern about their high dependence on municipal water and lack of access to electricity. This is mainly seen as a hindering factor in scaling up production activities and entering formal markets. More broadly, interviewees also showed awareness about the negative impacts of climate change and the possibility of future shocks in water and energy sectors. As one farmer put it:

> *"We need more talks about climate change. Because I heard that it's here to stay. It's not going away; it's getting worse and worse and worse and worse. (…) There will be more and more unfamiliar weather and crises, unless people can also act, do good things." (Interview 7)*

This quote indicates a general fear that small-scale farmers and distributors do not have sufficient absorptive capacity to deal with future shocks and stressors. Concerning distribution, one absorptive strategy found at the CTFPM was using water from the municipal supply system and accepting high water tariffs and fines to keep the market running. Concerning energy, the market uses a diesel generator to absorb impacts from load-shedding.

In conclusion, despite differing connectivity to water and energy grids, food production sites/actors displayed similar characteristics regarding diversity, redundancy and agency. Farmers were not able to compensate for water or energy shortages by relying on alternative sources, meaning diversity of energy and water supply is low. Furthermore, they do not have additional resources in reserve that could absorb some of the immediate effects. Their agency is also limited in that farmers are unable to respond appropriately to the crises to prevent negative consequences. Financial barriers are the main hindering factors, as producers cannot afford to keep redundant and diversified resources. The CTFPM on the other hand was able to absorb the consequences by accepting financial losses (paying high water and electricity tariffs, fines).

4.3.2. Adaptive capacities

Adaptive capacities concern the ability of actors to adjust and modify systems to moderate potential future shocks. To realise the learning opportunities that crises can present, actors need to be able to restructure their existing capabilities to adapt to new circumstances, also called flexibility (Mackay et al., 2020). Table 2 shows that actors have employed several adaptation strategies in food production and distribution.

A crucial adaptation strategy employed by farmers is the *planting of drought-tolerant crops*. When crops started to dry out and farmers lost harvest, they learned about certain crops that require less water, such as spinach, beans and sweet potatoes. Since then, these crops have become a staple in food production and farmers have noticed lower water consumption overall. As one interviewee put it:

"I wish we had that knowledge at the time, we could have planted indigenous crops to be able to continue with farming even without the water. So it challenged us to go out and look for knowledge during that time when we learned that there are other crops that you can farm that don't require much water. And as much as that time was challenging, it also was a lesson because it pushed us to research further on farming." (Interview 10).

Planting drought-tolerant crops is crucial for adapting to changing weather conditions while still producing a reliable yield in times of stress. It has high potential to secure food production as it diversifies farmers' resource base and does not require redundant and thus expensive components. Introducing new crops also helps maintaining the agrobiodiversity on farms, which is crucial to facilitate adaptation (Ackerman et al., 2014). Social media and the community played a key role in acquiring knowledge regarding new seeds and their planting process. Interviewees reached out to other farmers on Facebook who were willing to teach them about drought-tolerant crops. Now, interviewees pass on this knowledge to others in their community.

Furthermore, *rainwater collection systems* and *water tanks* were installed in Khayelitsha. This buffered the negative impacts of load-shedding, as water can be released when pumps do not work. Most water tanks were provided by local NGOs or the Department of Agriculture after the water crisis. However, farmers complained that the tanks came without gutters, without which rainwater cannot be collected. Farmers could not buy the gutters themselves due to financial constraints. Interviewees stated a desire for greater dialogue with government officials to address these problems. Farmers also adapted by watering plants directly instead of sprinkling it generously. This manual equivalent to drip-irrigation is time-intensive but more effectively controls water consumption.

When the municipality threatened the CTFPM with hefty fines for using too much water, the market also installed large *water tanks to catch rainwater*. The rainwater can be used for all activities that require water; however, it has limited availability during severe droughts and does cover the markets' daily needs. Furthermore, the CTFPM has installed a *borehole*, which provides water for cleaning purposes. The groundwater cannot be used in the cool chain or for consumption due to its high salt content but has drastically decreased the markets' water consumption and reliance on the municipal water supply system.

Concerning energy, an adaptation strategy found at the CTFPM is the instalment of *diesel generators.* The market has always been equipped with a diesel generator, however, when load-shedding increased, it acquired a second, more powerful one. With both generators, the market can fully function without disruptions during load-shedding. However, the CTFPM representative raised concern over rising diesel prices and the unsustainability of this alternative. Another concern is that - while the diesel generators keep the formal market running - small-scale distributors and retailers do not have the capacity to invest in alternative energy resources. When daily business from the small-scale sector suffers from load-shedding, the CTFPM is also affected. This highlights the interdependency of the large-scale and small-scale sectors and shows that both sectors benefit from a systems-approach in terms of resilience.

In summary, adaptive capacities to respond to water and energy shortages require financial liquidity, which small-scale food actors typically do not have. Small-scale producers rely more on reducing water consumption and adaptive practices. Technological innovations like water storage tanks and drip-irrigation systems could increase productivity and decrease resource use. However, the necessary know-how and financial assets are not given, which hinders the implementation of such technological adaptation strategies. Concerning energy, farmers have little agency to find alternative resources or adaptation strategies. This shows that the small-scale sector has limited flexibility in adapting to the energy crisis, which is grounded in the complicated institutionalisation of the energy sector.

Small-scale actors thus require financial support, for example in subsidies for technological innovations in water and energy management and storage. Furthermore, increasing the use of non-networked water sources could make farmers less dependent on municipal water supply, while also relieving stress on the system. For this to happen, small-scale farmers need governmental support, which the large-scale sector benefits from already. Recognising the significance of the small-scale food sector for food security in Cape Town could be a prerequisite for targeted and effective investments in adaptation strategies. Furthermore, as the previous analysis has shown, disseminating information is key for small-scale actors to learn and implement adaptation strategies, and consequently build capacity. While NGOs like Abalimi Bezekhaya already facilitate information sharing in the areas, the local government could play a stronger role in knowledge co-production and training.

4.3.3. Transformative capacities

Transformative capacity relates to the ability of actors to enact and encourage systemic change towards a more resilient food system. Whether the water and energy crises can inflict this positive change in the food sector depends on actors' capacity to understand and consciously engage in a long-term change process that shifts power and dominant ways of thinking (Ziervogel et al., 2016). Social, technological and infrastructural innovations are argued to enact this systemic change (Dolata, 2009).

As shown in Table 2, changing long-term agricultural practices to improve soil characteristics is an important innovation found in the cases. The soil on the Cape Flats is generally sandy, low in nutrients and dries out quickly (Abalimi Bezekhaya, 2018). During the drought, farmers began using techniques such as *trench beds, compost, mulching and growing legume to cover crops*. These are innovations concerning farming practices that increase soil productivity without exhausting it. Building soil rich in organic matter helps to increase water infiltration and retention, enhances soil structure, and makes nutrients more accessible to crops while also reducing the need for fertilisers (Rosenzweig & Tubiello, 2007). These practices are good examples of how small-scale actors can use their resources and knowledge to not only increase resilience, but also contribute to climate change mitigation through sequestration of soil carbon (ibid.).

In both the PHA and Khayelitsha, some farmers were found to have adopted the *Participatory Guarantee System* (PGS), a peer-review certification system where small-scale farmers collaborate to ensure that organic standards are being followed. PGS, which is promoted by PEDI and Abalimi Bezekhaya, is based on principles of fairness, active participation, trust, honesty and shared vision. While this system existed before, PEDI has noticed a significant increase in participation since the water crisis. In contrast to costly and bureaucratic standard certification processes, this participatory approach is based on trust between farmers and consumers, making it a low-cost and low-risk alternative (Home & Nelson, 2015). Thus, PGS changes not only the relationships within the farming community, but also with consumers. It simultaneously creates more awareness regarding food production which gives consumers the ability to make more conscious choices (Paganini et al., 2017). This inclusive process is more likely to address the issues that local stakeholders consider most urgent (Rasul & Shamra, 2016). It demonstrates that small-scale producers have the capacity to enable transformative practices that have mutual benefits for the environment, producers, and consumers.

Concerning innovations in energy infrastructures, PEDI was found to have installed *solar panels* on the roof of its agri-hub complex. However, for the solar panels to function, electricity from Eskom is still needed. PEDI (and the market it operates) are thus not exempt from load-shedding. The organisation is currently working on fixing this issue and expanding its solar panel network all over the Philippi area, which relies on investments. While the goal of PEDI is to connect small-scale farmers at the PHA to solar, as the challenge is many farmers are cultivating informally and do not possess legal land rights. The CTFPM is currently also planning to switch to solar energy, a transformation that is in close collaboration with the CoCT (Interview 15).

For small-scale producers, many possible technological or systems-level innovations in the energy sector were found not to be financially feasible, as one farmer put it:

> *"It is a challenge because there is no funding to change the current electricity, because I know we could use solar panels too for electricity […] but it is very expensive to install one, but if we could have one that would be great." (Interview 10)*

Small-scale producers and distributors were found to be largely dependent on organisations like PEDI to transform energy infrastructures. However, legislation concerning independent power production is currently being renewed (Richards & Stolp, 2021), which is hoped to make electricity cheaper and more accessible to small-scale food actors.

Consistent understanding and perceptions of the goal of food transformation are lacking. While all interviewees expressed the need to transform water, energy and food systems, actors have different perceptions of what constitutes ’resilience’ and the transformations needed. Representatives of NGOs and researchers had more ambitious goals regarding changing agricultural practices. ‘Climate-smart agriculture’ and ‘controlled environment farming’ were two innovations mentioned. This is reflected in the following statement by PEDI’s representative:

“One of our aims is to put the small-scale farmer, one hectare, one family, and use technology to increase the throughput and the viability of those farmers. That's what we're working towards.” (Interview 16)

However, these highly technological approaches rely on water and energy infrastructures' functioning and their accessibility. Currently, high-tech farming solutions are already common practice in the large-scale sector, however, they may not be sufficient to fully meet demand. The following section discusses the findings of this research and compares small-scale and large-scale resilience capacities.

5. Discussion of findings and conclusion

This research combined literature on food system resilience and WEF nexus thinking by examining underlying vulnerabilities and resilience capacities of the small-scale food sector in Cape Town to interrelated WEF crises. Little previous research has focused on WEF interactions in the small-scale food sector. While scholars have argued previously that small-holder farmers are particularly vulnerable to disturbances (Mabhaudhi et al., 2018), how farmers are adapting to crises and what type of resilience strategies and innovations they are already implementing has not been researched yet. This research thus aimed to gain a better understanding of existing transformative capacities to water and energy crises in the (often informal) small-scale food sector.

The preceding analysis has shown that the small-scale food sector in Cape Town is highly vulnerable to water and energy crises. Despite having moderate resilience capacity, technological innovation in water and energy infrastructures is hindered by financial, social and institutional barriers. Primary impacts of the crises highlight the interdependency of water, energy and food systems. This finding corresponds with existing WEF nexus literature and emphasises the need for more coordinated governance of the three sectors. Secondary impacts, such as social unrest and increased food insecurity among farmers, highlight the sectors’ underlying vulnerabilities, which were ultimately found to impair resilience strategies. These underlying vulnerabilities are the result of unequal market and infrastructure access, the informality of the small-scale sector and socio-economic inequalities. The inequalities of the dualistic food system in South Africa are discussed widely in literature (Greenberg, 2019; Cousins et al., 2018; Battersby et al., 2016); however, how these secondary impacts affect resilience capacities of small-scale food actors can provide new insight into resilience debates.

These findings underline the differences of vulnerabilities and capacities between small-scale and large-scale food actors in Cape Town. While this research has focused on small-scale food sector resilience, previous research has shown that the large-scale sector was likewise affected by the crises (Hartebeest, 2019). Many large-scale farmers however had their own non-networked water infrastructure (such as private dams), which was – to a large extent – not affected by the water crisis (Tom, 2020). Previous research on the energy crisis has shown that load-shedding interrupts energy-intensive technologies common in the large-scale sector, such as precision farming (Rawlins, 2019). Hence, some large-scale producers, distributors and retailers have invested in private alternative energy production, such as solar panels or biogas (RCL Foods, 2020; Lewis, 2021). Distributors are said to be able to compensate for lower food production in Cape Town by buying produce from other regions or farmers who are not affected (WCEDP, 2021). The large-scale sector thus seems to have greater financial means, access to know-how and institutional backing that the small-scale sector is lacking (Makwela, 2017). This perpetuates the economic and agricultural system that is currently in place and makes it more difficult for small-scale actors to engage in systemic change. Further research on the difference in resilience capacities between small-scale and large-scale sectors in Cape Town is recommended.

Concerning resilience capacities, this study indicates that small-scale actors across the case study locations have low absorptive capacities to water and energy crises, with little possibilities to buffer negative consequences and avoid increasing food insecurity. An exception is the CTFPM, as the market has reported to have access to financing and support from the CoCT. It has also been found that financial and governance support from local authorities is needed in order to increase adaptive capacities. Currently, the national government is responsible for food policies, whereas local authorities govern water and energy sectors and can offer incentives, subsidies and access to infrastructures (WCEDP, 2021). This research thus suggests that coordinating WEF resources should be taken up by local authorities, who can pay better attention to place-based attributes. For this to be feasible, the small-scale food system must be recognised as an integral and formal part of Cape Town's food system – which would guarantee actors' access to markets, infrastructure and other organisations (Haysom et al., 2017). In terms of access to water and energy, non-networked sources are seen as a solution to current vulnerabilities such as water restrictions and high electricity tariffs in times of crises. They create more flexibility and make actors less dependent on ill-functioning networked infrastructures, as is the case for the large-scale sector.

The results also reveal that transformative capacities in the small-scale sector revolved around technological or system-level innovations in water and energy. Small-scale producers were found to have implemented transformative strategies that increase soil productivity and reduce the need for fertilisers. The types of innovations furthermore demonstrate that small-scale actors have more capabilities for transformative capacity in the water sector as compared to the energy sector. This is not only because water is considered more important for farming activities (crops do not grow without water), but also because water can be stored, saved, and made use of easier than electricity. This is because there currently only is one source for electricity (Eskom), which only a few interviewed farmers were connected to. Furthermore, NGOs, farmers and previous research were found to focus more on the small-scale sectors' connectivity to water, which may impede opportunities for research and investment in increasing energy connectivity.

Due to aforementioned financial and institutional barriers, external support is key for successfully implementing more technological innovations. External support, for example, refers to financial assistance for new technologies, training farmers to work with these technologies and enabling connectivity to energy and water infrastructures. NGOs, the local government and other organisations such as PEDI should play a crucial role in this. Involving small-scale actors in decision-making and implementation processes is thereby key, as has been demonstrated by missing gutters for gifted water tanks in Khayelitsha.

Considering the high food insecurity and underlying vulnerabilities rooted in socio-economic inequalities, this research has shown that going back to the systems' pre-crises 'equilibrium' is not desirable. In line with Tendall et al.'s (2015) and Walker et al.'s (2014) understanding, an enabling environment for systemic change is key to increasing resilience to future crises. This requires stronger coordination between water, energy and food governance. It must also take into account WEF interactions with social, economic and environmental systems.

Currently, resilience literature focuses on single challenges in 'complex' systems; however, as has been shown in this research, food systems are inherently interlinked with water and energy systems. Food systems do not function without water and energy, and vice versa (Gulati et al., 2013). It is thus impossible to look at resilience challenges in an isolated way. New conceptualisations of (food system) resilience thinking would thus benefit from integrating WEF nexus thinking. Instead of solely looking at internal disturbances, external disturbances should be considered and added to definitions of food system resilience. Consequently, water and energy security would also become social goals of resilient food systems.

This research has potential limitations. Firstly, the study population was restricted to those with access to internet, which made it difficult to reach small-scale distributors and a broader variety of producers. Moreover, this study includes only production and distribution activities. While this makes a more detailed analysis possible, further research could examine the effects of the water and energy crises on other food systems activities, such as processing and consumption, and their resilience capacities. As the PEDI interview touched upon, future research could look into what type of farming practices (e.g. precision farming, controlled environment farming) could potentially be suitable and culturally acceptable for small-scale farmers.

To conclude, this research has revealed that underlying socio-economic and financial vulnerabilities impede resilience capacities of small-scale food production and distribution activities in Cape Town. In order to become more resilient to water and energy crises, the sector needs coordinated support from local authorities. This support must not look at food systems in an isolated way, but rather recognise its embeddedness in other related systems. Finally, moving towards a sustainable and resilient food system requires social, institutional (governance) and technical (technological changes that enable the transition) innovation.

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Appendix I Overview Interviewees

#	Job/Role	Organisation/Case study Site	Part of Food Systems Activity	Date	Duration
1	WEF Nexusing Project Leader	WCEDP	Facilitator	24/11/21	1 hour

2	WEF Nexusing Project Group	WCEDP	Facilitator	weekly	30 minutes
3	WEF Nexusing Researcher	Utrecht University	Research	08/11/21	40 minutes
4	Project Leader	UCook	Distribution/Enabler	16/11/21	30 minutes
5	Smallholder farmer	PHA	Small-scale production	24/11/21	1 hour
6	Smallholder farmer	PHA	Small-scale production	15/11/21	1 hour
7	Smallholder farmer	PHA	Small-scale production	02/12/21	1 hour
8	Smallholder farmer	Khayelitsha/Abalimi Bezekhaya	Small-scale production	17/12/21	1 hour
9	Smallholder farmer	Khayelitsha/Abalimi Bezekhaya	Small-scale production	15/01/22	1 hour
10	Smallholder farmer	Khayelitsha/Abalimi Bezekhaya	Small-scale production	22/01/22	45 minutes
11	Researcher, former member of Environmental Humanities South (EHS) in Cape Town	University of Cape Town	Research	16/01/22	50 minutes
12	Researcher and professor	Southern Africa Food Lab, Stellenbosch University	Research	17/12/21	1 hour 20 minutes
13	Researcher	University of Western Cape, DST-NRF Centre of Excellence on Food Security	Research	18/01/22	40 minutes
14	Researcher	University of Western Cape, DST-NRF Centre of Excellence on Food Security	Research	21/01/22	55 minutes
15	Floor Manager	Cape Town Fresh Produce Market	Large-scale and small-scale distribution	18/01/22	30 minutes
16	Chief Executive Officer	Philippi Economic Development Initiative (PEDI)	Small-scale distribution and processing	28/01/22	1 hour 30 minutes
17	Chief Executive Officer	Agricultural Produce Agents Council (APAC)	Large-scale distribution	28/01/22	1 hour