SHEFS

RESEARCH EVIDENCE SYNTHESIS SUMMARY 2024

EXECUTIVE SUMMARY

The primary aim of SHEFS is to provide policy makers with novel, interdisciplinary research evidence to define future food systems policies that deliver nutritious and healthy foods in a sustainable and equitable manner. The concept of SHEFS was developed with the aim to achieve policy outcomes that transcend the boundaries between food security, environment, and health for a sustainable society. SHEFS was funded by the Wellcome Trust from September 2017 to September 2023. The South African component of SHEFS includes four inter-related research components, namely, agriculture, environment, poverty and inequality, and community development and health.

This SHEFS South Africa Synthesis Report shares the outcomes of the first five years of SHEFS research into the links between food, health and the environment, conducted by the SHEFS research consortium. This Report provides a summary of all evidence that was generated, framed around two key questions, providing key insights around five broad themes relevant to government priority areas, and proposes policy related solutions.

KEY QUESTIONS

The evidence and findings aim to contribute to answering the following two key questions in South Africa:

1. **What are the important considerations and potential pathways for sustainably increasing access to equitable food production and nutritional security to the benefit of previously under-privileged South African communities?**

2. **Where can resource use be improved to enhance food productivity, distribution and consumption without driving resource scarcity?**

Related to the key questions, this Synthesis Report provides evidence framed around the following four themes, that are considered as key focus areas for policy actors:

1. **Systemic inequalities (barriers to small-scale actors, nutrition inequalities)**
   - Enable smallholder farmers to participate in markets by easing systemic barriers
   - Recognise and target the pathways to good nutrition and wellbeing with spatial data on food environments and social data on everyday food practices

2. **Enhanced health outcomes (well-being)**
   - Extend support for production and marketing of unconventional nutritious foods such as insects, non-staple grains, and biofortified foods
   - Educate farmers and consumers on the environmental and health benefits of diverse, indigenous, nutritious foods

3. **Environmental sustainability (unsustainable and hidden costs)**
   - Consider long-term landscape implications on water productivity when planning for changes in food crops
   - Involve local communities in decision-making and implementation to ensure sustainability of government interventions

4. **Fragmented governance (silos, inefficient policy and legislation, strategy implementation)**
   - Scale and integrate food and health policies to respond to local needs, and for better implementation
   - Reorientate policy to be more inclusive of indigenous crops and smallholder farmers so that extension support covers wider food systems

Authors:
Dr Rashieda Davids
Dr Nafiisa Sobratee
Mallika Sardeshpande
Stephanie Walton
Dr Mjabu Ngidi
Prof Catherine Sutherland
Prof Tafadzwa Mabhaudhi
Prof Rob Slotow

WITH THANKS TO

REPORT DESIGN: **whitecreativecompany.co.uk**

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INTRODUCTION AND BACKGROUND

The Sustainable and Healthy Food Systems (SHEFS) project, funded by the Wellcome Trust, is multi-partner research consortium led by the London School of Hygiene & Tropical Hygiene. Partner organisations include University of KwaZulu-Natal (UKZN) in South Africa, University College, London, the School of Oriental and African Studies (SOAS) University of London, the Centre for Food Policy at City University of London, The Food Foundation, the Royal Veterinary College (RVC), the Public Health Foundation of India and Ashoka Trust for Research in Ecology and the Environment (ATREE).

The primary aim of SHEFS is to provide policy makers with novel, interdisciplinary research evidence to define future food systems policies that deliver nutritious and healthy foods in a sustainable and equitable manner. The programme aims to develop comprehensive and integrated understandings of the links between the environment, food systems, and health. The South African partner of SHEFS is the University of KwaZulu-Natal (UKZN), led by Professor Rob Slotow. The UKZN focus includes four inter-related research components, namely, agriculture, environment, human development (poverty alleviation and community upliftment, and health.

The UKZN component of SHEFS currently has over 50 team members, including project team contributors; principal investigators, principal collaborators, researchers, post-doctoral researchers, MSc level Interns, PhD level Interns, and research assistants. Core team members include people from provincial and local government and ongoing 'internal' policy actor engagements have taken place over the years. This report is the compilation of five years of research into the links between food, health and the environment conducted by the SHEFS research consortium in South Africa.

1.1 Knowledge co-production through stakeholder engagement

Co-generation of data and knowledge with stakeholders is often critical to ensure uptake of results and effective future co-management of natural resources. The SHEFS project has included continuous consultation with relevant stakeholders, to ensure co-production of research, and to facilitate research outcomes that are relevant to policy and practice. SHEFS has hosted structured workshops and engagements with external stakeholders between 2017 - 2021.

A Crops Systems Mapping Workshop hosted by UKZN in October 2017 brought together stakeholders from key government sectors, and representatives from non-governmental organisations (NGOs), practitioners, academics and students. The outcomes of this workshop were published as a paper discussing the collaborative framework required to develop impact-driven activities needed to inform evidence-based policies on sustainable diets (Sobratee et al. 2022).

SHEFS has involved policymakers and practitioners from research inception through to project completion

UKZN and RVC hosted a Livestock Systems Mapping Workshop in March 2018, bringing together representatives from the communal farming communities, the Department of Agriculture, Forestry and Fisheries, KwaZulu-Natal Department of Agriculture and Rural Development, private and commercial sectors, NGOs and other individual researchers and scientists working within the field. A paper was published, which shares the systems approach undertaken and described how this approach helped to identify root causes, feedback mechanisms, potential unintended consequences, and opportunities for integrated, durable solutions (Queenan et al 2020).

In May 2018, SHEFS UKZN hosted a Policy Engagement Workshop to explore the ways in which SHEFS could support better policy making in South Africa. A Briefing Note was prepared for the workshop consisting of a mapping of the policies already in place in South Africa with potential to influence sustainability and health. The workshop produced two conclusions, namely that policy coordination and implementation is more important than new policy development, and there are opportunities for SHEFS research to support policymaking, especially in areas where policy choices are contested by different interest groups.

In July 2019, UKZN hosted a workshop on the SHEFS Theory of Change (ToC) to unpack SHEFS activities for: a) what we proposed to do, b) what we are doing and c) what we plan to do. The workshop was attended by policy stakeholders and researchers from SHEFS. The workshop was successful in showing that most participants, despite their differing backgrounds, had similar aspirations related to achieving the Sustainable Development Goals (SDGs). This created a sense of shared vision among participants.

A policy actor engagement panel was hosted via Zoom in October 2021, with a panel discussion on: How can the critical practice of science, achieved so far in SHEFS, be enhanced to inform policymaking on a sustainable and healthy food system?

The interactive panel session was held to examine whether the interdisciplinary evidence produced by SHEFS takes into account the challenges that practitioners and policymakers faced. The SHEFS SA Research Synthesis Summary received positive feedback from the five panellists who participated in the discussion. Five strategic points emerged as recommendations for SHEFS going forward:

- SHEFS should engage with the top (Department Directorates) and the bottom (Communities) to meet in the middle.
- Provide 'applicable templates' such as measurable intervention plans for stakeholders to test and integrate into their strategies.
- Find spaces to nest interventions within existing policies, plans and strategies (e.g., specificity and implementation).
- Highlight gaps and problems, and also ways in which we can partner to solve them.
- Use maps whenever appropriate.

Workshops were held in May and June 2021, and May and October 2023 in Quarry Road West

informal settlement with community members and municipal officials. These workshops explored the potential for establishing a food garden and indigenous nursery in Quarry Road West informal settlement as part of ecological restoration in the area in the wake of the 2019 and 2022 floods.

In October 2022, UKZN hosted a workshop, which included focus group engagements, with community leaders (councilors and izinduna) and members from KwaNdela Village, Bizana on the lived experiences of food in rural and informal areas. The workshop explored ideas around healthy food and food transitions between traditional and modern systems. There was great interest in the workshop with 52 village members attending.

In October 2022, SHEFS Global presented their research synthesis reports to the public in a joint webinar hosted as part of the FAO Science and Innovation Forum. Government stakeholders were invited as panelists to discuss findings for each country, and the South African government was represented by the Department of Agriculture, Land Reform and Rural Development and the Department of Social Development. Panelists acknowledged the usefulness of the synthesis and concluded that South African food systems can benefit from extension, supply chain, and policy support for smallholder farmers, and cohesive governance across agriculture, environment, and health mandates.

2 SHEFS SOUTH AFRICA RESEARCH SUMMARY

At this stage of SHEFS, five years of research have provided data and outcomes that shed light on the two key questions (Page 2), each of which have deeper insights on food system sustainability problems, and offer solutions and recommendations for improvement through policy actions.

2.1 Scale and policy contexts

The overall objective of SHEFS is to ensure international influence, as there are other countries other than South Africa, UK and India, that could benefit from the project. Work reported here was undertaken at multiple scales – local (site specific or city wide), provincial and/or national. Within South Africa, study sites were selected across multiple geographical contexts, from rural, to peri-urban and urban. Similarly, policy considerations range from local and provincial to national contexts. Consideration of multi-level perspectives provided for alignment and scaling to be co-evolutionary.

2.2 Systems approach towards sustainable food systems and achievement of the SDGs

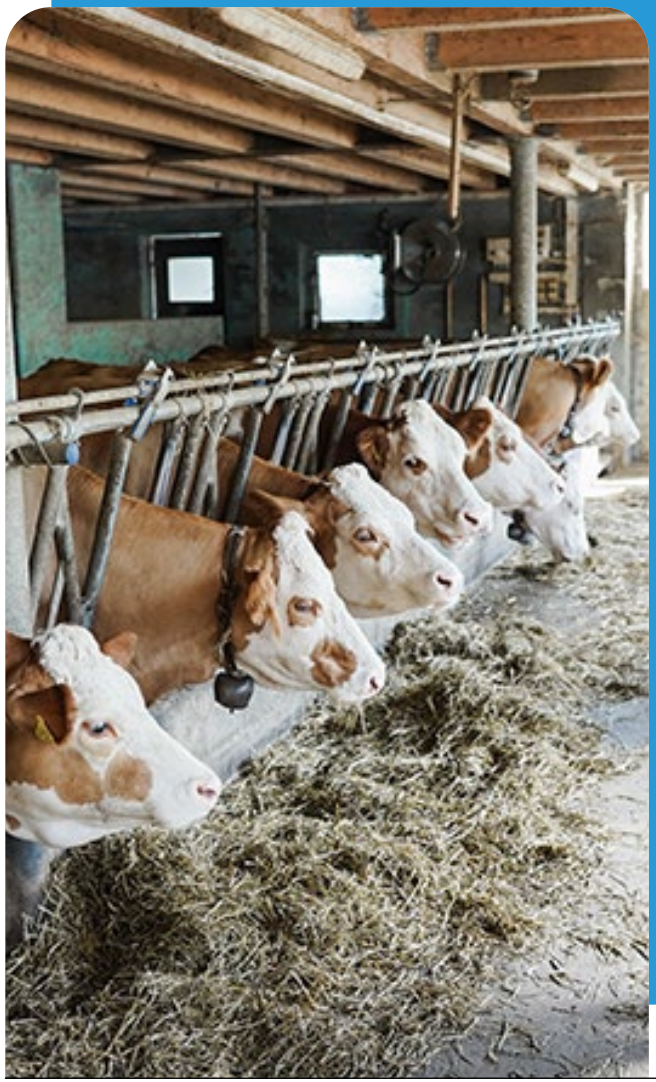
Designing policies for improving healthy, sustainable, and equitable food systems, requires understanding of how food, health and the environment are interconnected. In line with the SHEFS ToC, the research aimed at achieving the 'Human Outcomes' - SDGs - with a systems lens. For example, improved nutrition (SDG 3: Good health and well-being) is not simply a matter of producing more food, but of ensuring food is available (SDG 2: Zero hunger) and affordable (SDG 1: No poverty) to those who need it. Improved livelihoods (SDG 8: Decent work & economic growth) through food production requires ensuring that the economic benefits of agriculture are equitably distributed throughout the population (SDG 10: Reduced inequalities) and that producing food today does not harm the ability to produce food in the future (SDG 11: Sustainable cities & communities; SDG 13: Climate action; SDG 14: Life below water and SDG 15: Life on land). Rather than operating in isolation, food, health, and the environment are interlinked in a complex dynamic system and understanding this system is crucial to developing effective policies for improving livelihoods and nutrition.

2.3 Key takeaways relevant to government priorities

SHEFS research has been framed to respond to four cross-cutting government priority areas:

1. **Systemic inequalities (barriers to small-scale actors, nutrition inequalities)**
2. **Enhanced health outcomes (well-being)**
3. **Environmental sustainability (unsustainable and hidden costs)**
4. **Fragmented governance (silos, inefficient policy and legislation, strategy implementation)**

Results from SHEFS research are presented in three categories for each of the themes, namely status quo, gaps or challenges, and solutions.



3 SYSTEMIC INEQUALITIES (barriers to small-scale actors, nutrition inequalities)

3.1 Status quo

While food production is increasing, food insecurity is still prevalent in many parts of the country. One study revealed high rates of food insecurity in areas with reliable rainfall and fertile soils highly suitable for agricultural crop and livestock production, resulting in a “Food Security Paradox” (Tomita et al., 2020a) (Figure 1). Food and nutritional insecurity may be precipitated by structural inequalities at landscape and household level, other deficits in physical and mental health, and urbanisation.

Smallholder farmers are locked into unprofitable production due to market barriers

3.1.1 Structural inequalities

Structural inequalities within the South African food system underpin a "success to the successful" trend, that presents barriers to entry for those not included (Queenan et al., 2020). Research into the dynamics of livestock-derived food (LDF) showed that production is rooted in historic and persistent inequalities, including access to land, inputs, markets, and knowledge, which make it difficult for small and medium-scale producers to participate (Queenan et al., 2020). Commercial production of LDF is closely linked to the dominant distribution networks of large-scale supermarkets and fast-food franchises that are equally difficult for SMEs to access (Queenan et al. 2020). To address these inequalities, bold policies are required to affect the deep structural change that is needed but should be based on a system-wide understanding to mitigate risks of system destabilisation (Queenan et al., 2020).

3.1.2 Nutritional deficits

Nutritional benefits from increased food production are similarly not guaranteed to flow to the populations that need it. One study found that, between 2008-2017, while stunting has declined among South African children, wasting and obesity appear largely unchanged (Tomita et al., 2019), suggesting that development and public health interventions have had a variable impact. Obesity was more pronounced in the east of the country and thinness/wasting more pronounced in the west and there is an increasing prevalence of both conditions in children under the age of 2 years (Tomita et al., 2019). Children in lower-income and food-insecure households with young, malnourished mothers were significantly more likely to be thin/wasted (Sartorius et al., 2020). Individuals who are female, young, have low educational attainment and receive social grants are at most risk of household food insecurity (Tomita et al., 2019).

3.1.3 Inequalities and urbanisation

Urbanisation leads to changes in food production, consumption and food identities. Urbanisation results in unequal outcomes for individuals as a result of their access to power and urban resources, particularly in terms of land, economic and social opportunities, housing and services. Access to and consumption of food is shaped by multiple trajectories of urban life, many of which are spatially determined (location, transport, type of settlement, space available for food gardens). Urban residents with connections to rural areas retain strong linkages with rural food systems, and value food produced from the soil, as well as indigenous foods.

However, the consumption of fast foods high in fat and refined carbohydrates is perceived, particularly by urban youth including students, to enhance their social status. The convenience of fast foods and their ability to 'fill the stomach' increases their consumption in informal settlements. Through the posting of related pictures on social media they model fast food consumption as highly desirable (Pereira et al. 2020).

3.2 Gaps / Challenges

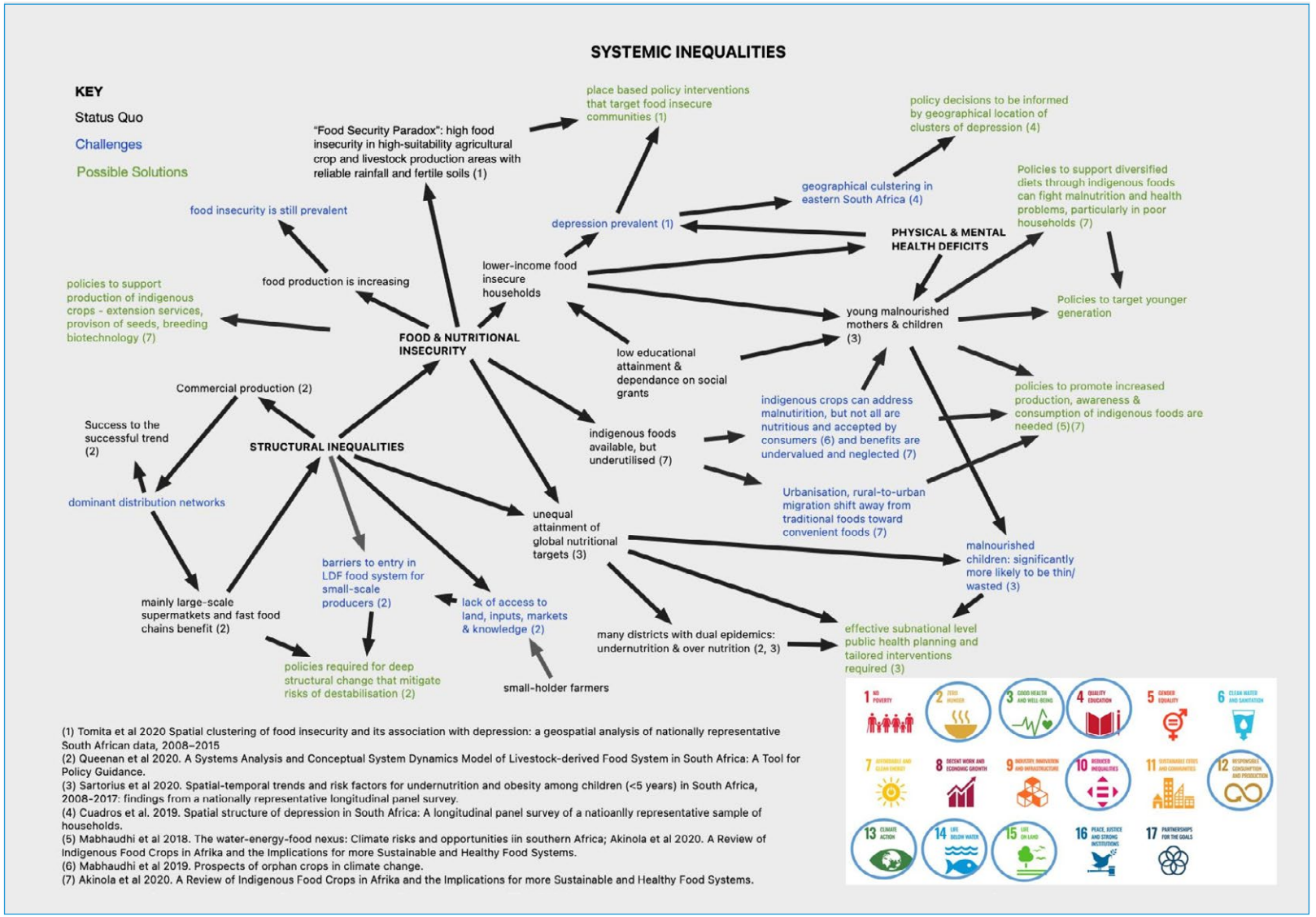
The geographic and sociodemographic heterogeneity in childhood malnutrition has implications for equitable attainment of global nutritional targets for 2025, with many districts having dual epidemics of undernutrition and overnutrition (Sartorius et al 2020).

In some urban areas, residents have good knowledge of healthy food, while in others this knowledge is limited, and households and individuals consume highly processed convenience foods due to its affordability, convenience, and ability to 'still' hunger. Urbanisation and rural-urban migration caused a shift away from traditional foods (Akinola et al 2020). Although indigenous crops can address malnutrition, they are not widely accepted by consumers and are undervalued and neglected (Akinola et al 2020).

3.3 Solutions

- There is a need for location-specific policy interventions that target communities vulnerable to food insecurity, and also to reduce the burden of depression (Tomita et al 2020).
- Effective subnational-level public health planning and tailored interventions are required to address the challenge of under- and over- nutrition (Sartorius et al 2020).
- Policies are required for deep structural change that mitigates risks of destabilization of food systems while removing barriers for smallholders (Queenan et al 2020).
- Policies to promote increased production, awareness and consumption of indigenous foods are needed (Mabhaudhi et al 2018; Akinola et al 2020).
- Policies to support diversified diets through indigenous foods can fight malnutrition and health problems, particularly in poor households (Akinola et al 2020).
- Policies to support production of indigenous crops – through extension services, provision of seeds and use of biotechnology in breeding (Akinola et al 2020).
- Policy decisions to be informed by geographical location of clusters of depression (Cuadros et al 2019).

Figure 1: Systemic inequalities, barriers to small-scale actors, nutrition inequalities, mental health



4 ENHANCED HEALTH OUTCOMES (well-being)

4.1 Status quo

4.1.1 Socio-economic status and food outcomes

Food insecurity and diet-related diseases do not only have detrimental effects to human health, but are also underpinned by food systems that are environmentally unsustainable and culturally disconnected. Ensuring access to a healthy, affordable, and sustainable diet is one of the greatest challenges facing many low- and middle-income countries such as South Africa (Pereira et al 2021). Multiple studies showed that access to nutritious foods and subsequent health outcomes are linked to socio-economic status. Historic inequalities in access to land and resources have perpetuated an unequal system of food production and distribution, leading to negative economic and health outcomes. This was shown to be the case particularly in the production of livestock-derived foods, where access to land, inputs and veterinary services is unequal (Queenan et al., 2020; Queenan et al., 2021) and in the case of residents of informal settlements and low-cost housing projects (Sutherland et al. 2019). Furthermore, food safety was of low priority compared to affordability for poorer consumers, increasing their risk of foodborne disease relating to livestock-derived foods, specifically broiler products (Queenan et al., 2021) (Figure 2).

4.1.2 Food choices and health outcomes

Circular migration sustains connections between rural and urban food production, consumption, and value (Sim et al. 2018). Modernity and tradition intersect and influence everyday food choices (Pereira et al. 2020). Urban settlement types (informal settlement, peri-urban, rural, and formal housing) influence and shape food outcomes (Pereira et al. 2022). Shocks (such as pandemics and social unrest) have a significant impact on daily food practices (Mazeka et al. 2019). Alcohol consumption is a serious social problem which impacts on well-being, including food consumption. There appears to be a detachment from traditional foods and an avoidance of healthier 'poor man's food' (Sobratee et al. 2022).

Cultural disconnect, malnourished mothers, and constrained living environments precipitate poor health outcomes

4.1.3 Nutrition deficiencies

Children in South Africa suffer nutrient deficiencies (Sartorius et al. 2020). Children in lower income and food-insecure households with young malnourished mothers are likely to be thin or wasted, while children with higher birth weights, living in lower income households are likely to be obese. Incidence of vitamin A and iron deficiency among children below five years is 43.6% and 11%, respectively, while the risk of Zinc deficiency is 45.3% among children aged 1 to 9 years. Despite several strategies, i.e., supplementation and commercial fortification, micronutrient deficiencies remain high. Biofortified crops may offer solutions to nutrient deficiencies (Siwela et al. 2020).

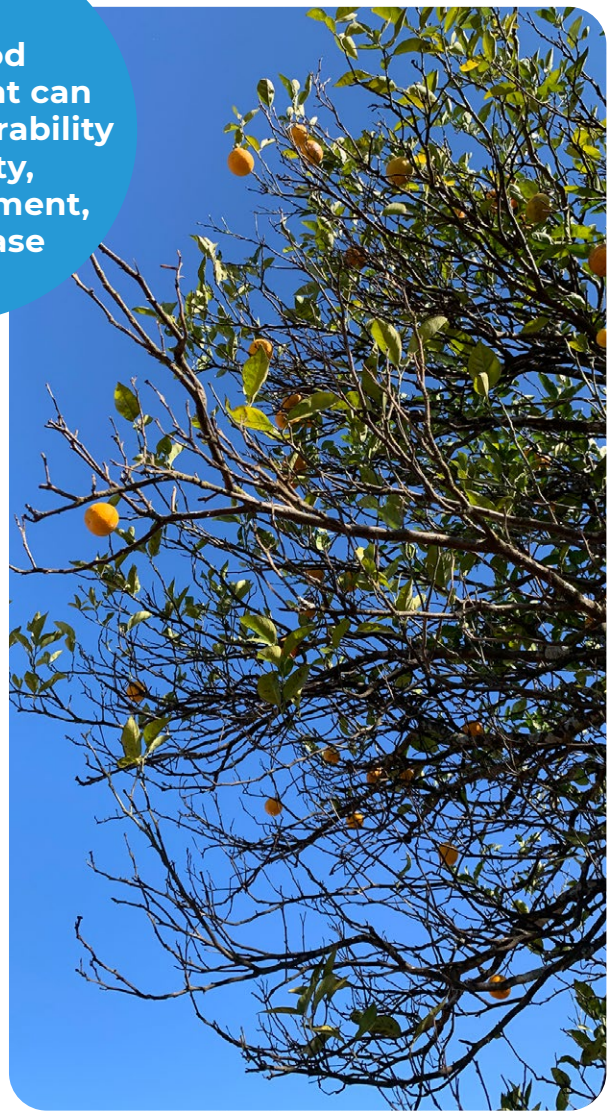
4.1.4 Negative mental health outcomes

Tomita et al. (2020b) identified clear geographical 'hotspots' with concentration of individuals reporting new depressive symptoms. Geographical clustering could reflect differences in exposure to various risk factors, including socio-economic and epidemiological factors, driving or reinforcing the spatial structure of depression. People living within 5 km of waste sites was were found to be significantly associated with asthma, tuberculosis, diabetes, and depression (Tomita et al., 2020b). Another study found that major depressive episode (MDE) in individuals with multidrug resistant tuberculosis (MDR-TB) was significantly associated with household food insecurity, independent of other socio-economic circumstances (Tomita et al. 2019). Mental health problems linked to geography, with excessive numbers of new cases concentrated in the eastern part of the country. Clusters overlap with those of self-reported cases of tuberculosis in the same region, as well as with poorer, less educated people living in traditional rural communities (Caudros et al., 2019).

4.1.5 Rural resource management

Rural livelihood development can reduce vulnerability to poverty, malnourishment, and disease

About 60% of southern Africa's population lives in rural areas with limited access to basic services and amenities such as clean and safe water, affordable and clean energy, and balanced and nutritious diets. Resource scarcity has direct and indirect impacts on nutrition, human health, and well-being of mostly poor rural communities (Mabhaudhi et al. 2019). Climate change impacts in the region are manifesting through low crop yields, upsurge of vector borne diseases (malaria and dengue fever), and water and food-borne diseases (cholera and diarrhoea) (Mabhaudhi et al. 2019). Smallholder farmers and women are marginalised from food trade (Mabhaudhi et al. 2018; Mabhaudhi et al. 2019). Participation in smallholder markets is limited by many factors: gender, wealth and HIV. These challenges need to be addressed to encourage smallholder farmers to participate in the market and indicate a need for government to hire sufficient and skilled extension workers who understand both production and market related issues (Hlatshwayo et al. 2021).



4.2 Gaps / Challenges

Coherent agricultural development policies could promote a shift towards more inclusive livestock value chains, in particular in the broiler sector (Cuevas et al. 2021). This could support smallholder livelihoods, while potentially also promoting access to nutritious foods for populations whose electricity supply might be unreliable or who might have limited access to cold chain and mainstream supply chains, mainly in rural areas and townships. South Africa's broiler system is dominated by commercial production and formal retail trade, with competition from cheap imports. Affordability is unintentionally traded off against non-communicable disease risks through brining of most frozen products, and ultra-processing of fast-food items (Queenan et al. 2022).

While improvements in stunting have been observed since the early 2000s, thinness/wasting and obesity prevalence remain largely unchanged. The geographic and sociodemographic heterogeneity in childhood malnutrition has implications for equitable attainment of global nutritional targets for 2025, with many districts having dual epidemics of undernutrition and overnutrition (Sartorius et al 2020).

4.3 Solutions

- One strategy for improving nutrition, particularly for rural population could be the development of biofortified crops (Govender et al., 2019a; Govender et al., 2019b). However, consumer acceptability would need to be considered. For example, consumer acceptability of orange-fleshed sweet potato and provitamin A biofortified maize were higher among children compared to adults (Siwela et al., 2020).

- Accelerating the development of other biofortified staple crops to increase their availability, is essential. Nutrition education should be integrated with community health programmes to improve the consumption of the biofortified crops, coupled with further research to develop suitable recipes/formulations for biofortified foods (Siwela et al. 2020).

- Communication and social learning is essential to transition towards sustainable and healthy food systems. Building on urban resident's understanding of, and value of access to healthy food could improve urban nutrition outcomes (Sutherland et al. 2019).

- Smallholders and medium-scale producers, young women and children, and recipients of government financial and medical aid could benefit most from nutritional interventions.

- Current broiler production policies focus on local commercial production, formal markets, and affordability without cognisance of the broader broiler food system. Foodborne disease control is critical, given the proportion of vulnerable individuals, and greater coherence of food safety policy is urgently needed (Queenan et al. 2022).

- Factors that need to be addressed to encourage smallholder farmers to participate in the market indicate that there is a need for government to hire sufficient and skilled extension workers who understand the market related issues. With the help of extension workers and policymakers, government need to organize smallholder farmers into groups that

are easy to manage, train, and support. Smallholder farmers' groups should have their farmers registered, visible, and easily accessible for coordinated government support services. They also need to do more workshops in rural areas to encourage young people to be involved in agriculture. Such efforts will lead to sustainable production, alleviation of poverty, improvement of the economy, and food security (Hlatshwayo et al. 2021).

- Improved agricultural extension services to educate farmers about new agricultural practices. These efforts should be combined with improved data collection and analysis of natural resource use. For example, a machine learning algorithm was able to generate more accurate maps of water irrigation areas – knowledge of which is crucial to making informed assessments on crop water requirements, water allocation, agricultural land planning, crop evapotranspiration patterns, basin hydrology and the impact of different types of irrigation at any spatial scale on an annual basis (Magidi et al. 2021).

- In rural contexts, the WEF nexus decision support tool can be used to provide better adaptation options, and guide decision making processes by identifying priority areas needing intervention, enhancing synergies, and minimising trade-offs necessary for resilient rural communities (Mabhaudhi et al. 2019).

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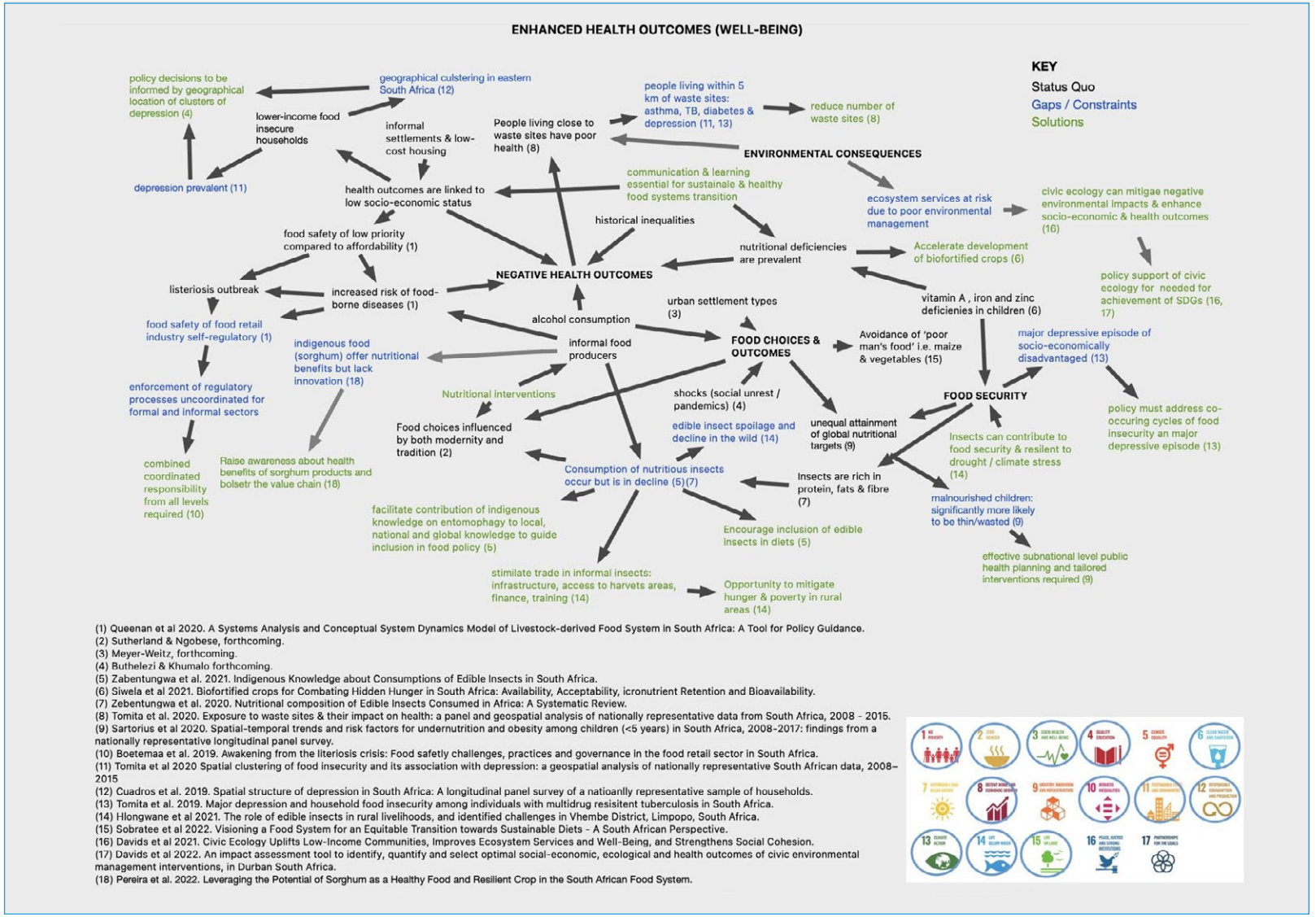
Figure 2: Enhanced health outcomes



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5 ENVIRONMENTAL SUSTAINABILITY

5.1 Status quo

5.1.1 Environmental benefits of indigenous foods

Indigenous crops are well-suited to growing in the environment in which they evolved and, can play an important role in adapting to the climatic, ecological, and natural limits in which resource-poor farmers reside. Promoting the increased production of indigenous and underutilised foods could have considerable nutritional, environmental and economic benefits compared to staple crops (Mabhaudhi et al. 2018; Akinola et al. 2020). There is potential for orphan crops to be grown on otherwise unsuitable land, although this needs to be supported with crop suitability mapping (Mugiyo et al. 2021). Indigenous foods are also valuable reservoirs of crop genetic diversity and biological diversity. They require fewer inputs and can have environmental benefits if complemented with efforts to mainstream sound agricultural practices (Akinola et al. 2020). Scientific evidence based on experimentation and prediction can help farmers make informed choices of crops that are likely to yield well in their environment.

Underutilised crops such as sorghum and millets, which have been traditional staples, but replaced by mainstream grains such as maize and wheat, offer opportunities to address malnutrition. However, not all crops are more nutritious or acceptable to consumers and further research would need to be conducted on the nutritional density of these crops (Mabhaudhi et al., 2019). A major obstacle is that people are not valuing indigenous foods and the potential benefit that can be derived from using them is thus neglected. Furthermore, knowledge is being lost from one generation to the next, with potentially dire implications for long-term sustainable food security (Akinola et al., 2020). The loss of sorghum from the South African food system can significantly hamper climate adaptation and agro-biodiversity (Hadebe et al. 2017). The outcomes of a successful sorghum innovation programme could improve smallholder farmers' livelihoods, make healthy food more accessible to South Africans and develop a local market for innovative products that utilize a crop that is resilient to projected climatic changes (Pereira and Hawkes 2022).

Edible insects contribute to human nutrition and play an important role in improving the livelihoods of people in rural areas of South Africa (Hlongwane et al. 2021). Insects are rich in protein, fats and fibre, with Lepidoptera having the highest protein and fat content and Coleoptera having the highest carbohydrate content (Hlongwane et al., 2020a). Some of these are already consumed at high rates in South Africa and could be promoted further. For example, eight insect species are used as food in Limpopo and KwaZulu-Natal (Hlongwane et al., 2020b). However, trade in insects is primarily an informal activity. Despite several benefits associated with trading in insects, there are many challenges such as insect spoilage and a decline in the availability of edible insects in the wild (Hlongwane et al 2021). Only four governmental organisations in Limpopo included edible insects in economic development strategies. Better support and inclusion of edible insects in food supply chains could improve nutrition outcomes.

5.1.2 Environmental and climate change impacts on food production

Indigenous species are set to perform differently under projected climate change scenarios. Crop production, specifically staple cereal crop production, will have to adapt to water scarcity and improved water productivity (output per water input) to meet food requirements (Hadebe et al. 2017). Sorghum is adaptive to climate change, is drought tolerant and was shown to have increased yields under CO2 enrichment in dry areas, and remains unaffected by higher rainfall (Hadebe et al. 2017; Pereira et al. 2021). The promotion and inclusion of sorghum among subsistence farmers will improve water productivity and food security (Hadebe et al. 2017; Pereira et al. 2021).

Climate change impacts could be managed by exploring new cropping calendars. synchronous planting increased yield and water use efficiency (WUE) for both maize landrace (5 and 14%) and bambara groundnut (35 and 47%). The most significant improvements were observed when the crops were planted 2-3 months apart. To reduce yield gaps in intercrop systems, low-cost management options (e.g., changing plant populations and sequential cropping) can increase yield and WUE under projected climate change. Consideration can also be given to how different crops grow in different soil nutrient environments. For example, *Mucuna pruriens* can adapt and grow in Phosphorus limited soils by establishing symbiosis with multiple bacterial genera and fungi, allocating its resources to the below-ground biomass to increase surface area and utilize soil Nitrogen during Phosphorus deficiency. In the KwaZulu-Natal region, farmers in grassland and savanna Phosphorus poor ecosystems can use *M. pruriens* as a green manure crop (Magadlela et al. 2020).

Rotating with indigenous crops can improve farm income, soil quality, and water productivity

New modelling systems can provide important information on the impact of climate change on cropping systems. One study found that, there was no significant difference in average rainfall across timescales, but late-century projections show an average temperature increase of 3.5°C and reference crop evapotranspiration of 155 mm (Chimonyo et al. 2020). In another study, results show a marked increase in drought frequency and intensity (one drought event in every three years), decreasing rainfall totals accompanied by both increasing temperatures and water stress during the summer season (Mpandeli et al. 2019). Emerging machine learning algorithms can predict water irrigation areas with 88% accuracy (Mgidi et al. 2021). Agricultural extension services can help farmers make informed assessments on crop water requirements, water allocation, agricultural land planning, crop evapotranspiration patterns, basin hydrology, and the impact of different types of irrigation at any spatial scale on an annual basis.

One study has found that farming of potatoes, pulses, grapes, rice, and wheat, relying on irrigation in arid areas, has created significant 'water debts' with the environment (Bonetti et al. 2022). This means surface and groundwater resources are overexploited to cultivate the crops, by a factor of up to 30, and this is expected to worsen under future climate change. Regions where this mismatch between renewable water supply and irrigation needs is particularly important are some districts in Free State, Limpopo, Northwest, and Western Cape provinces.

5.1.3 Local communities' interaction with the environment

The impacts of environmental change will differ by geography. One study showed that changes in rainfall and air temperature were uneven and thus will impact local communities differently. Thus, interventions will need to be designed at a local level and focus on educating rural populations on specific adaptation and mitigation measures (Ndlovu et al. 2021).

Growing community awareness of the environment – known as 'civic ecology' – can have important environmental benefits as well as community benefits. In one study the community reported positive changes after civic ecology interventions had been implemented (Davids et al. 2021, Martel et al. 2022a, Martel et al. 2022b). Respondents noted numerous improvements: decrease in invasive alien plants, less pollution, improved condition of wetlands and increased production of diverse vegetables. Improved habitats were linked to enhanced ecosystem services: clean water, agricultural production, harvesting of wood and increased cultural and spiritual activities. Civic ecology was shown to contribute to social-ecological system benefits and ecosystem service protection and enhancement and provides opportunities for social cohesion, education and new business opportunities (Davids et al. 2021). Urban management of ecological infrastructure can enhance food security. Civic ecology is also effective in mitigating negative environmental impacts and contributing towards the achievement of the SDGs (Davids et al. 2022).

The improvement of relationships between environment and society needs to be built through adaptive, emergent, interdependent and dynamic interventions, rather than the technical, linear and deterministic interventions of the past (Martel et al. 2019, Ziervogel et al. 2021). Locally devolved governance can play a major role in maintaining and rehabilitating sites of social-ecological importance, such as river catchments (Sutherland et al. 2019b). Building state-citizen relations through the capacity building of actors at various levels is a cornerstone to successful co-governance, and intermediaries such as civil society and academic organisations play an important role in developing this capacity (Martel et al. 2022a).

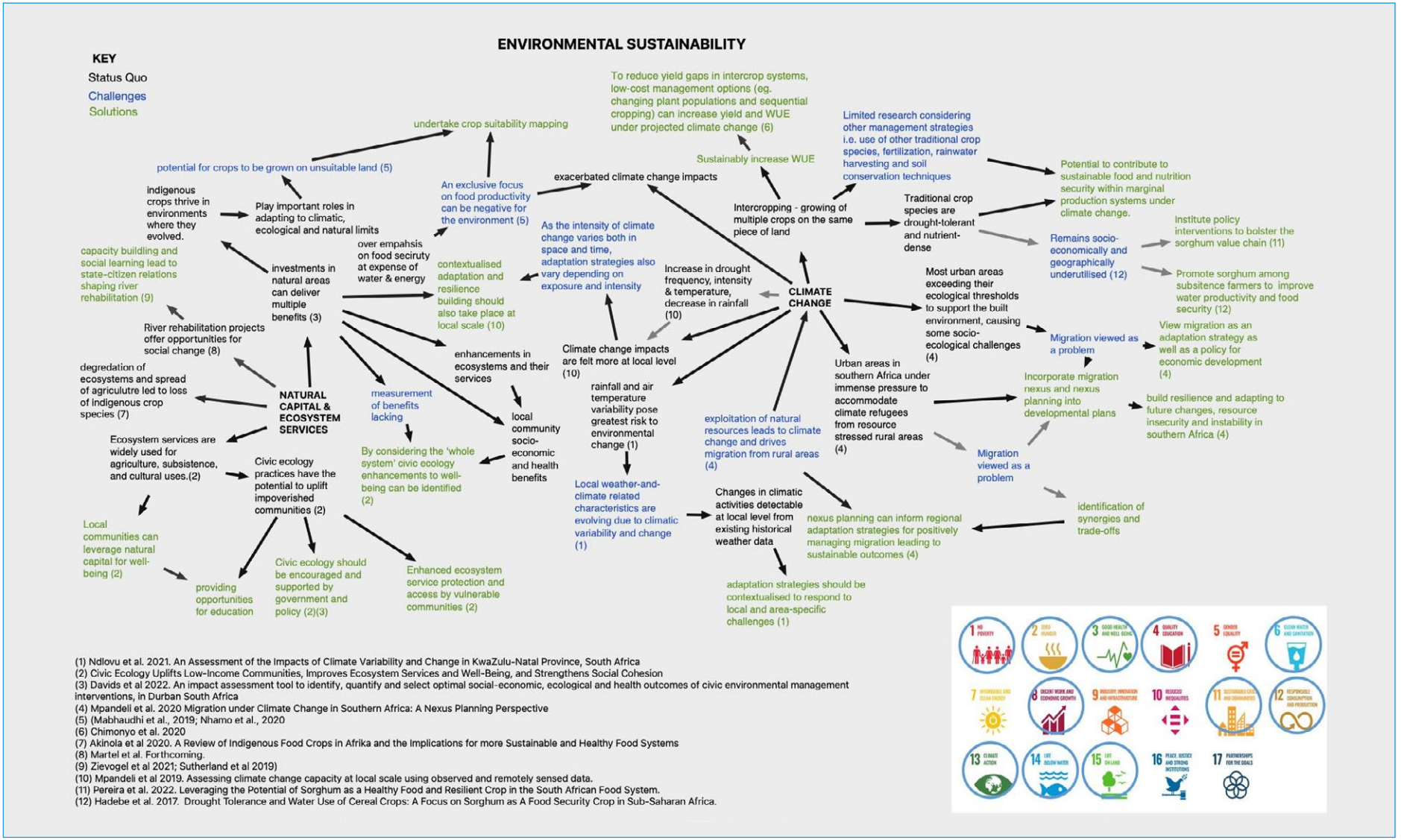
5.2 Gaps / Challenges

Exploitation of natural resources leads to climate change and drives migration from rural areas (Mpandeli et al. 2020). Migration is seen as a problem and not recognised as an adaptation strategy (Mpandeli et al. 2020). An exclusive focus on food productivity can have negative spill-over effects on the environment. For example, there is currently an overemphasis on food security at the expense of water and energy (Mabhaudhi et al. 2019; Nhamo et al. 2020). The exploitation of natural resources may exacerbate the impacts of climate change and drive increasing migration out of rural areas (Mpandeli et al. 2020). Scientific evidence based on experimentation and prediction can help farmers make informed choices of crops that are likely to yield well in their environment. New mitigation and adaptation strategies will be crucial to curbing the negative impacts of climate change on food production.

5.3 Solutions

- Considering the excellent source of nutrition, and potential socio-economic benefits edible insects can contribute strongly to improved food security, and rural development in developing countries (Hlongwane et al. 2021).
- The government could stimulate community benefits by providing infrastructure, access to insect harvest areas, financial support, and business training as part of a rural empowerment strategy to end hunger and poverty while creating employment opportunities in rural areas (Hlongwane et al. 2021).
- Policies to promote increased production of indigenous foods are needed to improve agricultural land and water use efficiency (Mabhaudhi et al. 2018; Akinola et al. 2020).
- The re-inclusion of sorghum in mainstream food supply chains could not only diversify diets, but could also move toward breaking colonial stereotypes of what constitutes aspirational food. Policy interventions to bolster the sorghum value chain and improve food security could have significant benefits (Hadebe et al. 2017; Pereira 2023).
- View migration as an adaptation strategy as well as a policy for economic development (Mpandeli et al. 2020). Incorporate migration nexus and nexus planning into developmental plans, this will build resilience and adapting to future changes, resource insecurity and instability in southern Africa (Mpandeli et al. 2020).
- To reduce yield gaps in intercrop systems, low-cost management options like changing plant populations and sequential cropping can increase yield and WUE under projected climate change (Chimonyo et al. 2020).
- Future land use planning and management strategies should carefully consider the spatial distribution of crop water requirements and their local sustainability to simultaneously alleviate blue-water scarcity in hotspot regions and guarantee food security in the long- term (Bonetti et al. 2022).
- Urban management of ecological infrastructure can enhance food security and would require policy support, to ensure that communities are educated and upskilled to manage natural resources for maximum benefits (Davids et al. 2021, Martel et al. 2019, 2022a, 2022b).
- Agricultural extension services can help farmers make informed assessments on crop water requirements, water allocation, agricultural land planning, crop evapotranspiration patterns, basin hydrology, and the impact of different types of irrigation at any spatial scale on an annual basis.

Figure 3: Environmental sustainability



6 FRAGMENTED GOVERNANCE

(silos, inefficient policy and legislation, strategy implementation)

6.1 Status quo

In a scan of national-level policies governing food systems in South Africa, our research found ninety-one policies covering eight main domains of the food system: agriculture, environment, economic development, land and land reform, health, education, and social protection (Kushitor et al. 2022). Agricultural production received the most significant emphasis amongst food policies, although more recent formulation has broadened the scope to include livelihoods, social protection, and nutrition. Nonetheless, policy formulations continue to exist in silos offering few tangible mechanisms to address inter-linked, systemic issues (Kushitor et al. 2022) (Figure 3). International experience reveals that food policy development often occurs in silos and offers few tangible mechanisms to address the interlinked, systemic issues underpinning food and nutrition insecurity (Kushitor et al. 2022). We investigated what South African government policies cover in terms of different aspects of the food system, who is responsible for them, and how coordinated they are (Kushitor et al. 2022). Policies were formulated and implemented in silos. (Figure 4)

The impacts of disjointed governance can particularly be seen in the oversight of food safety. A study of the 2017-18 foodborne listeriosis outbreak revealed that a lack of clarity on the distribution of responsibility over food safety across government departments limits the degree to which businesses are held accountable and how well food handlers are educated on food safety practices (Boatemaa et al. 2019). A study of the commercial broiler chicken system also showed similar results, highlighting the lack of policy coherence and enforcement capacity, and recommending an overarching Food Safety Authority and improved surveillance to prevent future foodborne disease outbreaks (Queenan et al. 2021).

Holistic consideration of social-ecological system, namely, interplays between communities social, economic and environmental aspects, shows that opportunities exist for focussed environmental management that yields benefits for socio-economic upliftment and improved food security through ecosystem services (Davids et al. 2021). However, this holistic viewpoint is not considered intentionally in any one policy. The global goal to end hunger requires the interpretation of problems and change across multiple domains to create the scope for collaboration, learning, and impactful research (Sobratee et al. 2022). This study highlighted the main forces governing the current context: access to dietary diversity, sustainable beneficiation of natural capital, and 'food choice for well-being'.

Policy must recognise that food safety, sustainability, quality, and livelihoods are interlinked

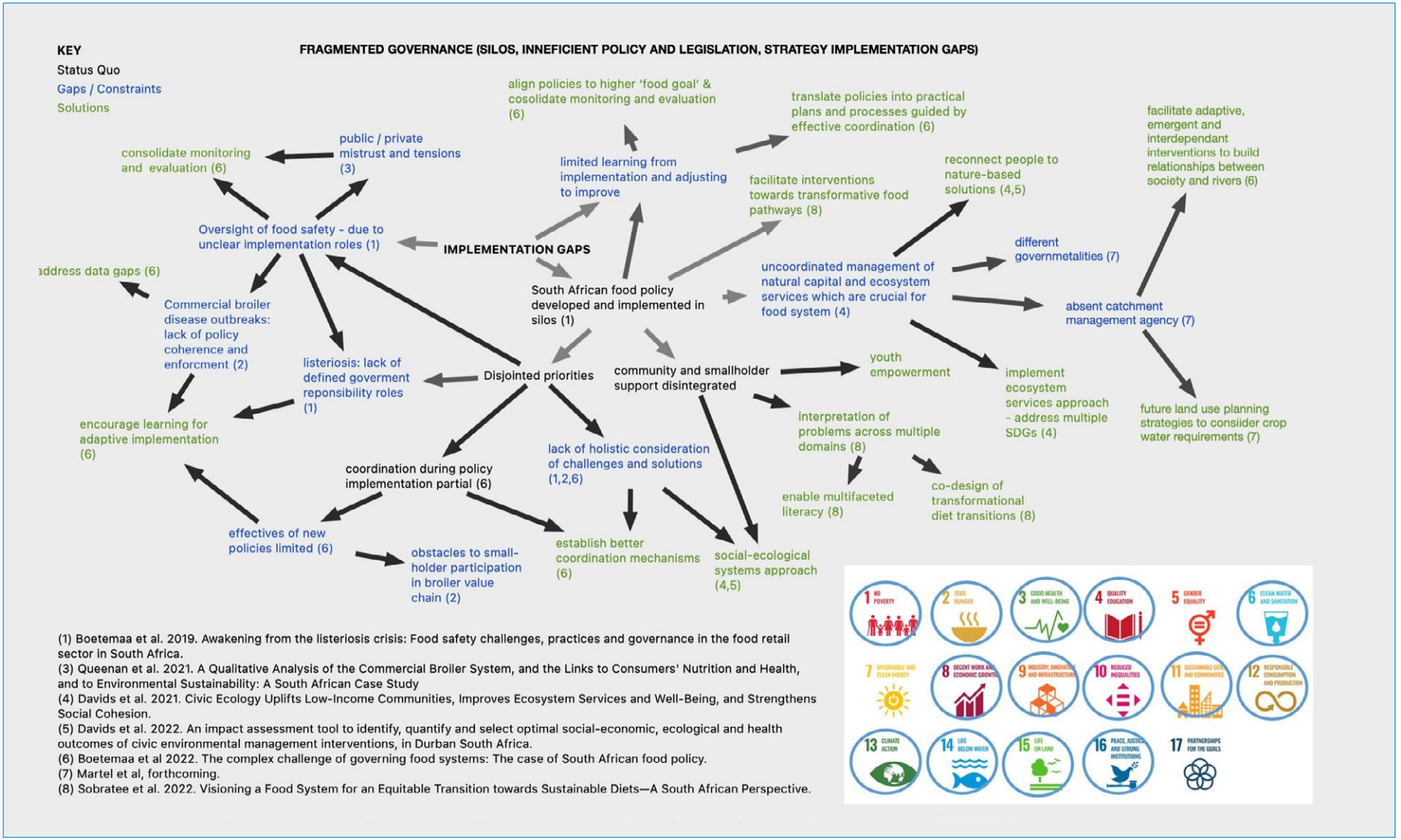
6.2 Gaps / Challenges

As a result of siloed policy mandates, learning from implementation, and adjusting to improve impact has been limited. Particularly important is that co-ordination during implementation, across these complex domains, has been partial and limits the effectiveness of new policies (Kushitor et al. 2022). Mistrust and tensions between public and private stakeholders' interests were identified as a key barrier to policy progression within the commercial broiler chicken system (Queenan et al. 2021). Insufficient coherence and integration in the implementation of agricultural development policies was also identified as important obstacles for the promotion of small holder participation in the broiler value chain (Cuevas et al. 2021).

6.3 Solutions

- To overcome these limitations, policies need to have a higher-level "food goal", establish better co-ordination mechanisms, consolidate an effective monitoring and evaluation approach to address data gaps and encourage learning for adaptive implementation (Kushitor et al. 2022).
- In order to achieve its stated food and nutrition outcomes, including Sustainable Development Goal (SDG) 2, South Africa needs to translate its policies into tangible, practical plans and processes guided by effective coordination and alignment (Kushitor et al. 2022).
- SHEFS identified microlevel leverage points via a crop systems mapping workshop —multi- faceted literacy, youth empowerment, deliberative policymaking, and promotion of sustainable diet aspirations— which can be linked and developed through existing national macro-level strategies. Thus, co-designing sustainable diet transitions could streamline research implementation outcomes to re-structure socio-technical sectors and reconnect people to the environment using nature-based solutions (Sobratee et al, 2022).

Figure 4: Fragmented governance



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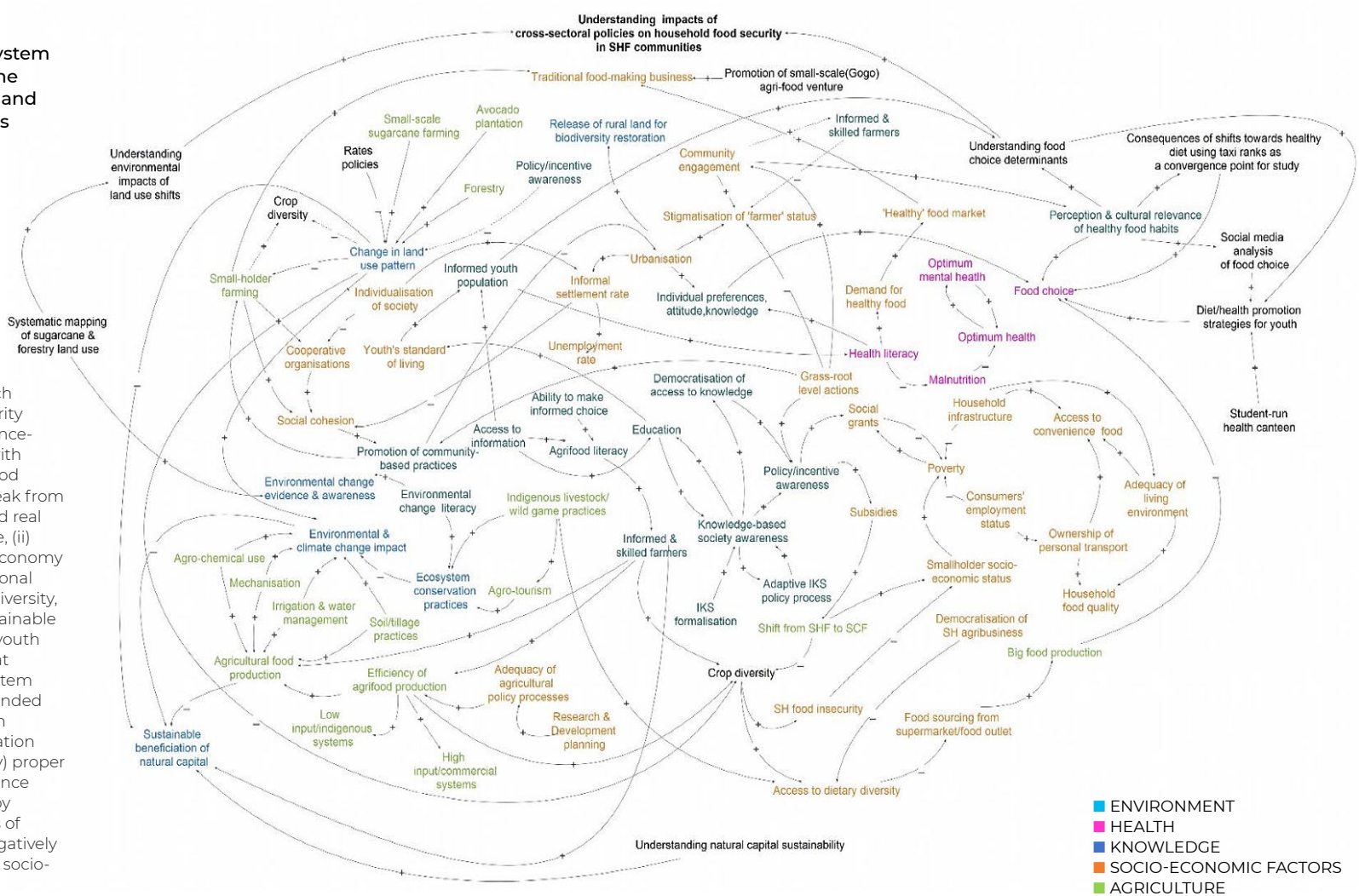
Appendix 1

Map of the foodcrop system with interlinkages to the environmental, health and socio-economic sectors

The different sub-systems are linked through causality. Altogether, the interlinkages provide a schematic understanding of how complex policy-making for sustainable diet can be.

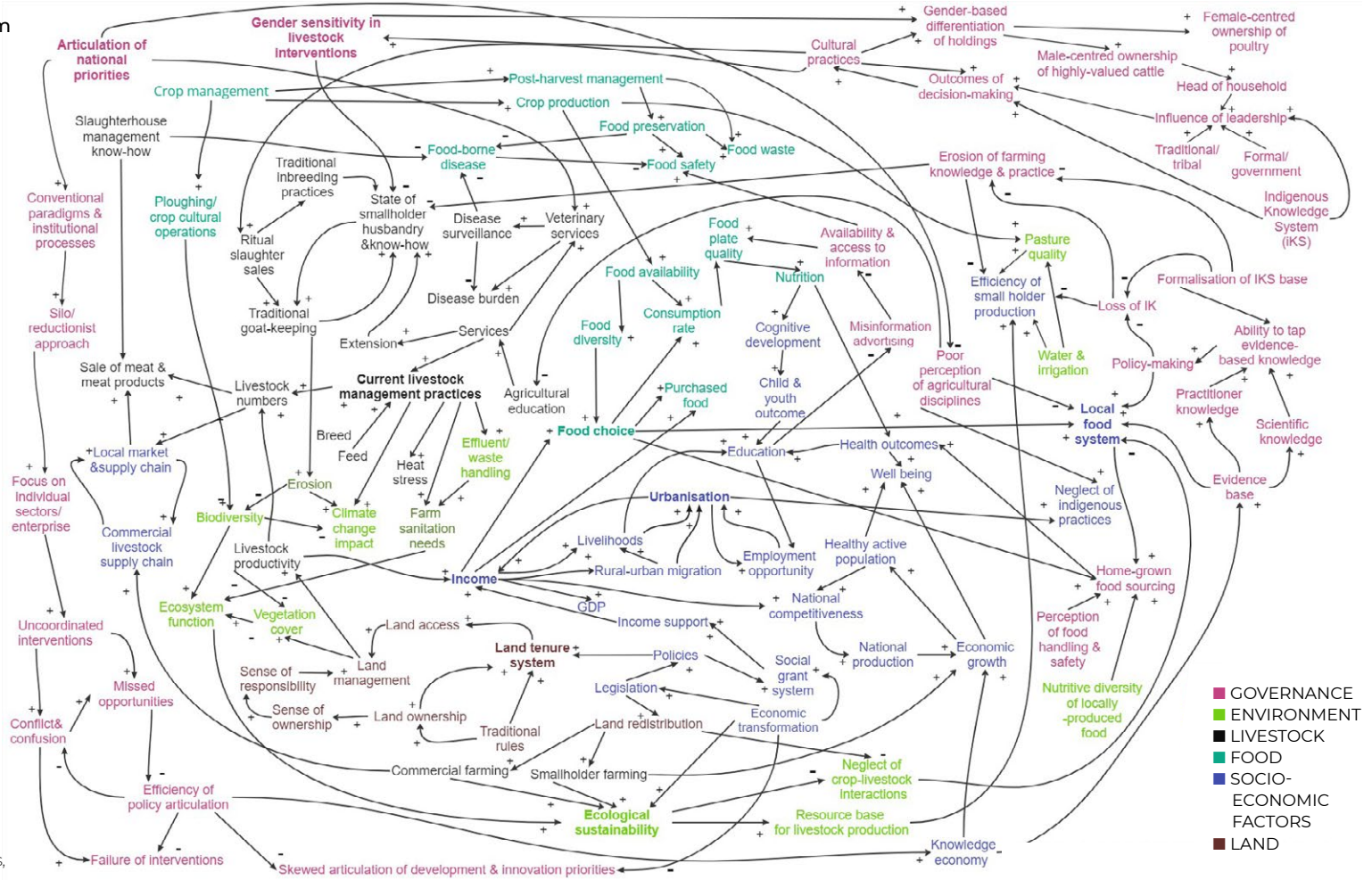
Five areas emerged from the stakeholder engagement process which can be used to define priority entry points to build evidence-based policies that align with sustainable and healthy food systems: (i) the need to break from the legacy of apartheid and real transformative governance, (ii) boosting the knowledge economy by promoting multi-functional literacy in agriculture, biodiversity, health and in guiding sustainable lifestyle aspirations of the youth (iv) agricultural policies that render the smallholder system resilient by tackling unintended consequences arising from focusing on commercialisation aspects in policymaking, (v) proper recognition of the importance of environmental literacy by mainstreaming awareness of biodiversity loss and its negatively reinforcing impacts across socio-ecological systems.



Appendix 2

Map of the livestock system with interlinkages to the environmental, health and socio-economic sector

The 'silos' in health and agriculture are driven by conventional paradigms and uncoordinated and missed opportunities. Low market access of small holders is inked to low productivity of animals. There are no incentives to increase productivity if access to the market is low. There is a perception that agriculture is an unattractive discipline. There are gender sensitivities in farming livestock. Additional income can be achieved through informing (educating) or expanding small scale farmers. Regional and global forces influence the local sphere. Land availability and access is an issue in South Africa. Land reform has good institutional models and could promote social cohesion and the upskill of communities. Most of the land is for commercial farming. There is an issue of ownership, whereby through communal ownership people can share grazing land, however, that does not mean the livestock is communally owned. Even in communal areas, livestock is individually owned.



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