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World Food Programme
SAVING LIVES
CHANGING LIVES

Unlocking Sustainable Solutions through Systems Thinking

Cases from Southern Africa

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Foreword

Southern Africa faces unique challenges that require thoughtful, practical solutions. As Regional Director of the World Food Programme (WFP), I am encouraged by how this approach helps us better understand the complex factors affecting food systems and identify effective levers for action.

This report demonstrates the value of Systems Thinking and System Dynamics in shaping smarter interventions. By examining how production, distribution, and consumption interact, we can pinpoint opportunities to make a real difference—whether by improving agricultural practices, strengthening supply chains, or ensuring the most vulnerable have access to nutritious food.

The insights shared here also highlight the power of regional collaboration. Many challenges—like low agricultural productivity or supply chain inefficiencies—are shared across borders. By working together, sharing resources, and learning from one another, we can amplify our impact and create meaningful change.

Looking ahead, I believe that this systemic approach will strengthen our partnerships, improve coordination, and enable us to deliver results that truly transform lives. Together, we can build a more resilient and sustainable future for all.

Eric Perdison

Regional Director
World Food Programme – Southern Africa

Executive summary

The World Food Programme (WFP) is actively engaged in reducing hunger and malnutrition, aligning its efforts with the Sustainable Development Goals (SDGs), particularly emphasising SDG 2 (Zero Hunger) and SDG 17 (Partnerships). Recognising the complexity of global and regional challenges, WFP has adopted a multifaceted approach tailored to individual countries. This approach actively involves national stakeholders in decision-making processes, with WFP as a facilitator. This shift towards inclusivity is reflected in the development of Country Strategic Plans (CSPs), uniquely crafted for each country, encompassing a comprehensive humanitarian and development portfolio. These plans outline clearly defined Strategic Outcomes closely aligned with National Development Plans.

WFP has employed qualitative and quantitative systems approaches, such as Systems Thinking and System Dynamics, to underpin its strategic analyses. These methodologies examine national and regional dynamics within the context of stated development objectives, thus formulating thematic and sectoral strategies. They facilitate the exploration of both national and regional synergies, as delineated in the CSPs. The models in this report cover past and expected changes in the short, medium, and long term, reaching up to 2050. This long time frame helps us understand how CSP interventions might affect society and the economy.

Systems Thinking is an approach that allows us to understand better and forecast the outcomes of decisions across sectors and economic actors over time and space. (Probst & Bassi, 2014). It emphasises that the system comprises several interconnected parts rather than focusing on its individual parts.

The merging of knowledge using Systems Thinking and System Dynamics has notably enhanced the strategic planning process for WFP Country Strategic Plans. Systems Thinking utilises practical tools such as Causal Loop Diagrams, while Systems Dynamics takes it a step further by developing corresponding

mathematical models. These tools provide a robust foundation for collaborative action, steering national initiatives towards effective measures that drive food system sustainability and are also reflected in the country-led CSPs.

Countries have shown similar trends, demonstrating the potential relevance of a regional systems approach. For instance, challenges related to low profitability in food production, constraints and opportunities within distribution networks, and dietary challenges are consistently observed across different countries. This highlights the potential for utilising Systems Thinking and System Dynamics to address common challenges and find solutions that create synergies at a regional level, particularly in Southern Africa.

Critical Strategies for the use of Systems Thinking and System Dynamics at the regional level are twofold: (i) to provide coordinated inputs for the preparation of CSPs and (ii) to conduct analyses relevant to national and regional development strategies. These recommendations support the promotion of collaboration across sectors, applying systemic thinking in decision-making beyond food systems and extending this approach to national and regional development planning. Additionally, they endorse the use of the Green Economy Model (GEM), the integration of climate resilience into decision-making, the facilitation of regional coordination, and the building of capacity for evidence-informed decision-making.

Systems approaches are expected to contribute to overcoming program fragmentation and coordination gaps, thereby improving the implementation effectiveness of CSPs and regional development strategies.

1 Background

1.1 MOTIVATION OF WFP'S ENGAGEMENT IN STRATEGIC PLANNING

The World Food Programme (WFP) is working towards the reduction of hunger and malnutrition in alignment with the Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger) and SDG 17 (Partnerships for the Goals). Recognising the diverse challenges nations face at varying stages of development, with different economic, social, and demographic profiles, as well as factors like conflict and population displacement, **WFP is committed to working hand in hand with national governments.** In response to the complexities of global and regional challenges and acknowledging the unique characteristics of local contexts, WFP has been developing strategies with an integrated and diversified approach. The organisation emphasises inclusivity by involving national stakeholders in its decision-making, acting as an enabler, and bringing stakeholders across the region together. This shift is reflected in Country Strategic Plans (CSPs), designed to be unique for each country, incorporating the entire humanitarian and development portfolio into clearly defined Strategic Outcomes that fully align with national development goals.

Government, development, humanitarian organisations, institutional actors, and civil society are involved in country-led reviews and national policy documents that inform the WFP CSPs. The preparatory work prioritises the country's development goals and generates plans aligned with national strategies. These plans are systemic in integrating different development targets, inclusive in assessing implementation outcomes across various stakeholders, and designed for up to five years.

WFP uses qualitative and quantitative approaches (including Systems Thinking and System Dynamics) to provide a base of analysis for positioning its strategies. This includes analysing national and regional dynamics in the context of stated development goals to formulate thematic and sectoral strategies and explore synergies across these at the national and regional levels, as presented in the CSPs.

Qualitative and quantitative modelling has been piloted to inform the creation of several country-led CSPs. The models in this report cover past and expected changes in the short, medium, and long term, reaching up to 2050. This long timeframe helps us understand the impact of CSP interventions, with direct, indirect, and induced annual and cumulative impacts emerging across social, economic, and environmental indicators.

The long-term foresight in CSPs contributes to overcoming program fragmentation and internal and external coordination gaps. Through CSPs, WFP aims to strategically coordinate all interventions within a country to achieve zero hunger effectively, align with the 2030 Agenda as a shared global responsibility, and enhance coordination and collaboration at the regional level.

1.2 INTRODUCING COUNTRY STRATEGIC PLANS (CSPS)

CSPs are intended to maximise WFPs' contribution to achieving zero hunger while combining short- and long-term development objectives at the national and sub-national levels. Implementation of CSPs results in the creation of synergies, improved coordination and increased effectiveness. CSPs often focus on food systems due to their central role in addressing hunger and shaping the development at the country level, particularly regarding food supply and nutrition. The research by Schneider et al. (2023) offers a good overview of the state of food systems worldwide via an indicator framework that considers global development, health, and sustainability objectives. The study groups indicators into these five primary themes: (i) diets, nutrition, and health; (ii) governance; (iii) livelihoods, poverty, and equity; (iv) resilience; and (v) environment, natural resources, and production. The overall conclusion drawn from the study is that no country, region, or income group shows satisfactory performance across all indicators. Specifically, regarding diets, nutrition, and health, the research found that while the cost of healthy diets is comparable across most countries, it remains unaffordable, mainly in low- and middle-income countries. Concerning governance, outcomes indicate that only 29 countries explicitly acknowledge the right to food, and health-related food taxes are present in 38 countries only. Regarding livelihoods, poverty, and equity, unemployment in urban areas emerges, with under employment becoming more widespread in rural areas. Moreover, a notable gender gap exists in rural areas' labour force and landholdings. **Regarding resilience, the Southern Africa region is characterised by high exposure or lower resilience capacities, as evidenced by increased food price volatility and food supply variability** (e.g. for Lesotho and Madagascar), resulting in a growing trend of undernourishment over the last decade (FAO, AUC, ECA and WFP, 2023).

Indicators on the environment, natural resources, and production suggest that the availability of fruits and vegetables is generally challenging in low- and middle-income countries. In contrast, high-income countries tend to have widespread access to ultra-processed foods. The data indicates that northern Africa and western and southern Asia are most at risk of depleting water resources. Finally, despite recent improvements, the study notes that total food system emissions are rising, mainly in high-income countries.

Since food systems encompass a complex network of activities involving food production, distribution, and consumption, CSPs cover several sectors, economic actors, and policy outcomes. As a result, several challenges must be considered in preparing a CSP, which requires a systemic approach. A few examples are provided next.

Production challenges include (i) climate change impacts, posing a significant threat to agricultural production (Intergovernmental Panel on Climate Change, 2014). Changing weather patterns, including altered precipitation and temperature levels, can lead to more variable crop yields and affect the overall productivity of the land (Fanzo, Davis, McLaren, & Choufani, 2018), and hence, it can impact income creation and food availability. (ii) Issues in securing production inputs such as seeds, fertilisers, and pesticides for farmers, with limited access to these resources hindering optimal agricultural practices and reducing crop yields (Kook Woo, Riley, & Wu, 2020). (iii) Difficulties in adopting sustainable and efficient production practices involving the promotion of agroecological methods, precision farming, and technology adoption to enhance productivity while minimising environmental impact (Meemken & Qaim, 2018), and possibly improving habitat quality and biodiversity.

Distribution challenges include (i) inadequate transportation and storage infrastructure, exacerbated by the impacts of extreme weather events, which can impede the efficient movement of food from production areas to distribution points and ultimately to consumers (Brown, et al., 2015). (ii) The absence of a reliable cold chain and insufficient storage facilities contribute significantly to post-harvest losses, especially in perishable goods. Temperature fluctuations during transportation and storage can compromise food quality and safety related to climate change. (iii) Limited capacity among farmers to aggregate their produce can hinder economies of scale in distribution. Strengthening farmers' cooperatives and facilitating collective marketing efforts can improve distribution efficiency.

Consumption challenges include food availability, accessibility, and affordability. On the former, (i) ensuring a consistent and diverse supply of nutritious food is crucial for promoting healthy diets. Factors such as climate change impacting agriculture and food distribution can affect the availability of certain food items in local markets. (ii) Access to food is about physical proximity, as well as (iii) affordability (Brown, et al., 2015). Economic factors and income levels influence individuals' access to a diverse and nutritious diet. Finally, (iv) the lack of knowledge about healthy diets is a concern. Promoting awareness and understanding about nutrition and healthy diets is crucial for influencing consumption patterns. Education campaigns can help individuals make informed choices about their food intake.

Addressing these challenges requires a societal approach involving governments, NGOs, the private sector, and local communities, which aligns with the CSP process implemented by WFP. The role of WFP and the strategic importance of CSPs becomes even more critical when considering that sustainable and resilient food systems are crucial enablers of sustainable development. They support human health and labour productivity while limiting costs for health provisioning.

Finally, the knowledge integration offered by the use of Systems Thinking and the participatory, co-creation process used to create the CLDs, allowed for (i) the implementation of an effective process in the elaboration of other planning exercises, including the Common Country Analysis (CCA) in Madagascar. Similarly, the broad and systemic scope of the CCA provided inputs to the development of the CSP at the country level. While the latter is more focused, the use of Systems Thinking made so that it remained systemic and explored the emergence of different dynamics over time.

2 Using Systems Thinking for the formulation of CSPs

2.1 INTRODUCING SYSTEMS THINKING (ST) AND SYSTEM DYNAMICS (SD)

Systems thinking is an interdisciplinary approach that views systems as interacting and interdependent rather than a collection of individual parts. It allows us to understand better and forecast the outcomes of our decisions across sectors and economic actors over time and in space (Probst & Bassi, 2014).

With ST being an approach, several methodologies and tools support its implementation and the identification of the underlying functioning mechanisms of a system and their quantification and evolution over time. In general terms, it can be said that identifying a system's components and their relationships (e.g., carried out using a qualitative Causal Loop Diagram) represents (i) the soft side of Systems Thinking. While, attempts to quantify these linkages and forecast how their strength might change over time (e.g., carried out using System Dynamics models) represent (ii) the hard side of the field.

Concerning the soft, qualitative side (i), system maps create a shared understanding of how the **system works and identify effective entry points for (human) intervention,** such as public policies. When done using a participatory approach, creating system maps helps bring people together, making the required building blocks for co-creating a shared and influential theory of change. On the rugged, quantitative side (ii), **System Dynamic models allow us to quantify policy outcomes across social, economic, and environmental indicators** (UNEP, 2014), providing insights on the relative strength of various drivers of change (scenario analysis) and supporting the identification and prioritisation of policy intervention (policy analysis). These models can be bottom-up or top-down. (Probst & Bassi, 2014).

ST and SD have been extensively used to inform policymaking for sustainable development. UNEP, GGGI, GIZ, WRI and several other organisations have supported the creation of SD models for Green Economy and Green Growth policy assessments in more than 30 countries. Currently, SD models are used to support the creation or update of Nationally Determined Contributions (NDC) and Low Emission Development Strategies (LEDS) (e.g. in Ethiopia. (Belay, Elliott, & Hedeto, 2021; Tesfahunegn & Gebru, 2021; WRI, 2020; World Bank, 2021) and Burkina Faso), Net Zero and Nature Positive strategies (e.g. in Indonesia (BAPPENAS, 2021)). In the context of food systems, the TEEB AgriFood report promoted Systems Thinking as its underlying framework. (TEEB, 2018), and supported the creation of customised SD models in various countries (UNSD & TEEB, 2021).

In the context of the WFP CSP work, the role of ST is to assess the extent to which the main drivers of change considered (i.e., the factors that affect production, distribution, and consumption in the food systems) can shape future trends, positively impact existing policy effectiveness, and point out potential future interventions. This, in turn, allows us to identify a system's safe operating space and limits, anticipating the emergence of side effects across social, economic, and environmental indicators.

2.2 HOW WAS A SYSTEMIC APPROACH USED TO INFORM THE CREATION OF CSPS?

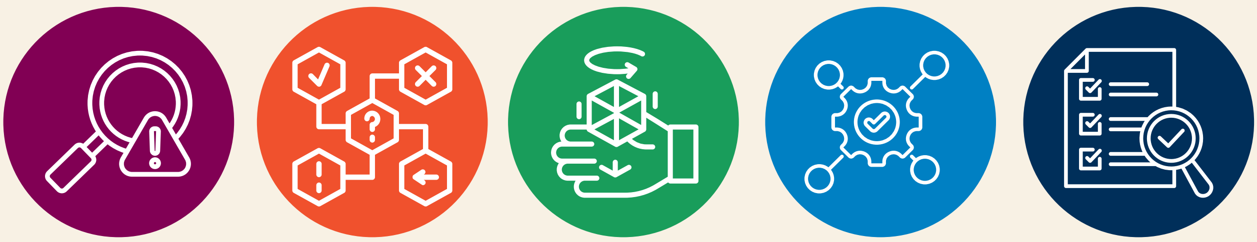
CSPs use ST and SD methodologies to combine knowledge from different areas, policies, documents, and data sources and support using a data-driven and science-based approach to strategy development. This approach aids WFP and its national partners understand the complex relationships within countries' food systems.

The support provided to the formulation of CSPs involved a structured 5-step process (Figure 1), consistently applied in each country through a co-creation approach. This process was tailored to the specific needs of each nation, with a focus on adapting the analysis and models according to national requirements.

Capacity building was offered about the methodology (i.e., Systems Thinking and CLDs) and its implementation (i.e., creating CLDs step-by-step, using a participatory and multi-stakeholder approach). Country offices have received training and support to enhance their understanding of these tools, both for improving their use in the CSP process and for other potential future uses. This empowers WFP country offices to navigate the complexity of their respective food systems, identify critical variables, analyse known and emerging trends, and assess the potential impacts of different interventions.

Resilient food systems are at the core of WFP's work and instrumental to realising multidimensional development objectives. They link the WFP's Saving Lives and Changing Lives agendas and are central to WFP's Strategic Plan (2022-25) and the Global Food Crisis Response (WFP, 2022). For this reason, the goal is to build the capacity of country offices to use these tools for strategic planning and decision-making so that the synergies between the work of WFP and national counterparts can be better harnessed.

FIGURE 1: RESEARCH METHOD, MORE DETAILS ARE PROVIDED IN ANNEX 2.



PROBLEM IDENTIFICATION
Considered the factors affecting a farmer's profitability and nutrition

DYNAMIC HYPOTHESIS
Creating a system map (also called Causal Loop Diagram, CLD) that supports the identification of key variables, their interconnections and the feedback loops that causes changes in the system.

MODEL FORMULATION
The creation of the mathematical model, using the CLD as a blueprint.

MODEL VALIDATION
Validating the model, considering both historical data and expected future trends.

POLICY ANALYSIS
Representing future scenarios to estimate effectiveness and efficiency, considering indicators of social, economic and environmental outcomes

Specifically, the following tasks have been performed in each of the countries supported:

1. **Problem identification:** Also called agenda setting, this task focuses on identifying the problem to be analysed. For the food systems of Madagascar, to provide an example, this includes issues of land productivity and pre- and post-harvest losses, the time to reach markets, the resulting distribution of food losses that affect farmers' profitability and nutrition, with limited varieties of food and incredibly fresh and nutritious food reaching markets. All these dynamics are impacted by climate change.

2. **Dynamic hypothesis:** This task consists of creating a system map (also called Causal Loop Diagram, CLD) that identifies crucial variables, their interconnections and the feedback loops that cause changes in the system. CLDs involved stakeholders, including WFP staff, government and civil society representatives. The CLD creation process lasts between two and eight hours, depending on the number of participants involved and the type of content to be covered (e.g., the time requirement increases if training is provided). The use of CLDs supports the creation of a shared understanding among all participants of the main drivers of change in the system (including both desirable and undesirable ones). As a result, CLDs offer a blueprint for quantitative analysis, i.e. CLDs include the indicators and dynamics that a quantitative model should consist of to conduct a study that more accurately reflects the local context and generates valuable insights to guide decision-making and policy formulation.

3. **Model formulation:** The systemic nature of the context analysed, as represented in the CLDs, calls for using a multi-method approach in creating quantitative scenarios. These methods include the creation of the SD model, complemented and supported by Geographic Information System (GIS) maps and spatial models, the use of climate forecasts (across different SSP scenarios generated with varying models of climate), and the synthesis of the assessment using an integrated Cost Benefit Analysis (CBA). At this stage, the scenarios that will be simulated and analysed are identified.

4. **Model validation**: This step consists of two main types of validation: structural and behavioural. The former pertains to the validation of variables, equations, and units. The latter regards the model's results, considering historical and future trends.

5. **Policy analysis:** a validated model, representing correctly historical trends and future scenarios (baseline and including intervention options, e.g., policies, targets, investments), are used to estimate the effectiveness and efficiency of action, considering indicators of social, economic, and environmental outcomes. This analysis can be performed for policies already in place or to inform the formulation of new strategies and intervention options (we define these as "what if", exploratory scenarios). The results of scenarios of inaction (BAU) and action (for production, distribution, consumption and all these areas simultaneously) are presented and analysed, including biophysical and economic indicators.

As indicated above, ST was used primarily for knowledge integration[1] , in the process of formulating CSPs. Three main approaches are used to quantify the key indicators and dynamics of food systems included in the CLD.

First, spatial models (e.g., those used to estimate the impacts of land cover change and the consequences of extreme weather events

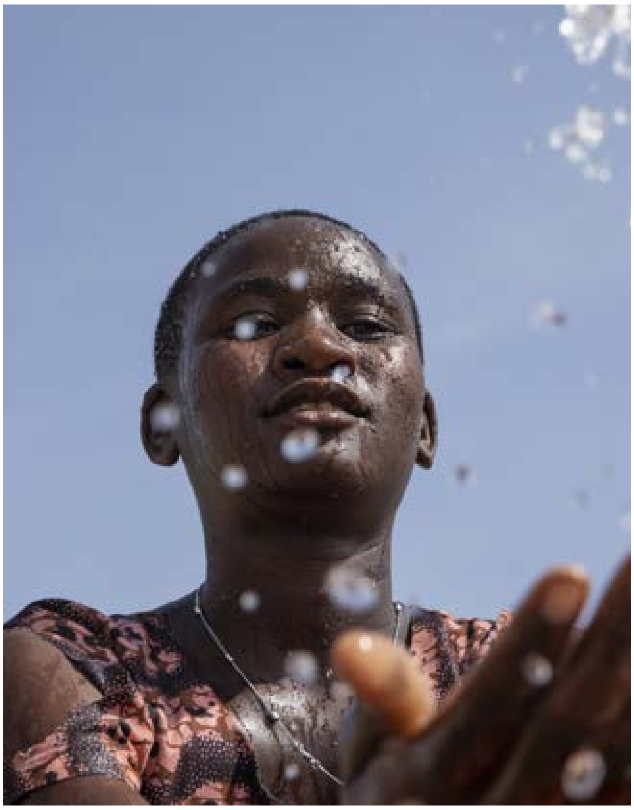
1 Example of integration: supporting the simultaneous consideration of several drivers of change, and various outcomes of policy intervention across social, economic, and environmental indicators

on agriculture production and infrastructure) play a vital role in understanding the spatial dynamics of food systems. They help visualise the distribution of resources, agricultural activities, and potential vulnerabilities to climate change. This spatial perspective contributes to more informed decision-making regarding resource allocation, infrastructure development, and disaster preparedness.

Second, climate forecasts were used to estimate the impact of climate change trends and the consequences of extreme weather events. Climate forecasts were downloaded from the EU Copernicus database, and the data was post-processed to extract the probability of extreme events related to floods and droughts.

Third, customised SD models were used to simulate the dynamic behaviour of a system over time, integrating all social, economic, and environmental indicators of relevance (i.e., those considered in the CLD and more) in a coherent analysis. System Dynamics models are a valuable tool for understanding the impact of various factors on social, economic, and environmental indicators. These models consider the interdependencies between different factors and use spatially explicit data and climate forecasts to calibrate the model. Users can gain insight into potential outcomes by testing scenarios and making informed decisions.

In summary, integrating knowledge using Systems Thinking and System Dynamics enhances the strategic planning process for the CSP. The emphasis on capacity building ensures that country offices are equipped to investigate complexity more effectively, creating value by fostering a deeper understanding of the development synergies that can be made with enhanced food systems.



Box 1: Example of approach in Madagascar

To provide an example, in the case of Madagascar, a systemic approach was employed for the estimation of the impacts of scenarios of action and inaction across sectors, for different economic actors, and covering all dimensions of sustainable development, for climate scenarios (i.e., SSP1, SSP3 and SSP5) and related shocks and stressors, in the context of food production, distribution and consumption. The application of the systemic approach includes the use of methods that are both qualitative (i.e., system mapping) and quantitative (i.e., a systemic model, coupled with the analysis of climate trends and localised impacts using land cover maps at the national level, for the north and south of the country). The combined use of these methods allowed for (i) the creation of a customised assessment and (ii) a comprehensive economic and financial analysis presented with a CBA that considers the societal impacts of investments in the sustainability of the food systems.

FIGURE 2: LAND-USE MAP OF MADAGASCAR IN 2015 (LEFT) AND ESTIMATION OF HABITAT QUALITY (RIGHT).

FIGURE 3: RUNOFF RETENTION VOLUME IN ANTANANARIVO, YEAR 2000 (LEFT) AND 2015 (RIGHT).

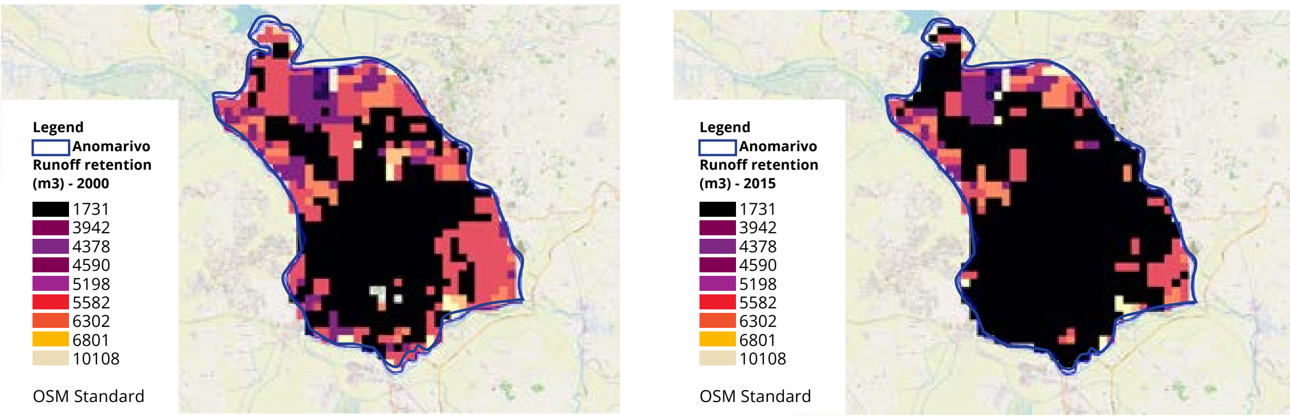
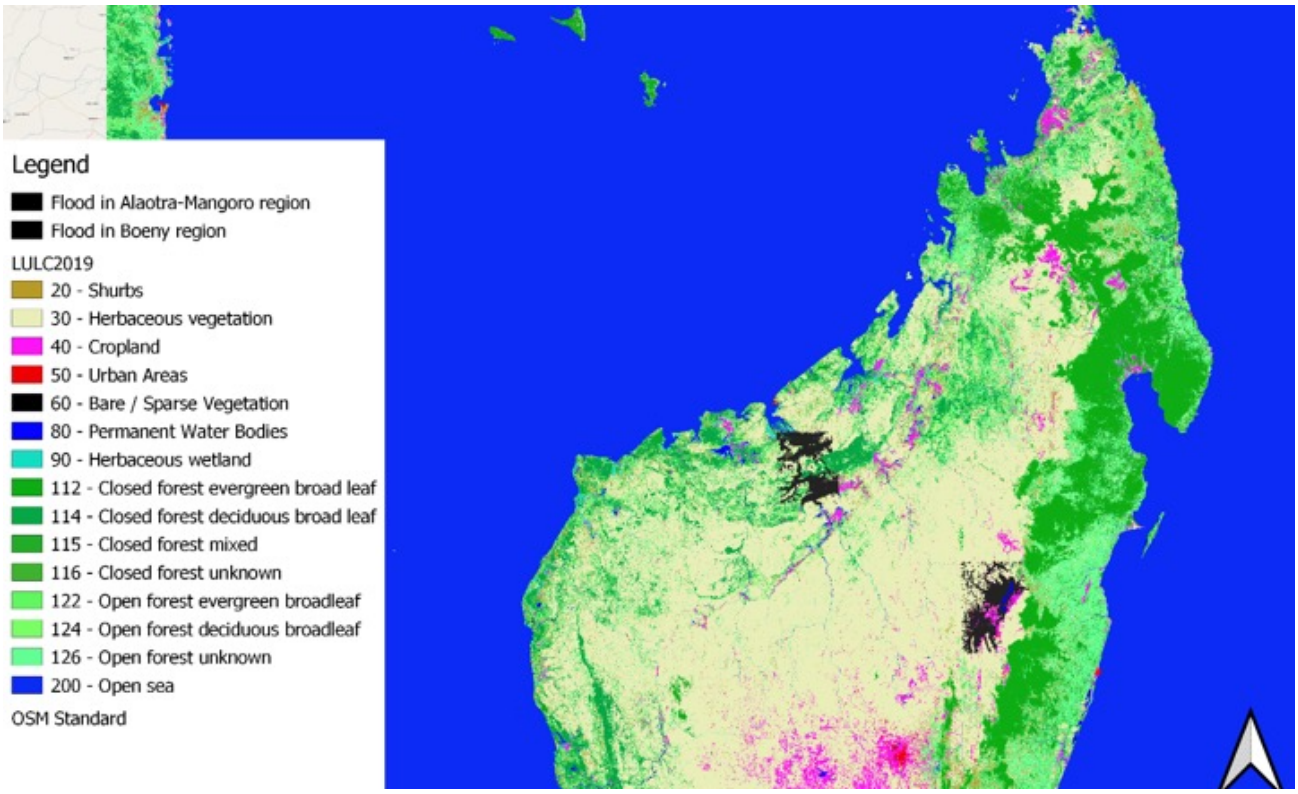


FIGURE 4: ANALYSIS OF FLOODED AREAS IN THE YEAR 2023 IN THE BOENY AND THE ALAOTRA-MANGORO REGIONS.



2.3 WHAT WERE THE OUTCOMES FOR CSPs?

The following presents a brief overview of the impact of the CSP process pertaining to Zambia, Lesotho, and Madagascar. This aims to underscore the diverse entry points for implementing systems approaches at the national level. Three cases in Tanzania, Malawi, and Madagascar are presented in more detail in the Annex to offer more information on the customisations to the modelling approach.

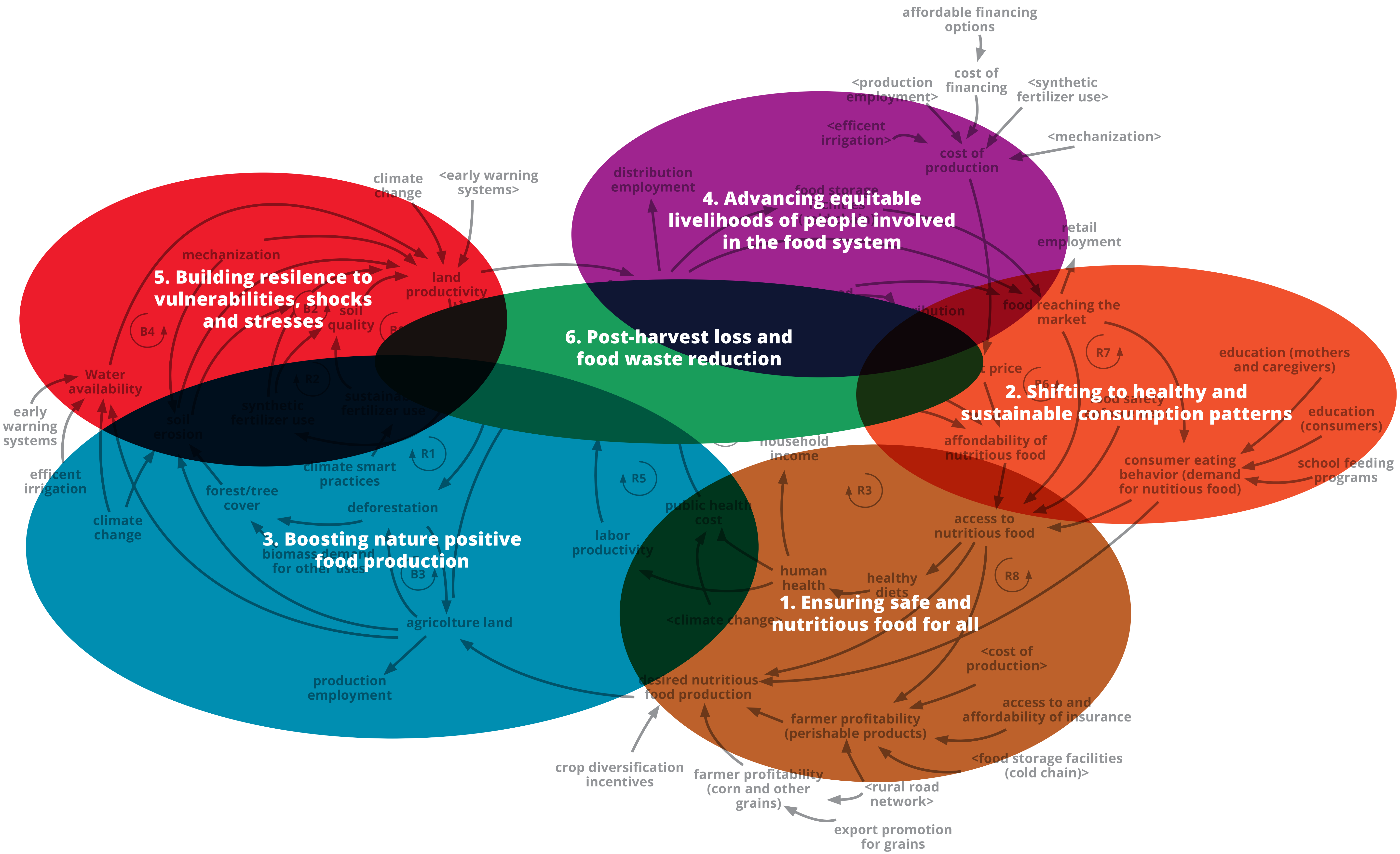
In Lesotho, the analysis focused on enhancing the sustainability of food systems, with an emphasis on increasing land productivity. It was found that improved land productivity could empower farmers to invest in better farming practices. This, in turn, could lead to higher-quality agricultural products and improved market access, mainly if the infrastructure is reliable and resilient to extreme events. Enhanced market access and stable demand may incentivise farmers to expand their cultivated area and diversify their crop mix. If there is enough demand for agricultural work, it can lead to a decrease in rural unemployment, an increase in income, and improved food affordability. This creates an explicit link between production, distribution, and consumption and has the potential to trigger systemic change.

In Zambia, the WFP country office is dedicated to reinforcing and revitalising local and national food systems to enhance their resilience to shocks and stressors. The primary focus mentioned in the CSP includes the development of robust, diverse, sustainable, and commercially viable food value chains, including in urban areas. Emphasis is placed on nutrition and resilience-building programs.

The qualitative modelling work implemented with the country team helped to identify the interconnections between WFP's areas of action and the six priority areas for the transformation of the food systems in Zambia (as depicted in the position paper "Sustainable food systems for Zambia"). Further, it has highlighted connections to (as well as synergies with) Sustainable Development Goals 2 and 17, Zambia's National Vision 2030, and the eighth National Development Plan (NDP). To realise these objectives, the strategy involves forming partnerships with various stakeholders, such as the government, private sector, FAO, other UN bodies, NGOs, and research centres. Through innovative, climate-sensitive, and evidence-based initiatives, the country office aims to contribute to the socioeconomic transformation agenda and advance progress towards zero hunger.

In Madagascar, the CSP for the period 2024-2028 aligns with the government's vision to transform food systems and enhance social protection for resilience. The overarching objective is strategically leveraging food assistance investments to address systemic issues within food systems, aiming for sustained reductions in vulnerability and hunger. Recognising the complexity of food systems, the CSP for Madagascar adopts a holistic and coordinated approach. The primary focus is building a sustainable food system that contributes to improved food diversity, livelihoods, and resilience in the face of various challenges. To achieve its goals, WFP will implement interventions that involve developing and maintaining essential infrastructure, including transportation facilities, transformation units, and cold storage. These efforts aim to improve efficiency, reduce losses, increase incomes, and enhance services for rural communities. Additionally, the modelling exercise highlighted the importance of collaborating with partners to facilitate access to land, invest in local food systems, strengthen connections with energy, and water investments and improve social cohesion.

FIGURE 5: CLD DEVELOPED FOR ZAMBIA, EMPHASISING THE INTERCONNECTIONS AMONG PRIORITY AREAS FOR TRANSFORMING THE FOOD SYSTEM.



2.4 LINKING NATIONAL CHALLENGES TO REGIONAL DYNAMICS

Understanding the regional dynamics in Southern Africa is crucial for addressing the complexities that impact food systems at the national level. Climate dynamics, food supply variability, distribution network efficiency, consumption patterns, and economic development disparities form the framework for assessing and enhancing food sustainability. Challenges and solutions often extend beyond national borders.

Climate change impacts, water scarcity and land degradation are widespread problems. Southern Africa is vulnerable to climate change, leading to increasingly unpredictable weather patterns, frequent droughts, floods, and other extreme events. These factors can negatively impact crop production, water availability, and food security. Unsustainable agricultural practices, deforestation, and soil erosion contribute to land degradation.

At the regional level, interventions can focus on improving access to production inputs and technology and sharing knowledge for best practices. Southern Africa faces significant challenges accessing agricultural inputs, such as improved seeds, fertilisers, and finance. To overcome these challenges, regional cooperation could provide an effective solution in creating economies of scale on the demand side (Steiner et al., 2020). Further, infrastructure investments, including those increasing market connectivity across countries related to transportation and storage facilities, can reduce post-harvest losses and improve the efficient distribution of food products. This, in turn, can positively impact nutrition (Fanzo et al., 2018). Finally, the policy could be tailored to improve access to regional and international markets, specifically for fresh and nutritious food (as opposed to grains). This could increase the economic viability of agriculture production, especially for healthy food that offers good margins for farmers.

Implementing these interventions is expected to benefit the region's overall resilience rather than individual countries. Agricultural diversification is expected to increase, reducing the current overreliance on a few crops or livestock breeds, often resulting in vulnerability to pests, diseases, and market fluctuations. Agricultural diversification can enhance resilience and sustainability and offer higher margins to farmers for investments in improved practices. This can reduce rural poverty and food insecurity, trigger cost savings on human health, and stimulate labour productivity.

As observed in several country CSPs, these improvements can trigger reinforcing feedback loops, generating a self-sustaining transition towards higher income, improved nutrition, and access to education, healthcare, and other economic opportunities. Further, enhanced rural development can lead to excellent political and financial stability, reducing economic volatility and improving social cohesion.

Using Systems Thinking for Enhanced Regional Coordination

Expanding the analytical framework to the regional level in addressing food system sustainability in Southern Africa involves employing practical tools for enhanced collaboration and decision-making. Further, the exchange of information can be bi-directional, with knowledge developed at the regional level (e.g., best practices, common challenges) being transferred to country offices and the experience at the country level being transferred to the regional level (e.g., on successes and failures, lessons learned).

System mapping and causal loop diagrams (CLDs), used within a Systems Thinking framework, help countries develop a shared understanding and vision for sustainable food systems. These tools identify feedback loops and analyse social, environmental, and economic dynamics. For example, regional coordination improves transport network resilience and climate change preparedness by sharing information on climate trends, impacts on rainfall, temperature, water levels in rivers and lakes, and extent of soil erosion, which can inform regional transboundary water agreements/decision-making and cross country corridor activities/logistics. Similar dynamics emerge in different countries' CLDs, such as low profitability in grain production, distribution network challenges, and dietary issues stemming from production and distribution challenges.

Using mathematical models makes complex challenges easier to understand. By generating quantitative forecasts, these models provide concrete outcomes that encourage collaborative efforts. For instance, they show how investing in road infrastructure benefits farmers, businesses, and residents. Simulation models, especially when estimating (i) social, economic, and environmental indicators, (ii) tangible and intangible indicators (including externalities), (iii) short, as well as medium- and longer-term impacts, offer a pragmatic basis for collaboration and alignment of priorities at both regional and national levels, as well as for monitoring progress towards the SDGs. This quantitative approach and shared understanding from system mapping ensure evidence-based decision-making, fostering collective responses to challenges.

In conclusion, the potential of utilising Causal Loop Diagrams and mathematical models at the regional level lies in their capacity to drive informed decision-making and promote sustainable solutions. These practical tools enhance understanding and provide a foundation for collaborative action, steering regional efforts towards effective and sustainable measures in food system sustainability that will benefit national actions, as depicted in country-led CSPs.

3 Looking ahead

The presented approach in this document is versatile and can be applied to a wide range of developmental contexts beyond national boundaries and food systems. The systemic approach adopted allows for identifying diverse entry points for action. In the specific realm of food systems, our analysis has encompassed interventions spanning food production, distribution, and consumption, identifying the synergies that emerge from strategic interventions in these interconnected domains. It has informed the analysis of **anticipatory** versus **reactive actions,** especially climate change.[2]

Practically, systems modelling can support (i) **strengthening the capacity of communities** and decision-makers at different levels, (ii) the **use of a people-centred approac**h by simultaneously making social, economic, and environmental considerations in the assessment of risks and opportunities, (iii) **integrating** not only **knowledge,** especially about the multistakeholder approach use, but **WFP programmes** also to create additional synergies for sustainable development. Moreover, (iv) the adaptability of this approach becomes evident when considering alternative entry points such as national development targets, for instance, related to education and human health, food systems, or industrialisation, highlighting the offering of **flexible and context-specific programming** rather than a pre-defined 'resilience package'.

Regarding programme and knowledge integration, while specific intervention options are available within these thematic areas, several synergies can be found when these are analysed simultaneously. For instance, improved sustainability in food systems bolsters nutritional outcomes and human health; at the same time, improved education would support farmers in adopting sustainable practices and help households appreciate nutritious and healthy diets, creating a synergy. Similarly, the improved sustainability of the food systems would support the creation of a more robust food value chain, stimulating investments in the industrial sector, for instance, for food processing; at the same time, investments in infrastructure and industrial development would enable improved access to markets for farmers, reducing post-harvest losses and creating synergy.

This underscores the inherent value of employing a systemic approach to inform decision-making processes for sustainable development. The opportunity lies in its numerous entry points for action, allowing policymakers and stakeholders to tailor interventions based on specific contexts and priorities. The goal is to realise the many varied synergies that can be created across sectors, for several economic actors, and across social, financial, and environmental development targets. Examples exist for extending the work carried out so far on food systems to the analysis of development planning strategies at the national and regional level, including multi-stakeholder processes related to sectoral and national plans, nationally Determined Contributions (NDC), Low Emission Development Strategies (LEDS), and more. One is the Green Economy Model (GEM), presented next. This type of model allows the quantification and analysis of the outcomes of WFP investments to assess the extent to which WFP contributes to the achievement of national development goals and what amount of additional public and private investment it could trigger over time, highlighting the possible emergence of synergies between WFP and public investment for development. The same analysis could be extended to the work of other UN agencies and development partners, providing an integrated assessment of the contribution of several interventions implemented by several

2 More information on the assessment of anticipatory action can be found at https://www.wfp.org/publications/2023-building-systems-anticipate-drought-southern-africa

different actors across sectors and areas of development.

The Green Economy Model (GEM) is a systems model offering an integrated representation of socio-economic and environmental dynamics and the natural capital supporting them at the country level. (Bassi, 2015; Pallaske, Bassi, Garrido, & Guzzetti, 2023). GEM is designed to inform policymaking towards sustainable development. It allows to forecast and assess the outcomes of various policies and investments concerning medium- and long-term national development targets and has been applied to date -in customised form- to more than 50 countries (see Annex 3: Applications of GEM in crucial sectors for future development). By offering a systemic approach, GEM forecasts the outcomes of action and inaction across sectors, actors, and dimensions of growth over time.

Further, GEM enables formulating policies and investment packages that result in a more inclusive, robust, and resilient outlook for the country. At the same time, using co-creation and the same method adopted to support the formulation of the country-led CSPs, GEM endorses creating a better understanding of the co-benefits associated with sustainable policies and investments, including climate action under different climate scenarios.

Figure 6 Presents the generalised underlying structure of GEM. Figure 7 Presents instead a sub-system diagram of the model. The former shows how four key capitals (built, social, human, and natural) are interconnected and how they shape future trends across social, economic, and environmental indicators. Specifically, feedback loops reinforce (R) in all economic growth and social development areas. These are driven by investments and knowledge creation and enabled by the availability of natural capital, which, if not properly managed, can constrain economic growth (hence the balancing loops -(B)- identified in the diagram). Policies can be implemented to promote sustainable consumption and production, decoupling economic growth from resource use (also through education and behavioural change) to mitigate the exploitation of natural capital and generate more robust and resilient green growth.

FIGURE 6: OVERVIEW OF GEM, BUILT ON (BASSI, 2015; PALLASKE, BASSI, GARRIDO, & GUZZETTI, 2023).

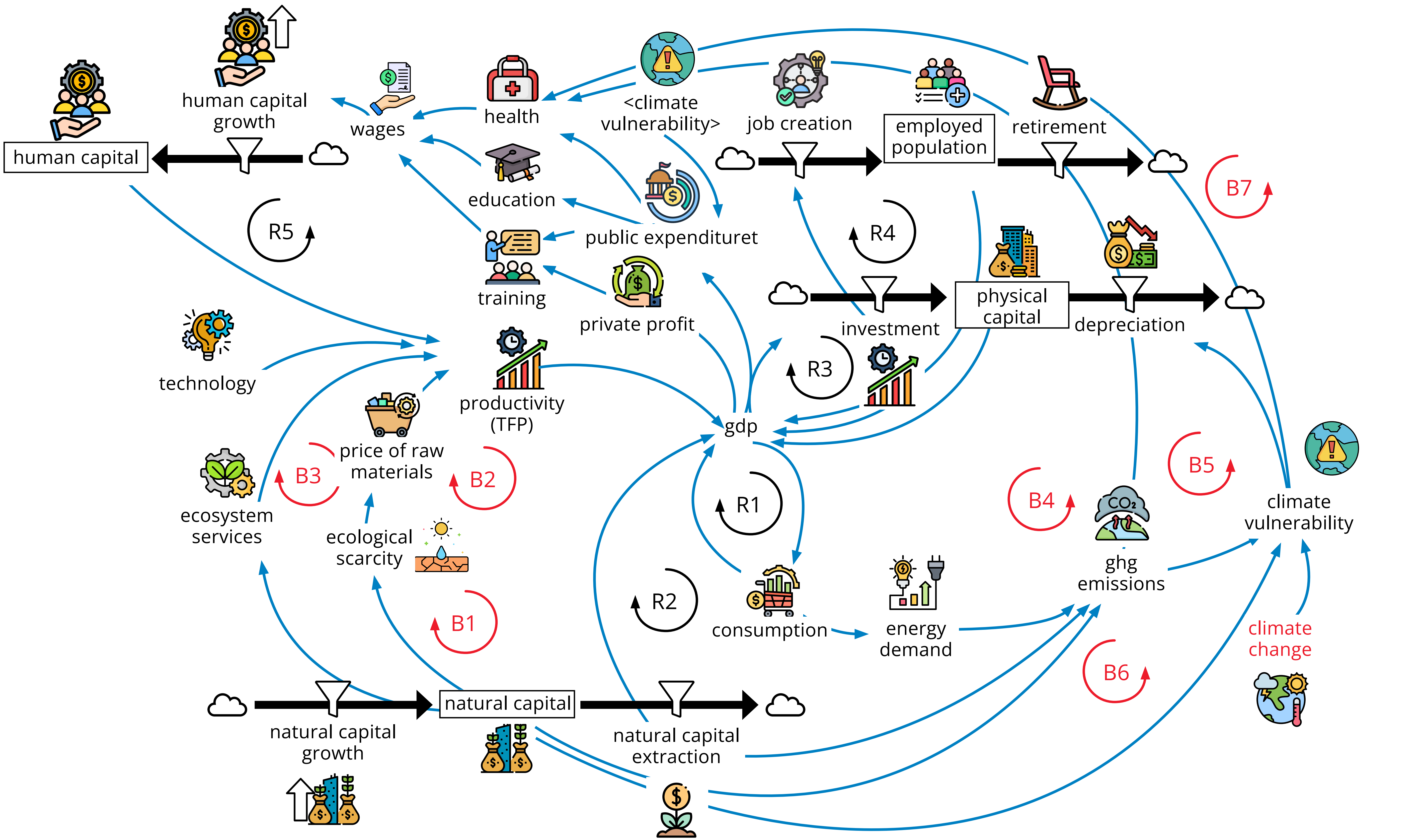
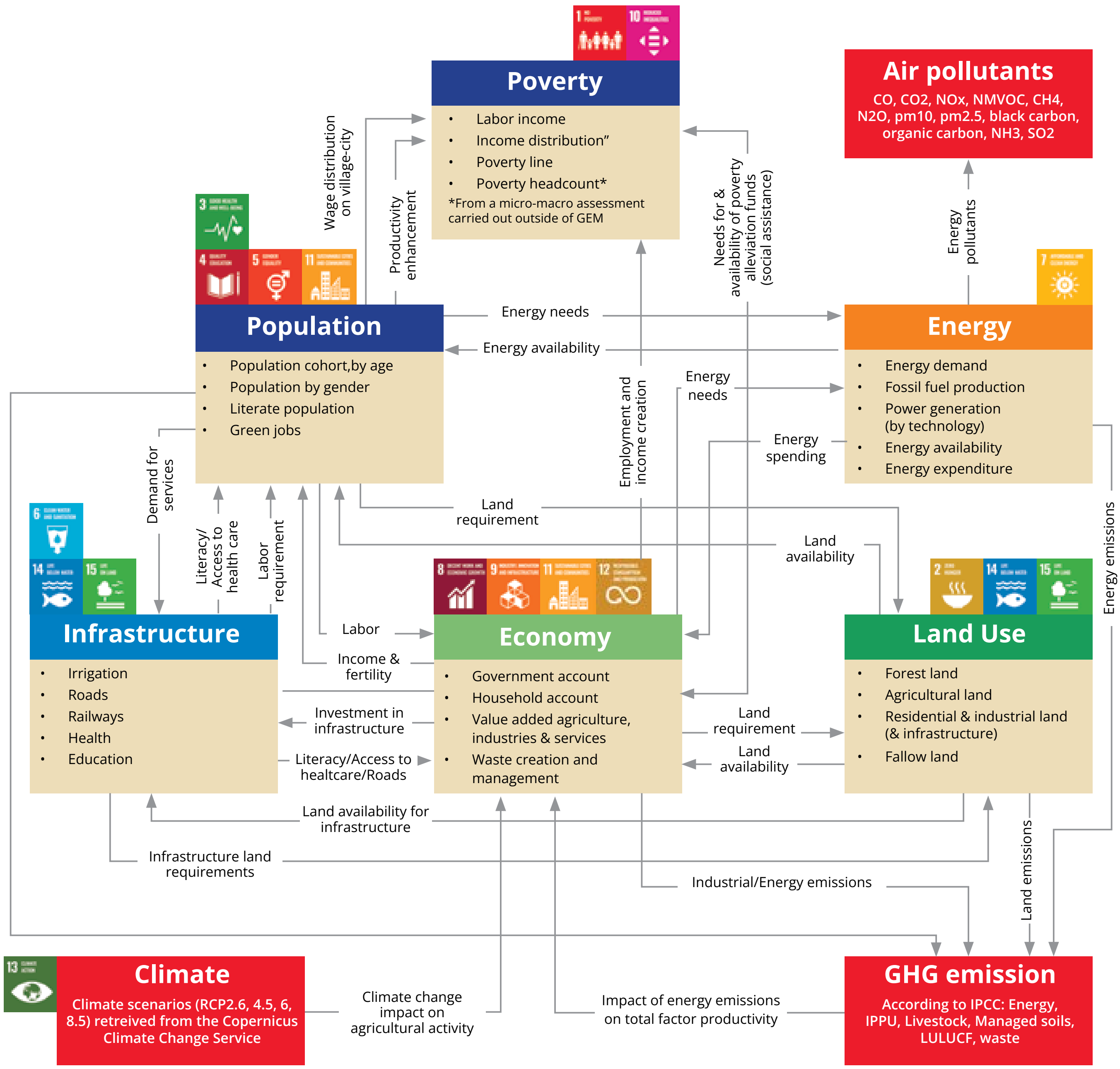


FIGURE 7: SUB-SYSTEM DIAGRAM PRESENTING THE KEY SECTORAL COMPONENTS OF GEM. (PALLASKE, BASSI, GARRIDO, & GUZZETTI, 2023).



Conclusions

In conclusion, the systemic approach employed to support the co-creation of CSPs, using Systems Thinking and System Dynamics, can contribute to a more **nuanced understanding of fragile contexts,** including but not exclusively for food systems, facilitate tailored strategic planning, and empower regional and national efforts toward sustainability and resilience.

Understanding the complexity of a system is crucial to identifying intervention options and formulating a strategy towards creating systemic change for sustainability. Three examples from Tanzania, Malawi, and Madagascar highlight this importance. Investing in distribution to improve supply and consumption effectiveness in Tanzania was crucial. Malawi found supply chains to be critical enablers for food system transformation, focusing on value chain development, capacity strengthening, market access, food safety, and value addition. Madagascar underscored the importance of climate resilience for sustainable food systems, emphasising simultaneous action in the production, distribution, and consumption stages. Integrating knowledge through Systems Thinking and System Dynamics enhanced the CSP strategic planning process. Capacity building ensured that country offices could effectively navigate system complexities, promoting a deeper understanding of synergies for sustainable food systems development. On the other hand, several limitations remain, especially in the quantitative analysis. For instance, in planning the next steps for implementation strategies, there would be value in integrating additional data on gender and youth to rerun the models and outline approaches that will effectively respond to power dynamics and inequalities in the systems analysed. These have been considered in the qualitative analysis but proved difficult to integrate in the quantitative model.

The regional view shows the potential to adopt ST and SD at a higher level of aggregation to tackle common challenges and analyse solutions that can create synergies in Southern Africa. For the region, the potential for interventions spans improved access to inputs, infrastructure investments, and policy improvements for regional and international markets. Through tools such as Causal Loop Diagrams and mathematical models, Systems Thinking at the regional level can deliver efficient decision-making and sustainable solutions, complementing those at the local and national levels.

Recommendations for the use of ST and SD at the regional level, both to provide coordinated inputs to the preparation of country CSPs as to develop analysis that is relevant to national and regional development strategies, include:

(1) Promote Cross-Sectoral Collaboration: Identify and leverage synergies between interventions in different countries and sectors, aiming for a holistic and integrated approach to sustainable development.

(2) Apply Systemic Thinking to Decision-Making and extend the Approach to National and Regional Development Planning:

- Extend the current approach beyond food systems to analyse development planning strategies at the national and regional levels.
- Consider multi-stakeholder processes related to sectoral and national plans, Nationally Determined Contributions (NDC), Low Emission Development Strategies (LEDS), etc.

(3) Utilize the Green Economy Model (GEM):

- Leverage GEM to inform policymaking towards sustainable development, considering socio-economic and environmental dynamics, including commitments to inclusion and women's empowerment.
- Forecast and assess the outcomes of various policies and investments related to medium- and long-term national development targets and estimate their impacts on food systems.

(4) Include Climate Resilience in Decision-Making:

- Consider climate resilience options and climate impacts in decision-making, integrating them into economic and financial assessments.
- Equip models, such as GEM, with climate resilience options to assess the economic and financial implications of climate action at the regional and national levels.

(5) Facilitate Regional Coordination:

- Encourage regional collaboration by addressing common challenges such as climate change impacts, water scarcity, and land degradation.
- Focus on regional interventions, such as improved access to production inputs, infrastructure investments, and policy improvements for access to regional and international markets.

(6) Build Capacity for Evidence-Informed Decision-Making:

- Build capacity among policymakers and stakeholders to use tools like system mapping, CLDs, and mathematical models for informed decision-making.
- Ensure that decision-making is evidence-based and grounded in tangible results, fostering a collective response to identified challenges.

Potential next steps for the application of systems approaches at the regional level include (i) the initiation of a pilot CLD workshop regionally to apply systemic thinking through practical exercises, (ii) defining a precise scope for the GEM model tailored to regional needs, (iii) conducting workshops for policymakers and stakeholders to enhance systemic thinking skills, triggering interest and generating demand for the use of both qualitative and quantitative systems models, and (iv) facilitate regional exchanges for peer-to-peer learning and encourage the development of case studies based on successful systemic interventions. These activities would involve WFP working at the regional level and in-country offices. Additional stakeholders could contribute to the process, including those working at the regional level (e.g., SADC, development partners, research organisations, and academia) and national decision-makers.

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Annex 1: Introducing Causal Loop Diagrams (CLDs)

The Systems Thinking tool used to identify relevant indicators and explore how these are interconnected with one another is called the Causal Loop Diagram (CLD). A CLD is a map of the system analysed or, better yet, a way to explore and represent the interconnections between the key indicators in the analysed sector or system. (Probst & Bassi, 2014). As indicated by John Sterman, "A causal diagram consists of variables connected by arrows denoting the causal influences among the variables. The important feedback loops are identified in the diagram. Causal links, shown by arrows, relate variables. Link polarities describe the structure of the system. They do not describe the behaviour of the variables. That is, they describe what would happen if there were a change. They do not describe what happens. Rather, it tells you what would happen if the variable were to change." (Sterman, 2000)

As mentioned by Sterman, CLDs include variables and arrows (called causal links), with the latter linking the variables together with a sign (either + or −) on each link, indicating a positive or negative causal relation (see Table 1). A causal link from variable A to variable B is positive if a change in A produces a change in B in the same direction. A causal link from variable A to variable B is negative if a change in A changes B in the opposite direction. Circular causal relations between variables form causal, or feedback, loops. There are two types of feedback loops: reinforcing and balancing. The former can be found when an intervention in the system triggers other changes that amplify that intervention's effect, thus reinforcing it. (Forrester, 2002). The latter, balancing loops, tend towards a goal or equilibrium, balancing the forces in the system. (Forrester, 2002).

TABLE 1: CAUSAL RELATIONS AND POLARITY

Variable A	Variable B	Sign
↑	↑	+
↓	↓	+
↑	↓	-
↓	↑	-

By highlighting the drivers and impacts of the issue to be addressed and mapping the causal relationships between the key indicators, CLDs support identifying policy outcomes using a systemic approach. (Probst & Bassi, 2014). CLDs can, in fact, be used to create storylines corresponding to the implementation of policy interventions by highlighting direct, indirect, and induced policy outcomes across social, economic, and environmental indicators.

Annex 2: Qualitative applications in Tanzania, Malawi, Madagascar, Lesotho and DRC

TANZANIA

The Causal Loop Diagrams3 (CLDs) presented in Figure 8 and Figure 9 Focus on the main dynamics influencing the food system in Tanzania. The diagram includes the key drivers of change in production, distribution, and access to food and their resulting impacts on producers (e.g., income creation and the potential to invest in improved production practices) and citizens (e.g. food affordability and nutrition). Figure 8 illustrates the full CLD, while Figure 9 highlights the main thematic areas included in the diagram. These figures present the final and most complete CLD created during two group model-building sessions.

The food system in Tanzania is complex and driven by many dynamics that often compete with one another. Some stimulate change, while others oppose it. Some result in desirable outcomes, while others prevent them. As a starting point, the team working on the co-creation of the CLD identified that a producer's decision on what crops (but this could also apply to animals, fish, forests, and home-based processed products) to grow depends on profitability as well as on the extent they require a nutritious and diversified diet, also based on cultural considerations. The presence of many women in the workforce of the agriculture sector could be used to create a positive, reinforcing feedback loop (R1) in Figure 8, women are better aware of the need for a diversified diet comprising grains, vegetables, and animal and fish products. If awareness is raised further and women are empowered, there is an opportunity to increase the sustainability of food production and the food system. Second, if production becomes more diversified, land and water productivity is expected to increase. This is due to the improved quality of soil that results from crop rotation and intercropping with legumes and vegetables. Reduced soil erosion, increased soil health, and improved water harvesting and management would increase land productivity and production and require smaller quantities of fertilisers. This higher productivity would stimulate more investments in diversified production, creating a second reinforcing loop, R2. Third, if investments in food processing accompany efforts in diversifying production, the number of products sold, and hence the revenues accrued by producers, will increase. This, represented by R3 in the CLD, further stimulates producers to diversify production. The advantage created by increasing food processing is twofold: it reduces the potential amount of food losses (growing revenues and profitability for producers). It increases the convenience of nutritious food (increasing demand, and hence indirectly increasing revenues for producers).

Fourth, building on the above, additional production of diversified and nutritious food and expanding the value chain to food processing will increase the availability of non-perishable, nutritious food in local markets. Processed food will increase the convenience of healthy food, stimulating demand, especially in urban areas or contexts with little time for caregiving. This higher demand provides an additional signal to producers, who will find it more compelling to invest in diversified production and more nutritious food (R4 in the CLD).

3 Both CLDs were prepared in two group model building sessions with internal WFP experts and government stakeholders. The sessions took place on May 31st (internal consultation) and June 15th, 2021 (external consultation) respectively.

Fifth, there are a few options to reduce food losses from distribution. On the one hand, as indicated above, food processing would reduce the risk of losses. On the other hand, if the transport network becomes more effective in delivering food promptly and storing food until demand emerges (e.g., by introducing cold storage), more fresh produce can reach the market and generate revenues. It results that, in the absence of an existing food processing value chain, the most immediate positive impact on producers' profitability is the improvement of transport and food storage infrastructure (R5 and R6 in the CLD). Increased production (also via reduced pre- and post-harvest losses) could make distribution more effective by allowing existing trucks (often oversized, 30 mt) to transport the produce.

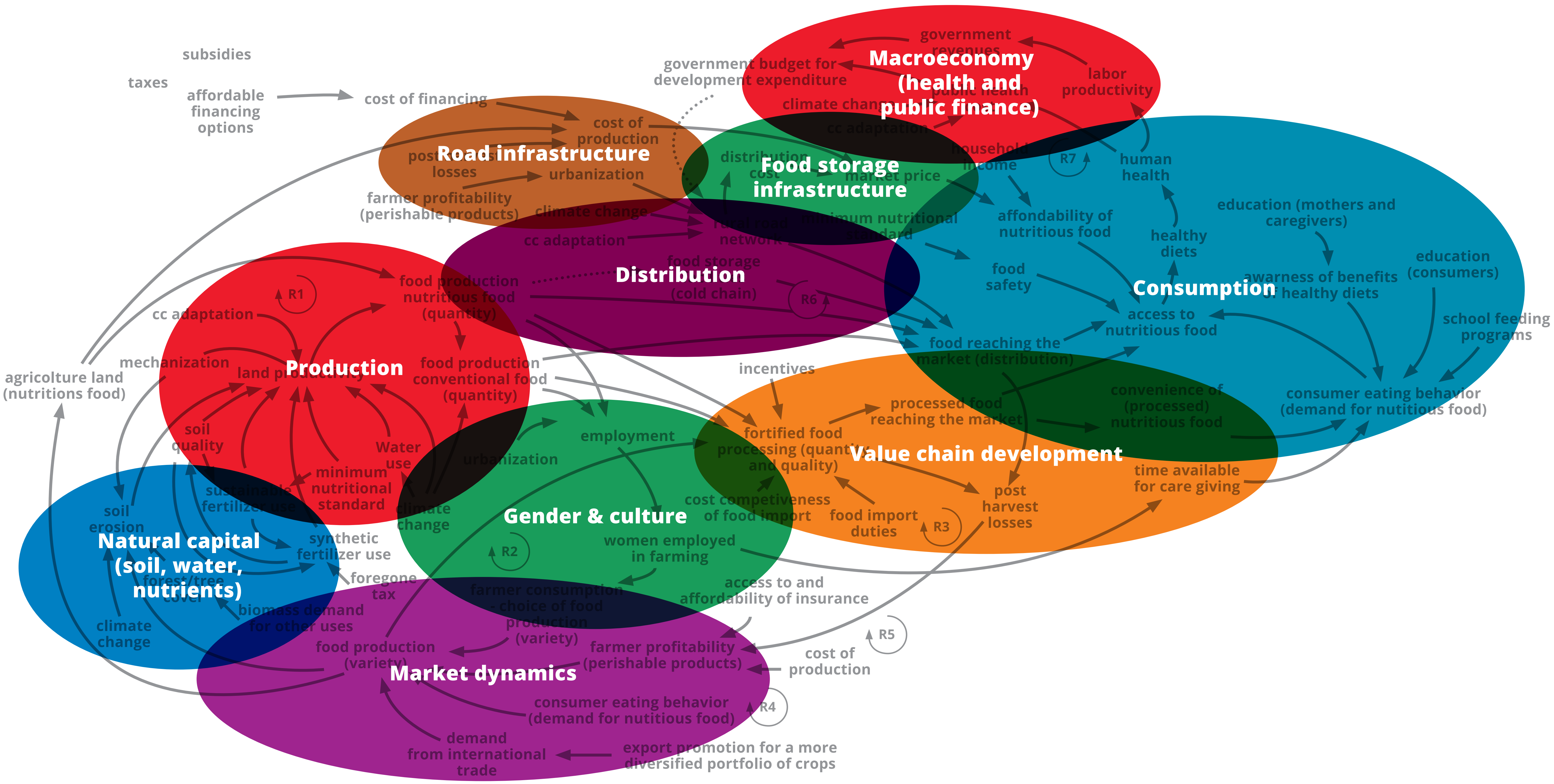
Considering the above, the study identified four main incentives for producers to invest in diversified production, namely: (1) the needs of producers and their families for food security and nutrition and income for basic needs; (2) the increased profitability from having reduced distribution losses (via an improved road network, food storage infrastructure and expanded food processing); (3) the increased consumer demand resulting from improved education and access to nutritious food; and (4) potential higher demand for exportable commodities, resulting from export promotion activities. Three of the four factors identified represent demand, and one reflects the need for the economic viability of the investment.

Many of the dynamics described above are characterised by reinforcing loops, which, when triggered, tend to be self-maintaining, creating virtuous cycles. On the other hand, historical data show that past developments have been less effective. Many challenges "break" the joyous, desirable feedback loops described above. Two of these interconnected challenges are the quality of the road network and the impact of climate change. Specifically, recent decades have seen vast improvements in the road network, but primarily in urban areas or areas that are more densely populated. This has resulted in unequal development, with comparatively lower investments in rural roads and the degradation of the quality of the road network in rural areas. This becomes even more crucial when rural roads include bridges and over/underpasses, which are more vulnerable to extreme weather events. For example, floods negatively impact unpaved highways and bridges. If roads are blocked, the time to reach markets could increase by hours, if not days. When the time to reach markets increases, the incentive to produce fresh products declines (because there is no certainty that fruits and vegetables will reach the market on time and will generate revenues). As a result, with the current quality of the road network, especially in rural areas, farmers are more incentivised to produce grains rather than horticultural and animal products. These offer lower profitability but have longer shelf lives and are more likely to generate revenues. On the other hand, the

lower profit margins of grains do not provide the resources necessary to invest in new and more sustainable climate-resilient practices. It results that, under these conditions, the production side of the food system is constrained and remains locked into low productivity, limited diversification of production and high reliance on grains and other commodities that are not impacted by the time to reach markets. Further, the concentration of supply into a few products makes the oversupply of grains an issue, possibly compressing margins. A diversified supply would prevent this problem from emerging. Roads impact decisions to invest in the expansion of agricultural land.

In conclusion, improving the food system's sustainability will likely generate benefits beyond production and distribution if known challenges are addressed well. Specifically, if higher access, affordability, and desirability of nutritious food translates into higher consumption, human health is expected to improve. The two direct outcomes of improved human health are higher labour productivity and reduced health costs for households and the government. Further, the government can expect increased revenues from improved economic performance. The combination of lower costs and higher revenues may free up resources for new investments, such as improved food storage and road networks in rural areas, to further create synergies and maximise value for money (R7 in the CLD).

FIGURE 8/9: THEMATIC AREAS INCLUDED IN THE FULL CLD (JUNE 15 SESSION) INCLUDE PRODUCTION, DISTRIBUTION, CONSUMPTION, AND INFRASTRUCTURE (FOOD STORAGE AND ROADS).



MALAWI

An integrated analysis was carried out to explore, analyse and understand the main factors affecting the food systems in Malawi. The starting point for this participatory and co-creation approach was the exploration of the drivers that affect quality of life. This is considered one of the main goals of development in the country, and food security, malnutrition and income generation were identified as critical factors affecting quality of life within the context of the food systems. We explored how the current setup influences the quality of life and how policy (affecting decision making for farmers and consumers) can improve the situation while addressing vulnerabilities emerging from external influences (e.g., climate change and trade dynamics). We explored how past and current trends have given rise to multifaceted challenges and the extent to which policy and investments aimed at improving sustainability can reduce future societal costs and generate new opportunities. The Causal Loop Diagram (CLD) developed (Figure 11) focuses on the main drivers of change in the system. It covers production, distribution, consumption, and their interactions (e.g., via access to finance, affordability, and macroeconomic performance) to fully represent the main components of the food systems in Malawi. In Figure 10, we overlay the CLD with key thematic areas to simplify the diagram and highlight the importance of considering cross-sectoral interrelations. A few fundamental dynamics and feedback loops (i.e., underlying drivers of change) emerge from the diagram (see Figure 11):

- First, we identified that food security, malnutrition and income generation are key factors affecting quality of life. We then determined that agriculture production affects all three indicators: increasing food security, reducing malnutrition and generating income for farmers and the rural population. As a result, there is strong potential for interventions in the food systems to support improving quality of life.
- Second, agriculture production is impacted by a variety of dynamics. On the one hand, soil productivity is driven by soil fertility, the ability to scale production, and the demand (and production) of a more diversified mix of crops, which is more resilient to climate change.
- Third, challenges emerge within the agriculture sector because of soil erosion, erratic climate trends, and worsening extreme events (frequency and strength) outside this sector. For instance, it was discussed that supply chain disruptions affect the access to quality production inputs (affecting soil productivity); it was mentioned that deforestation resulting from food demand (i.e., the need to expand agriculture land) and energy demand (i.e., due to the need for fuelwood, because of the limited electrification of rural areas) result in deforestation and the decline of the ecosystem services.
- Fourth, trade dynamics play an essential role in determining the sustainability of the food systems. On the one hand, food prices are impacted by demand and supply. If supply struggles to meet demand, local prices are expected to increase. Further, supply chain disruptions, high fuel costs, and an inefficient road network contributes to price increases by reducing the timely delivery of food to markets, challenging trade (within and outside the country), and exacerbating the gap between demand and supply. This reduces food affordability, adding a second economic dimension (after income generation) to determine the key drivers of quality of life.
- Fifth, the transport infrastructure's role was stressed as a potential enabler of development via the impacts it creates in the food systems. On the one hand, it provides access to markets, allowing for demand for a more diversified crop mix (which increases crop resilience to climate change, production, and nutrition). On the other hand, it reduces food (post-harvest) losses, making more agricultural produce available in the market. Either way, it increased

revenue generation for farmers. Further, reducing the time and cost of food transport increases food affordability, resulting in improved security and reduced malnutrition. In other words, transport infrastructure can positively impact all critical drivers of quality of life-related to the food systems.

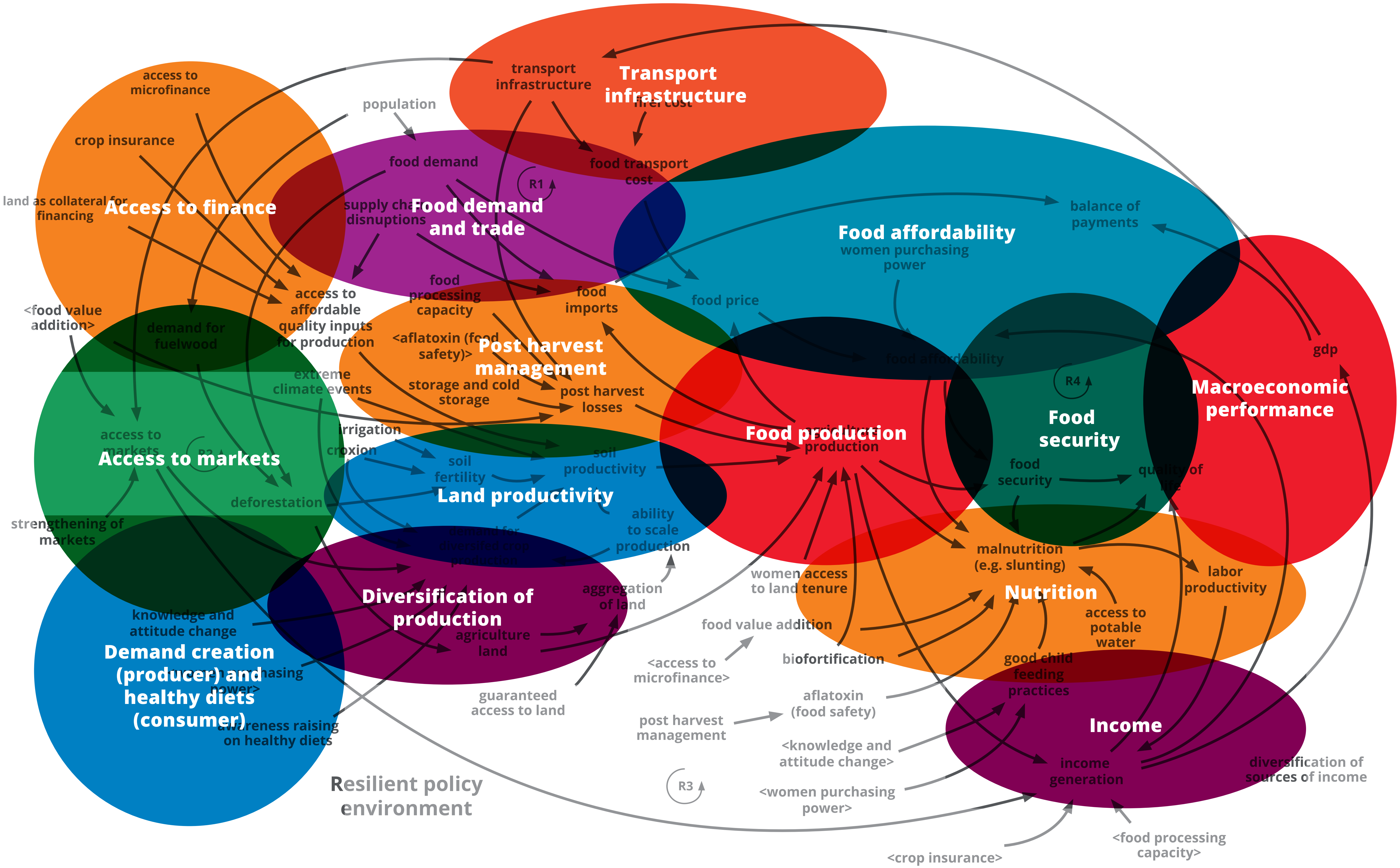
Overall, it was noted that the performance of the agriculture sector affects macroeconomic dynamics, including GDP (given the agriculture sector's importance in the national economy) and, ultimately, the country's balance of payments. This indicator is impacted by food imports, which increase if local supply cannot satisfy demand (e.g., due to low land productivity or climate change impacts).

Considering all the above, the food systems impact the country's social, economic, and environmental dynamics. Intervention options were introduced to the diagram as a final step in the system mapping exercise. The goal was to identify if actions are available to turn vicious cycles (those that have been experienced in recent years, representing challenges to production and distribution) can be turned into virtuous cycles. Examples include (i) knowledge and attitude change, awareness raising, increasing women purchasing power to support the diversification of diets and production, (ii) access to microfinance, crop insurance, using land as collateral for financing to increase access to quality inputs for production, (iii) cold storage and food processing capacity to reduce post-harvest losses and stimulate the creation of new value chains, (iv) biofortification, food value addition, post-harvest management and access to potable water to reduce malnutrition. These interventions can turn reinforcing loops representing vicious cycles into virtuous ones. Triggering one or more positive changes can create a domino effect, unlocking further opportunities for improving quality of life and sustainable development.

These dynamics are included in the CLD, represented via reinforcing (R) and balancing (B) loops, and can be summarised as follows:

- R1: The more transport infrastructure there is, the less post-harvest losses there will be. A decline in post-harvest losses increases the agricultural produce available in the market, resulting in higher income generation. With higher income, economic activity will improve (i.e., GDP), and a larger public budget will be available for investments in transport infrastructure.
- R2: The more transport infrastructure there is, the more market access, resulting in higher demand for diversified crops. A more diversified crop mix results in higher soil productivity and agriculture production. With more production, income, and GDP increase, more public budget will be available for investments in transport infrastructure.
- R3: The more transport infrastructure there is, the more market access, resulting in income and GDP increases (from sectors other than agriculture). Subsequently, the public budget would be higher, allowing for more investments in transport infrastructure.
- R4: With more income creation, food affordability is higher. With higher affordability, food security increases and malnutrition declines. With lower malnutrition, labour productivity increases, resulting in higher income generation.

FIGURE 10/11: CAUSAL LOOP DIAGRAM AND OVERLAP WITH KEY THEMATIC AREAS REPRESENTED IN THE DIAGRAM.



MADAGASCAR

The problem statement analysed for Madagascar. The food systems in Madagascar need to be made more sustainable, particularly concerning their impact on the climate. The team followed a variable-by-variable approach in creating a system map called a causal loop diagram (CLD). The complete diagram and the key thematic areas identified are presented in Figure 12. After assessing production, consumption, and nutrition, we focused on adding the main drivers of land productivity, including infrastructure, production practices and climate change. The analysis was broadened to include more aspects related to economic, social, and environmental factors that drive change. For instance, the process considered public investments in infrastructure, the role of gender equality in supporting labour productivity and investment decisions, and the extent to which it is possible to create new value chains while diversifying the sources of income. The CLD developed (Figure 13) includes all the variables that influence the main thematic areas and drivers of change in the system. It covers production, distribution, and consumption to fully represent the main components of the food systems in Madagascar. Simultaneously, these three components affect development and can, in turn, be impacted by various intervention options. A few fundamental dynamics and feedback loops (i.e., underlying drivers of change) emerge from the diagram (Figure 11). Overall, the diagram shows that the historical trends have been characterised by the dominance of challenges related primarily to low soil productivity (e.g., impacted by climate change, lack of access to financing, and limited knowledge of sustainable practices). These issues create subsequent undesirable consequences at the macroeconomic level (e.g., for GDP and government revenues). The limited contribution of the agriculture sector to the economy results in the lack of infrastructure and restricted access to basic services. Education, health, access to energy and water, and the road network are impacted negatively. It results in high postharvest losses, high food costs, difficulty creating new value chains, and limited consumption. The overall outcome is that making the conditions for increasing purchasing power via a healthy agriculture sector and income diversification is becoming increasingly challenging. On the other hand, several intervention options can change vicious cycles into virtuous ones. These are presented in orange in Figure 11. Examples include the empowerment of women to increase human capital and nutrition; diversification of production, allowing for reduced climate impacts and food losses; access to information and financing to enable the use of more efficient production practices; increased institutional capacity to better invest in infrastructure that can serve as an enabler of development. The dynamics described above are included in the CLD, represented via reinforcing (R) and balancing (B) loops, and can be summarised as follows:

- **R1:** The more production increases, the more the potential to create revenues for farmers. With higher revenues, there is more potential to access land and expand production, creating a reinforcing loop.
- **R2:** The more production increases, the more revenues and GDP increase in the agriculture sector. Given the importance of the agricultural sector in Madagascar, a higher GDP leads to increased public budget and investments, resulting in improved access to infrastructure. With more infrastructure, access to land (and land conversion as a result) would increase, resulting in higher agricultural land and production. This dynamic is reinforcing.
- **R3:** When production increases, consumption increases (directly via increased supply or indirectly via higher income). With higher consumption, nutrition also improves. Better nutrition improves human health, increasing labour productivity and production, creating a reinforcing loop.

- **R4:** With higher production, GDP, and public investment, several public services could be improved. Examples include access to energy, water, education, and health services. The empowerment from improved infrastructure results in higher labour productivity (via health and education) and soil productivity (via water and energy), all of which result in higher land productivity and production. These dynamics depict several reinforcing loops affected by infrastructure.

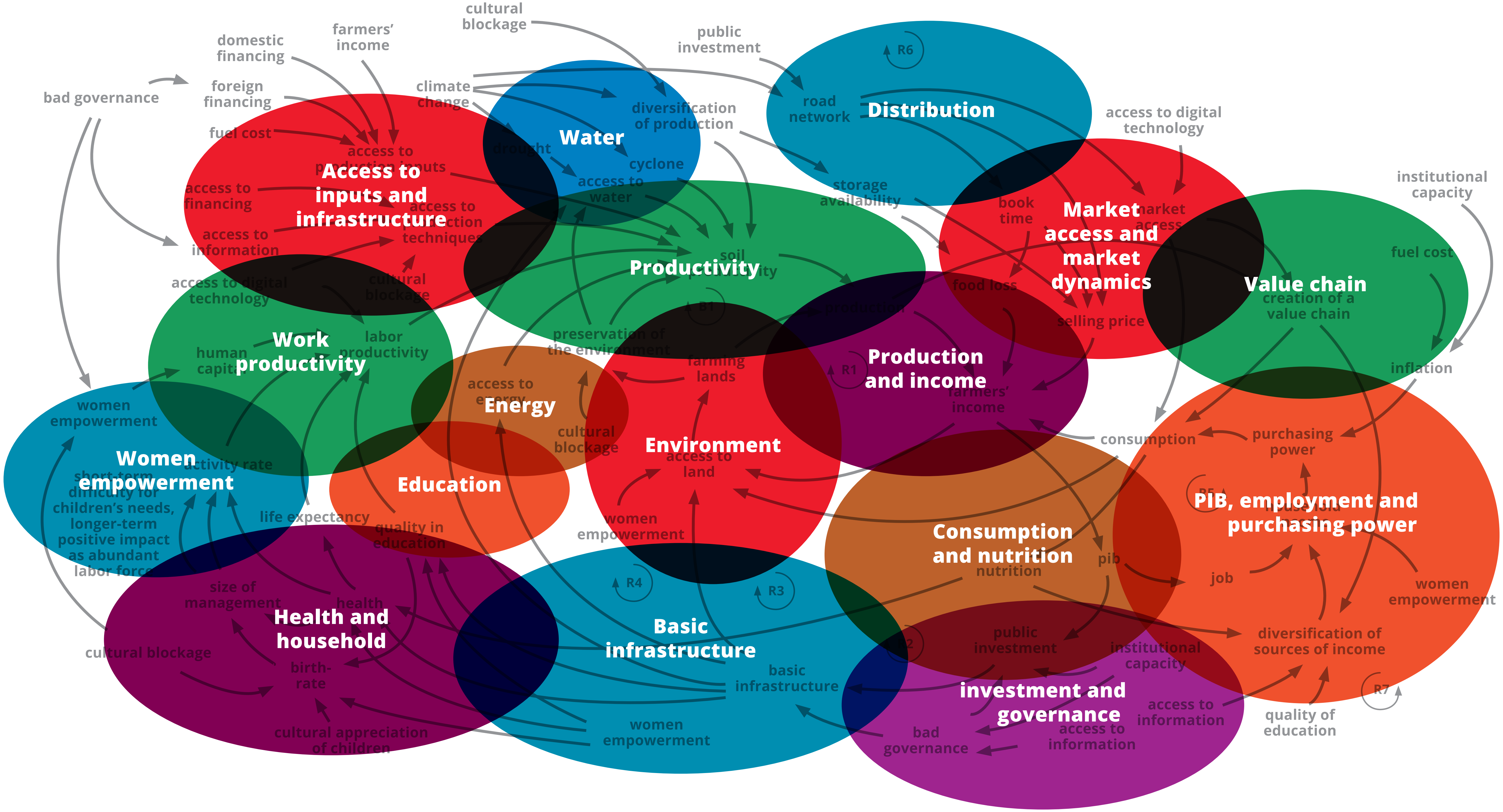
- **R5:** The more production increases, the more GDP grows. With higher GDP, employment creation occurs (both in the agriculture sector and other areas). Employment leads to income creation, which increases purchasing power. With higher purchasing power, there is more consumption, hence more revenues for farmers and higher economic activity (i.e., GDP), creating a reinforcing loop.

- **R6:** By increasing production, GDP and public investment, improving and expanding the road network is possible. This can lead to several positive impacts. Firstly, it would reduce the delivery time for food products, resulting in a decrease in food losses and an increase in farmers' revenues. This, in turn, would create a reinforcing loop, leading to further benefits. On the other hand, faster delivery translates into better quality food reaching markets, commanding a higher market price and resulting in higher revenue generation for farmers (a reinforcing loop). In addition, a more robust road network increases market access, increasing consumption (from the supply side) and creating a new value chain. These latter dynamics result in higher economic activity and income diversification, leading to a more resilient financial system.

- **R7:** The growth of agriculture production, GDP, and public investment, especially in education, creates the skills for a more diversified economy. This results in income diversification, which increases revenues, consumption, and GDP, creating a reinforcing loop.

- **B1:** A balancing loop was identified in addition to reinforcing dynamics, which stimulates change in the system. The higher the production, the higher the potential to convert land and expand agriculture production. On the other hand, the expansion of agricultural land and resulting deforestation would result in the degradation of the environment. With a lower quality ecosystem and a lower amount of intact ecosystem, land productivity will be reduced, e.g., via reduced access to water.

FIGURE 12/13: CAUSAL LOOP DIAGRAM OVERLAPS WITH THE KEY THEMATIC AREAS IDENTIFIED IN THE DIAGRAM



LESOTHO

The problem statement we have analysed is related to the opportunity to increase land productivity as a trigger to improve the sustainability of the food systems in Lesotho.

The CLD developed (Figure 11) focuses on the main drivers of change in the system. It covers production, distribution, and consumption to fully represent the main components of the food systems in Lesotho. Simultaneously, these three components affect development and can, in turn, be impacted by various intervention options.

In Figure 10, we overlay the CLD with the vital thematic areas discussed during the diagram's co-creation process.

A few fundamental dynamics and feedback loops (i.e., underlying drivers of change) emerge from the diagram (see Figure 11) as follows. Land productivity is influenced by several factors, including access to production inputs, the ability to select appropriate seeds, and adopting sustainable agricultural practices. Additionally, climate-related disasters and shocks can significantly impact land productivity. Land productivity may decline over time in regions with high climate vulnerability or fail to increase as expected.

The increase in land productivity is crucial as it directly affects the profitability of agricultural production. Higher profitability enables farmers to allocate more resources towards adopting sustainable agriculture practices and improve their access to production inputs (R2 and R3). These dynamics create a feedback loop that can either lead to progress through a virtuous cycle or result in an undesirable lock-in situation. Farmers cannot invest in improved practices and inputs in a low-profitability scenario, further perpetuating the cycle.

Increased profitability, coupled with adopting sustainable and certified production practices, is expected to enhance the quality of agricultural products, thereby facilitating market access (R1). This includes access to local and international markets, which may offer premium prices for high-quality produce. However, other factors should be considered when assessing market access potential, such as a well-developed road network (which can be affected by extreme weather events) and adequate food storage facilities. Additionally, farmers' knowledge and understanding of market dynamics are essential for successful market access.

With improved market access driven by increased profitability, farmers are motivated to expand their cultivated area. The combination of larger cultivated areas and higher land productivity leads to increased food production, which contributes to more significant revenue and income generation at the individual farmer level. At the macro level, food availability helps stabilise food prices and improve consumer affordability.

Expanding agricultural land is significant in job creation if there is interest in farming jobs. However, it is essential to note that agriculture employment is often not considered attractive due to limited profitability and the lack of public services in rural areas. Rural infrastructure, which extreme weather events can negatively impact, is another factor that affects the appeal of farming jobs.

Suppose there is sufficient demand for agricultural employment, which can be met. In that case, the decline in unemployment in rural areas and the increase in income generation contribute to improved food affordability and reduced food prices.

At this stage of the analysis, it becomes evident that an increase in land productivity not only enhances profitability and market access but has the potential to generate new jobs and income for farmers in rural areas. In urban areas with minimal agricultural land, the potential for job creation emanates from innovative initiatives like installing greenhouse technology for hydroponics horticulture, which is labour intensive, hence the element of job creation. These dynamics can reduce poverty and provide livelihood opportunities for the rural and urban population, eliminating the need for short-term income creation alternatives.

Reduced food insecurity, improved nutrition, and enhanced affordability lead to higher labour productivity and GDP, affecting employment and macroeconomic performance across sectors. The increase in GDP can create a positive feedback loop by enabling higher public expenditure, potentially leading to improvements in the road network (important for market access) and infrastructure in rural areas (relevant for generating interest in agriculture-related jobs). These dynamics create two additional reinforcing feedback loops (R4 and R5), which can contribute to autonomous progress. However, they can lead to lasting issues if there is a decline in GDP, such as climate impacts. In such a scenario, public expenditure may not increase as expected, resulting in a poorly maintained road network that negatively impacts food delivery, distribution losses, and affordability.

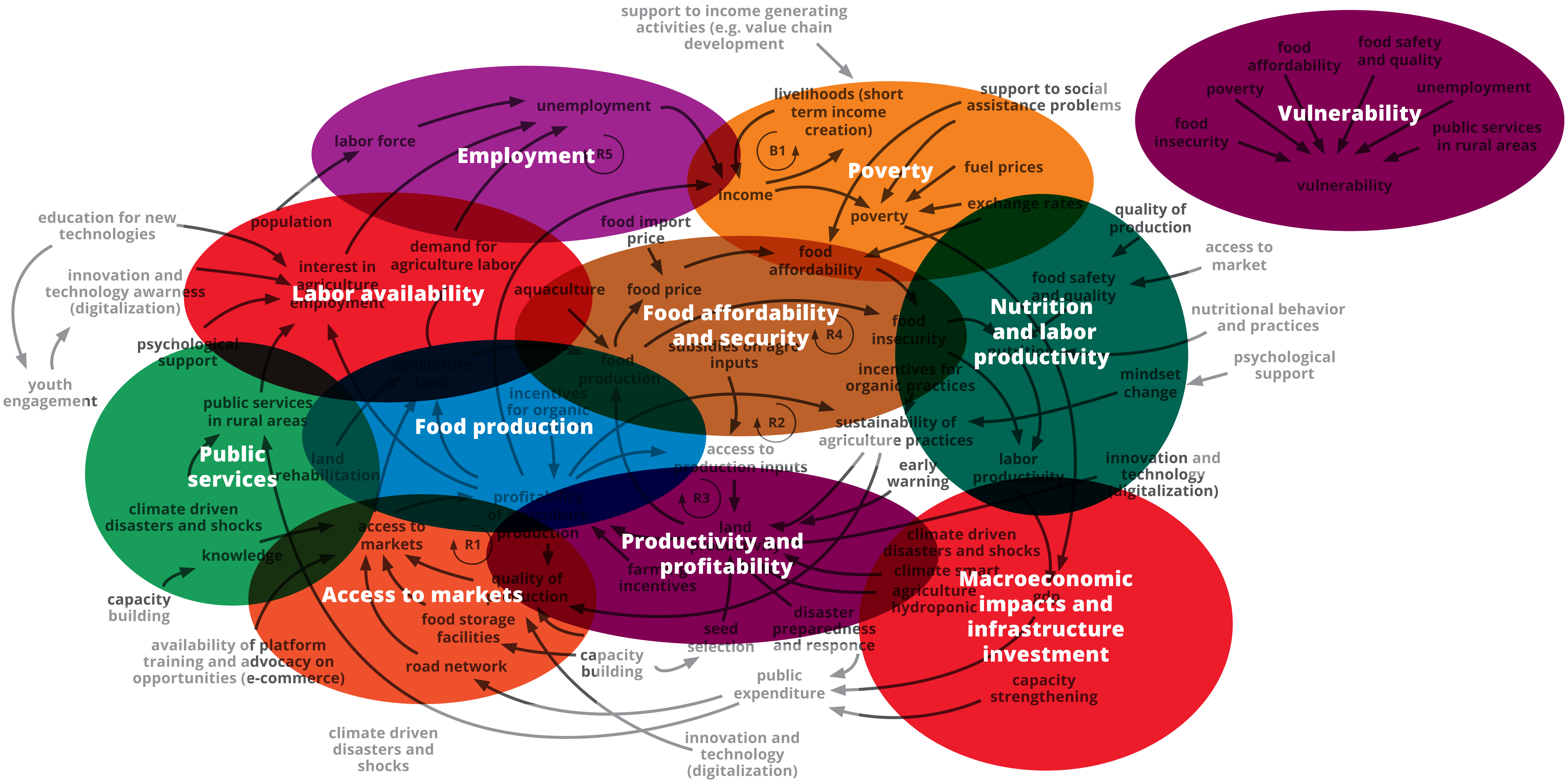
These dynamics highlight the high vulnerability of the food systems in Lesotho, which are simultaneously affected by poor food affordability, high food insecurity, limited food safety and quality, poverty, and limited public services in rural areas.

Several intervention options have been identified to transform the current vicious cycles into virtuous dynamics. These options include:

- Improving land productivity by addressing the impacts of climate change by implementing early warning systems, disaster preparedness and response measures, and adopting climate-smart agriculture practices.
- Supporting market access by introducing platforms, training, and advocacy efforts. Additionally, leveraging innovation and technology, such as digitalisation, can enhance market access and attract the interest of youth towards agriculture employment.
- Strengthening the government's capacity in planning and responding to climate change.
- Creating synergies with actions aimed at improving citizens' nutritional behaviour. This includes creating demand for nutritious food, enhancing the efficiency of public nutrition actions, and stimulating farmers' investments.

Implementing these interventions can break the negative cycles and foster positive dynamics in Lesotho's food systems. These actions can contribute to improved land productivity, increased market access, enhanced nutritional outcomes, and the overall resilience and sustainability of the food system.

FIGURE 14/15: CAUSAL LOOP DIAGRAM OVERLAPS WITH THE MAIN THEMATIC AREAS OF RELEVANCE TO THE FOOD SYSTEMS IN LESOTHO



DEMOCRATIC REPUBLIC OF THE CONGO

We have developed a systems map to support the formulation of the CSP, with the overall objective to design an adapted food assistance response in DRC which takes into account the different contexts (emergency and resilience/ development), while making sure no one is left behind due to extreme prioritization. The system map covers one of the key issue and potential pathways to realize this overall objective, and focuses on the design of an emergency response in conflict-prone areas in DRC which responds to the main principle of quality over quantity while making sure that no one is left behind due to extreme prioritization including but not limited to women, girls, boys, men, people with disabilities, marginalised people and other vulnerable people).

The Causal Loop Diagram (CLD) developed (Figure 16/17) focuses on the main drivers of conflicts and health conditions, with emphasis on food assistance support in DRC, considering (i) disaster risk, (ii) food consumption and feeding practices, (iii) access to food and public services, (iv) food production and employment, including the role of public and private investment to increase resilience and improve human capital, and how governance and political stability can support or hinder progress. In Figure 1 we overlay the CLD with the key thematic areas discussed during the co-creation process of the diagram.

A few key dynamics and feedback loops (i.e. underlying drivers of change) emerge from the diagram. While a detailed narrative is provided next, the main drivers of change include (i) the role of the government (being impacted negatively by extreme events and conflicts, and not having enough resources to improve infrastructure for social services), political stability and governance (being impacted by conflicts, access to resources and equality); (ii) the role of farmers, and especially women (being impacted by natural disasters, the lack of infrastructure and limited income, all contributing to minimal private investment and human capital development); and (iii) society (impacted by low food consumption and malnutrition, and challenged by unequitable access to resources and unequitable social and gender norms reinforcing unequal access to resources, including education, promoting unequal division of labour between men and women and limiting decision-making power of women). All these dynamics represent vicious reinforcing feedback loops (represented with an R sign in the CLD), but these can be turned into virtuous feedback loops, with targeted intervention options.

Specifically, the following narrative emerges from the CLD:

- We started the CLD co-creation process by examining the multifaceted factors contributing to the prevalence of malnutrition. These encompass health conditions and their impact on food access, and the occurrence of epidemics. Furthermore, we have identified additional factors affecting health condition, such as access to basic services, including family planning (impacted by access to education and by equitable social and gender norms), and adequate water, sanitation, and hygiene (WASH) facilities, alongside the prevalence of epidemics, and gender based violence (GBV) (directly impacted by conflicts).
- It was then clarified that conflicts significantly impact each of these critical factors affecting malnutrition. From restricting access to basic services to exacerbating challenges in maintaining proper hygiene and sanitation, conflicts exert both a direct and indirect yet substantial influence on the incidence of malnutrition. Moreover, the incidence of malnutrition itself serves as a precursor to heightened demand for emergency assistance.
- Malnutrition and conflicts lead to poverty, which affect youth unemployment and increases youth recruitment for resource control. The dynamics related to conflicts

and poverty result in unequal access and sustainable use of resources, which further triggers ethnic tensions, and stimulates more conflicts. To make things more challenging, conflicts and foreign interests can result in political instability, challenging governance and raising questions on the legitimacy of institutions, two factors that further affect unequal access and sustainable use of resources.

- Agriculture production is also impacted by conflicts (as does forestry, and access to ecosystem goods and services) and by the unequal access to -and the utilization of- natural resources. The ramifications of natural disasters and inequitable access to these resources can result in diminished land productivity, leading to reduced food production. Additionally, agricultural land may lie fallow due to the inability to cultivate them effectively. A decrease in food production consequently affects the quantity of food reaching markets, again contributing to heightened levels of malnutrition.

- The decline in food production can negatively affect employment and income creation for farmers. This, in turn, restricts resources available for private investment (in addition to putting a strain on consumption, via reduced food affordability), leading to shortages in agricultural inputs or a lack of machinery to expand cultivation areas, further diminishing food production. The desired expansion of agriculture land, on the other hand, may well have a negative impact on ecosystem condition, and hence on ecosystem goods and services.

- The requirement for emergency support affect all areas of development, directly and indirectly. Governments and donors are compelled to allocate substantial financial resources to cater to the needs of affected populations, particularly when the demand for assistance outpaces population growth. This scenario inevitably strains government budgets, diverting funds away from essential public investments. The same dynamics is found for the allocation of budget by donor countries, which then to concentrate towards emergency response.

- This diversion of resources towards emergency support leads to a reduction in investment in public infrastructure (both in relation to domestic investment, also impacted by poor governance, and donor investment), constraining the implementation of new interventions and infrastructure projects. The decline in public investment (or the insufficient level of public investment, in the face of growing population) goes on to affect various sectors, notably impacting access to basic services, WASH facilities, and transportation networks.

- The implications of diminished, or less efficient transportation infrastructure are profound. A reduction in the road network coverage directly impedes access to land, natural resources, as well as food and markets. Disruptions in the road network can also lead to higher post-harvest losses, particularly in instances where access to markets is impeded due to road/bridge damage caused by extreme weather events. Consequently, this impediment translates into decreased food consumption and, consequently, a heightened prevalence of malnutrition.

- The repercussions of reduced food production and income for farmers extend beyond the agricultural sector, thereby affecting all households that depend on agriculture-related income (extending to fisheries, livestock, forestry, farming). Diminished financial resources may hinder access to education, particularly for vulnerable groups. As a result, women, burdened with increased responsibilities in agricultural labor (to provide an example), may experience exacerbated challenges in ensuring adequate nutrition and care practices for children, exacerbating the prevalence of malnutrition. Unequitable social and gender norms contribute to the problem.

- All these factors (i.e. a reduction in income, access to education, basic services and WASH, as well as the incidence of malnutrition) affect human capital, and can impede economic growth and exacerbate vulnerability within the population. Consequently, the government may face increased expenditure demands due to natural disasters, challenges in food production, and the health-related impacts of conflicts, while simultaneously experiencing diminished revenues (caused by a limited improvement, or even a decline of human development).

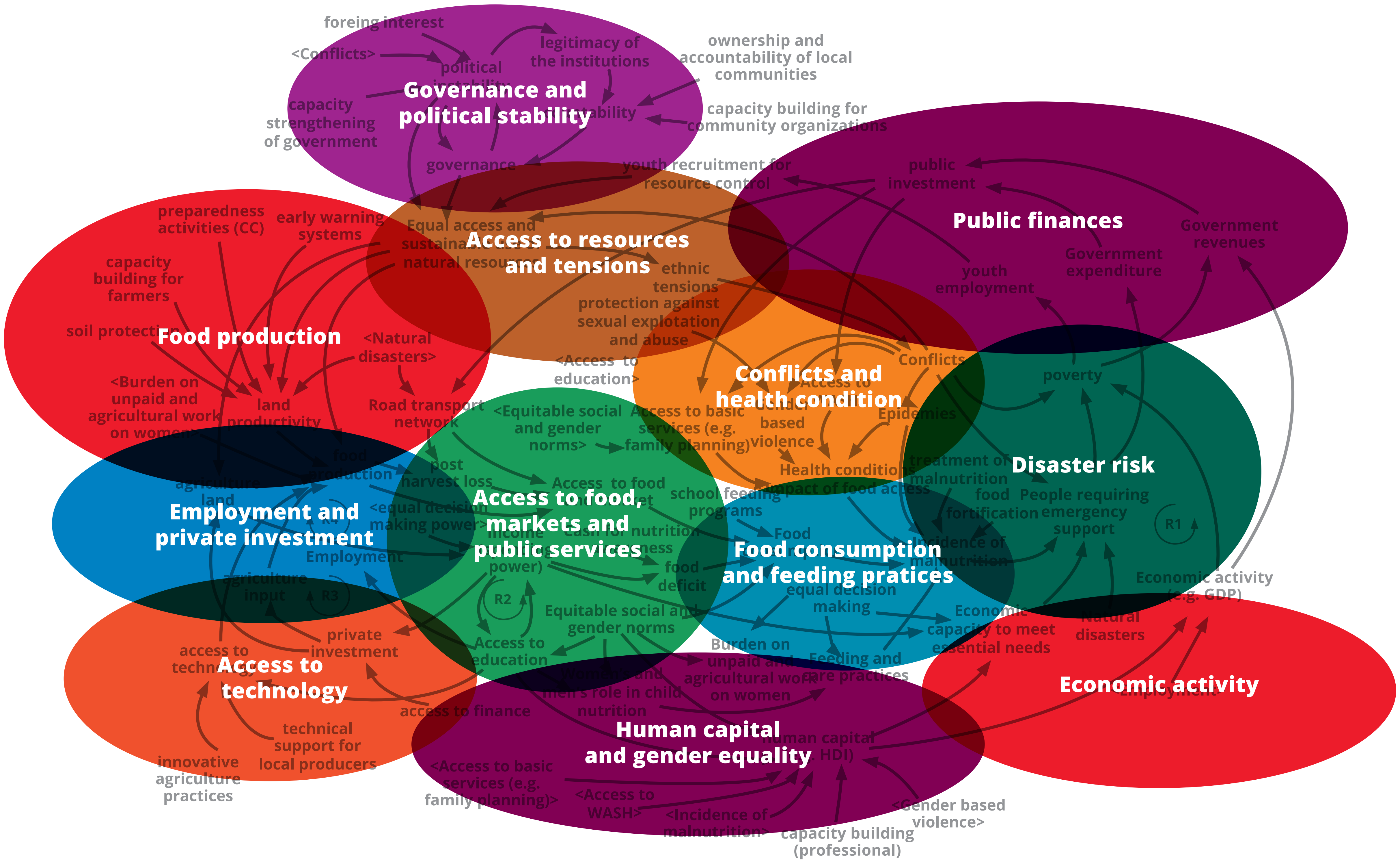
Gender considerations have emerged as cross-cutting, affecting several of the dynamics described above. Specifically, the diagrams highlights that traditional gender norms often reinforce inequalities, undermining development efforts and perpetuating cycles of conflict, resulting also in growing gender based violence (GBV). Emphasizing both men's and women's roles in child nutrition, the redistribution of the burden of unpaid and agricultural work, and the promotion equitable education and employment opportunities hold transformative potential (i.e. could support turning vicious reinforcing loops into virtuous drivers of change). Moreover, it emerged that social and gender norms significantly impact decision-making power, access to resources and technology, and family planning, which are vital for overall community wellbeing. For instance, unequal decision-making power and limited access to land and employment opportunities hinder women's contributions to agricultural productivity, spending and nutrition decision and economic stability.

In essence, this confluence of several factors (represented in the diagram as reinforcing and balancing feedback loops) creates a scenario where government expenditures rise amid declining revenues, leading to a reduction in public investment. Consequently, insufficient resources are available to support access to markets and public services. This negative cycle, also impacted by climate change and extreme weather events, perpetuates worsened conditions, exacerbating conflicts and impeding progress towards equitable access and sustainable utilization of natural resources.

Addressing these challenges necessitates a multifaceted approach aimed at transforming vicious cycles into virtuous ones. Capacity-building initiatives for farmers and professionals (but also to be extended to government staff, community based organizations, food systems actors) is but one option that was analyzed in the CLD creation process. This would enhance human capital, stimulate economic activity, and bolster government revenues, while reducing the number of people requiring emergency support and hence lowering public expenditure. Other options included in the CLD include (i) areas to strengthen accountability and governance, to reduce political instability, (ii) interventions to increase land productivity, and (iii) increase access to technology; further (iv) nutrition-related interventions were identified to improve food affordability and the quality of diets, in addition to treating malnutrition; last but not least (v) protection against sexual exploitation and abuse was considered to reduce gender-based violence and simultaneously improve health condition and human capital.

By fostering synergies between food supply, infrastructure and social development, a more stable development trajectory can be forged, reducing reliance on emergency support and fostering sustainable development at the local level.

FIGURE 16/17: CAUSAL LOOP DIAGRAM OVERLAPS WITH THE MAIN THEMATIC AREAS IDENTIFIED IN THE DIAGRAM



Annex 3: Quantitative applications in Tanzania, Malawi and Madagascar

TANZANIA: INVESTING IN THE SUPPLY CHAIN TO MAXIMISE THE EFFECTIVENESS OF SUPPLY AND DEMAND INTERVENTIONS.

Challenges

Food system challenges in Tanzania are amongst the root causes of food insecurity and hunger, with implications for food production, processing, distribution, and consumption. Food systems encompass the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption, and disposal of food products that originate from agriculture, forestry or fisheries and parts of the broader economic, societal, and natural environments in which they are embedded.

Many food system challenges in Tanzania and within the greater sub-region impact food and nutrition security outcomes and opportunities for improved production and demand. As a result, the current challenges prevent reaching a sustainable food system that supports (a) sustainable livelihoods, (b) provides adequate and affordable nutrition, (c) protects natural and animal resources and minimises climate and environmental impact.

The starting point is a food system that presents challenges for (1) production, with low soil productivity due to lack of knowledge, access to infrastructure and investment limited by low profitability; (2) distribution, with large amounts of distribution losses due to the lack of aggregation, missing cold storage and refrigerated vehicles, and high travel time due to poor road infrastructure, and (3) persistent issues with malnutrition, with the high costs and comparatively lower desirability of nutritious diets. Overall, the main impacts of inefficient food systems include (a) low profitability for producers due to low quality and quantity of the products sold; (b) limited food availability, especially for fresh and nutritious food, affecting food availability, affordability and access; (c) increased pressure on the environment, due to the inefficient utilisation of already scarce production inputs (e.g. water) and the continued land conversion at the expense of fragile ecosystems.

Methodology

The study aims to enable investments in sustainable production and improve food security and nutrition outcomes. In Tanzania, food systems with a focus on food distribution, considering scenarios of aggregation and processing. This is aligned with the process and outcomes of the "Pathways for Sustainable Food Systems 2030" carried out in 2020 and 2021 by the Government of Tanzania. The six areas of focus highlighted in the pathways analysis are interconnected in our assessment. Based on qualitative and quantitative research, investing in food distribution can increase profits and enable further financing (as stated in item 2 of the pathways document). This increase in funding can then be used to strengthen production (as indicated in item 1), resulting in a higher availability of nutritious food (as shown in item 3). Further, using more climate-resilient infrastructure (as stated in item 4) can improve the availability and quality of food. The overall outcome is a more resilient food system (as indicated in item 5), which is more resilient to climate change and trade dynamics.

Results

The analysis suggests that using an integrated approach to food systems leads to the most significant gains concerning farmer profitability, nutrition, and efficiency in using production inputs. This is based on the analysis of four scenarios (Error! Reference source not found.), three thematic cases and one integrated option with production, distribution, and consumption investments. According to the analysis, investing in production, distribution, and consumption is economically feasible and produces benefits. However, investing solely in production or consumption can generate benefits but will not lead to a market transformation or trigger self-sustaining dynamics. Specifically, investing in improved access to infrastructure, adequate storage, and suitable transport infrastructure results in lower distribution losses while ensuring that high-quality fresh produce reaches the market at affordable prices. This, in turn, leads to a change in consumer behaviour towards higher consumption of fresh fruit and vegetables, which in turn leads to a change in the composition of crops grown, stimulated by higher demand and profitability.

Practically, investing in food distribution infrastructure triggers many of the "game changers" listed in the "Pathways for Sustainable Food Systems 2030" document by generating the systemic change described above.

TABLE 1: OVERVIEW OF SCENARIO IMPACTS ON KEY MODEL INDICATORS FOR ALL SCENARIOS RELATIVE TO THE BAU SCENARIO

Indicator	Scenario results compared to BAU.			
	Improved production	Improved distribution	Consumer awareness	Full integration
Total production	↑	→	→	↑
Crop diversification	↑	→	↑	↑
Distribution losses	↗	↓	→	↓
Product Quality	→	↑	→	↑
Farm distance to road	→	↓	→	↓
Market access	→	↑	→	↑
Produce reaching the market.	↘	↑	→	↑
Nutrient sufficiency of diet	↘	→	↑	↑

Note: ↑ significant increase, ↗ mild increase, → no change, ↘ mild decline, ↓ significant decline.

Four main scenarios were simulated, each considering different intervention options. Specifically, (i) the improved production scenario assumes the introduction of sustainable agriculture practices. Sustainable management practices are assumed to entail a range of interventions, including climate-smart agriculture practices and the expansion of agriculture extension services; (ii) the improved distribution scenario considers the availability of refrigerated transport, processing of products to reduce perishability, the expansion of the road network, and the improvement of road quality in rural areas; (iii) the consumer awareness scenario simulates a change in consumer preferences, essentially artificially increasing the demand for fresh produce and, to a lesser extent, pulses and roots and tubers. Finally, (iv) the integrated scenario assumes that all the abovementioned production, distribution and awareness interventions are implemented simultaneously.

MALAWI: SUPPLY CHAIN AS AN ENABLER OF THE FOOD SYSTEMS TRANSFORMATION

Challenges

The analysis carried out for Malawi has highlighted how the country can embark on a journey to transform its food systems to ensure food security, reduce poverty, and improve nutrition. Supply chains play a pivotal role in facilitating this transformation by addressing key areas of intervention, including (i) value chain development, (ii) capacity strengthening, (iii) market access and development, (iv) food safety and quality, and (v) value addition and transformation. In this brief highlight of the analysis carried out for Malawi, we explore in more detail how these elements are interconnected and contribute to the broader goal of achieving a sustainable and resilient food system within the supply chain management domain.

Methodology

A systemic analysis focused on each key area of interest and their interconnections. **Value chain development** is a cornerstone of food system transformation in Malawi. By focusing on various stages of production, processing, and distribution, Malawi can enhance the efficiency and competitiveness of its agricultural sector. This involves optimising the production of staple crops like maize, rice, and legumes while diversifying into high-value crops such as fruits and vegetables. Developing value chains empowers smallholder farmers by connecting them to formal markets, increasing their incomes, and reducing postharvest losses.

Capacity-building initiatives are essential to equipping farmers, processors, and other actors in the supply chain with the knowledge and skills needed to adopt modern and sustainable agricultural practices. Training programs can improve crop management, pest control, and sustainable farming techniques, promoting resilience against climate change. Additionally, capacity building enhances business skills, allowing farmers and agribusinesses to make informed decisions and better negotiate market dynamics.

Market access is pivotal in supporting food system transformation. Efficient supply chains ensure that agricultural produce reaches consumers promptly and cost-effectively. Investment in transportation infrastructure can reduce postharvest losses and enhance the competitiveness of Malawian agriculture. The development of local and regional markets and access to export markets opens new opportunities for Malawian farmers and agribusinesses.

Food safety and quality standards increase consumer confidence and improve market access for producers. Supply chains must adhere to international and domestic food safety regulations to access premium markets and improve the population's overall health. This involves implementing good agricultural practices, improving post-harvest handling, and strengthening the quality control and testing capacity.

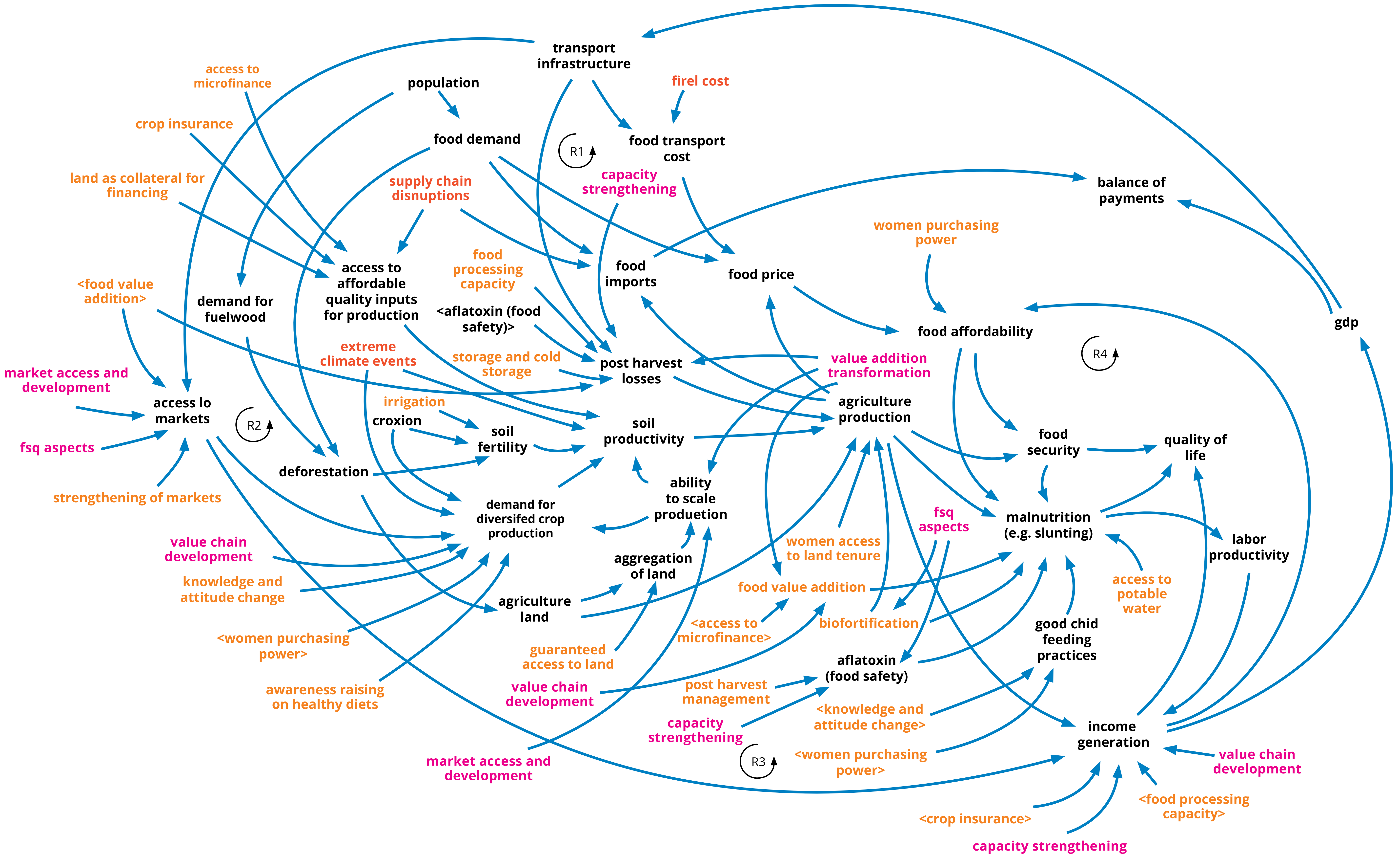
Value addition refers to the process of enhancing the value of agricultural products through processing and transformation. To improve their income and reduce post-harvest losses, Malawian farmers can engage in activities such as milling, packaging and food processing, which add value to their products. Promoting value addition supports the creation of a thriving agribusiness sector, providing employment and economic growth opportunities.

Results

With suitable investments and policies in supply chain strengthening and development, Malawi can more effectively achieve its vision of improved food security, reduced poverty,

and enhanced nutrition for its population. The qualitative and quantitative analyses found that supply chains are practical enablers of food systems transformation. Interventions. Interventions in value chain development, capacity strengthening, market access and development, food safety and quality, value addition and transformation are interconnected and mutually reinforcing. This is reflected in the many reinforcing loops that are impacted by investments and interventions in the strengthening of supply chains (all R1, R2, R3 and R4 in). A holistic approach that addresses these key areas can lead to a more resilient, sustainable, and inclusive food system in Malawi.

FIGURE 18. CAUSAL LOOP DIAGRAM FOR FOOD SECURITY IN MALAWI, INCLUDING SUPPLY CHAIN INTERVENTIONS (PINK).




WFP
Programme
Alimenta
Mondial
SAUVE

Entry Point	Concepts	Climate & Resilience	Nutrition	Smallholder Farmers	HGSF	Food Systems	EPR / AA
Value Chain Development	**Sesame and cowpea value chain development** Promotion of VCs to improve the livelihoods of SHFs while creating market linkages and enhanced trade and forex earnings.	X	X	X	X	X	
Capacity Strengthening: Systems Strengthening	**Strategic Grain Reserve – Systems strengthening.** Technical assistance related to food safety quality, storage, logistics planning and capacity, grain management, commodity accounting	X		X		X	X
Capacity Strengthening; Market Access and Development	**Local Procurement / Pro-SHF Procurement** To meet WFP regional demand, provide a structured market for SHFs, and support SHF earnings while stimulating the local economy.	X	X	X	X	X	X

Entry Point	Concepts	Climate & Resilience	Nutrition	Smallholder Farmers	HGSF	Food Systems	EPR / AA
Market Access and Development: Targeted locations	**Market Development Activities in Targeted Locations** Market strengthening and linkages, financial literacy/business skills, market infrastructure development, nutrition, and linkages with SGR/ADMARC markets are required. An impact/ monitoring plan is required.		X	X	X	X	X
Market Access and Development: Intelligence	**Market Intelligence** Strengthen data collection and analysis to identify critical bottlenecks and entry points for further market development. Data can benefit not only WFP but also the government and partners.			X	X	X	
FSQ Aspects	**Food Safety and Quality** Capacity development of the Malawi Bureau of Standards for food for export and local consumption (trade, nutrition)		X	X	X		X

Entry Point	Concepts	Climate & Resilience	Nutrition	Smallholder Farmers	HGSF	Food Systems	EPR / AA
Value Addition and Transformation	**Transformation / Processing** Capacity development of existing processors for WFP demand and local market (CSB+). Support SGR actors in developing maize flour processing to boost local production (less import reliance). Linked to other value chains, the private sector should be engaged in the establishment of processing facilities for value addition (Sesame, flour, etc.).	X	X	X	X	X	

MADAGASCAR: THE IMPORTANCE OF CLIMATE RESILIENCE FOR THE SUSTAINABILITY OF FOOD SYSTEMS

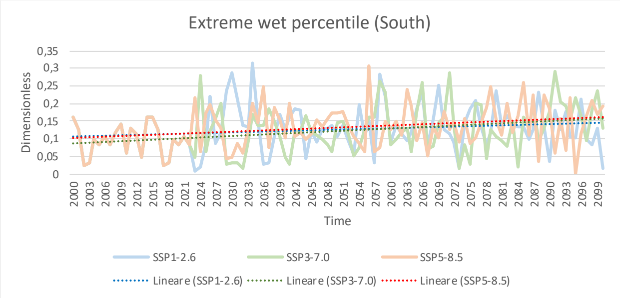
Challenges

This project is centred around an analysis of the food systems in Madagascar, with a specific focus on the unique context of the country, specifically regarding the climatic differences between the North and the South. The analysis aims to identify, quantify, and understand the effects of various shocks, particularly climate-related natural hazards, that WFP can positively impact. The main shocks analysed include prolonged drought, cyclones, flooding leading to the destruction of houses and livelihoods, plant infestation and reduced land productivity and food production.

Methodology

Several climate indicators were utilised to support this analysis and gain insights into climate anomalies, such as extreme wet or dry events. For instance, we analysed medium to long-term trends and the occurrence and severity of extreme events (exceptionally high or low rainfall and exceptionally high or low temperature) compared to the historical average. Figure 19 presents the extreme wet percentile for the Southern region of Madagascar. Across three SSP scenarios, in the southern region, all three scenarios project an increase in extreme wet months. This indicates a rise in months with high precipitation, which, when combined with arid soil and water scarcity, is likely to intensify the risk of crop failure, floods, and related soil loss.

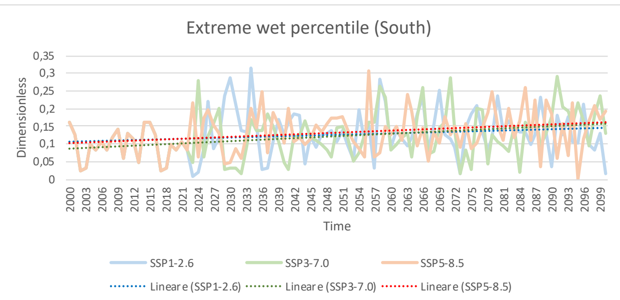
FIGURE 19: EXTREME WET PERCENTILE – SOUTH.



The extreme dry percentile is presented in Figure 20. The climate projections indicate an increase in the occurrence of months with lower rainfall compared to their historical mean. The increase in the extreme dry percentile indicates that farmers in Madagascar will face even more constraints about water availability. Longer dry periods further benefit the spread of crop pests and molds, which puts additional pressure on the production sector and may increase the occurrence of crop failure and declining yields.

Results

FIGURE 20: EXTREME DRY PERCENTILE – SOUTH.



Simultaneous action in all three stages of the food systems (production, distribution, consumption) generates the highest absolute benefits at the country level, backed by the analysis of interventions targeting different stages. Integrated action across the supply chain yields USD 30.04 billion in benefits for a total cost of USD 5.95 billion between 2022 and 2050, resulting in a Benefit to Cost Ratio (BCR) of 4.54, indicating that 4.54 USD in benefits materialise per USD invested. For comparison, we analyse scenarios with interventions confined to individual stages, where the distribution sector interventions result in the highest absolute benefits, followed by those targeting production and consumption.

Production-related interventions enhance the climate resilience of the primary production sector and increase total production levels. Implementing climate-smart practices leads to higher production levels and increased employment opportunities. Farmers can sell their produce at a premium price, generating more significant total revenue. However, higher production outputs lead to higher losses without interventions targeting the distribution sector. Increased production volumes expose more produce to risk, and the lack of incentives to grow more nutritious foods is due to underdeveloped processing and cold storage facilities. Interventions targeting the distribution sector improve the quality of food reaching the markets and reduce transportation-related losses, creating a synergy with production. Finally, education and increased consumer awareness lead to the production of more nutritious foods.

Annex 4: : Applications of GEM in key sectors for future development

GEM has been applied to more than 50 countries and was designed to include all key sectors that are relevant for future development, for instance, in the context of low-carbon development (HMIT, 2021; BAPPENAS, 2021) and green recovery packages (UNEP, 2020). These include, among others, population, food demand and supply, land use and land cover, economic activity (via the use of national accounts), employment, access to health care, education, energy demand and supply, air emissions, water pollution, and climate trends. The model provides an economic valuation for several externalities, including GHG emissions (social cost of carbon), air pollution, wastewater, waste, traffic-related impacts (e.g., accidents, noise), the opportunity cost of water (from savings in the agriculture sector) and biodiversity.

With Aroha, in the context of the Climate Prosperity Plan (CPP) project, GEM has been equipped with several additional climate impacts and more than 20 additional climate resilience options, now coupled with an equal amount of transition investments. This allows for a complete economic and financial assessment of climate action (built on physical indicators and summarised in a CBA) for transition and climate resilience.

GEM is built using the System Dynamics (SD) methodology, primarily as a knowledge integrator. SD is a form of computer simulation modelling designed to facilitate a comprehensive approach to development planning in the medium to long term (Meadows, 1980; Randers, 1980; Richardson & Pugh, 1981; Forrester, 2002). SD operates by simulating differential equations with "what if" scenarios, explicitly represents stocks and flows (critical to estimate climate change impacts on infrastructure and how such impacts accumulate over time to affect economic productivity, among other indicators), can integrate optimisation and econometrics and support model coupling (e.g., in conjunction with spatially explicit models, sectoral models for energy and the economy).

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