WFP
World Food Programme

SAVING LIVES CHANGING LIVES

Food Systems in Tanzania

Investing in Distribution to Trigger Systemic Change

November 2021


дерации

Contents

Acknowledgement

This study was made possible thanks to the cooperation with the Government of Tanzania, namely through their participation in the exercise of Casual Loop Diagrams. Also the various data inputs have been sourced from their incumbent technical institutions such as the Ministry of Agriculture and National Statistics Bureau but also partner institutions such as the World Bank, United Nations Specialized Agencies such as FAO and UNICEF.

The analysis and production of this report was led by Dr Andrea M. Bassi, with support from Georg Pallaske and Marco Guzzetti, working closely with the WFP Tanzania Country Office and the WFP Regional Bureau in Johannesburg. Their technical input and guidance were instrumental in the successful completion of this study.

The analysis and finalization of the report also benefited from a review and comments received from various stakeholders including Rome HQ.

A special thanks goes to Dr Honest Kessy, Director of Food Security Analysis System and National convenor in preparations of the UN 2021 Food system summit, for his support in coordination but also technical inputs.

LIST OF FIGURES

LIST OF TABLES

Executive summary

Food system challenges in Tanzania are among 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 those parts of the broader economic, societal and natural environments within which they are embedded.

There are many food system challenges in Tanzania and within the greater sub-region that impact on food- and nutrition-security outcomes and influence the opportunities for improved production and demand.

The starting point is a food system that presents challanges for:

Production
with low soil productivity due to lack of knowledge, poor access to infrastructure and investment that is limited by low profitability

Distribution
with a large number of losses due to the lack of aggregation, missing cold storage and refrigerated vehicles, and long travel times due to poor road infrastructure

Nutrition
with persistent issues of malnutrition, underpinned by the high cost and comparatively lower desirability of nutritious diets

Overall, the main impacts of an inefficient food system include:

a. **low profitability** for producers, due to the poor quality and/or quantity of products sold;

b. **limited food availability**, especially for fresh and nutritious foods, affecting food availability, affordability and access; and

c. **increased pressure on the environment**, due to the inefficient use of already scarce production inputs (e.g. water) and continued land conversion at the expense of fragile ecosystems.

The **current challenges prevent the attainment of a sustainable food system that: supports viable livelihoods** (corresponding to **a** above); **provides adequate and affordable nutrition** (corresponding to **b** above); and **protects natural resources and minimizes climate and environmental impact** (corresponding to **c** above).

This study analyses the Tanzanian food system, and specifically food distribution, where the latter enables investment in sustainable production and improves food security and nutritional outcomes.[1] We define food systems here with reference to the food value-chain in its totality, taking into account all the elements, their relationships and the related effects for a multitude of economic actors. We consider all relevant causal variables of a problem and all social, environmental and economic impacts of the solutions to achieve transformational, systemic changes. Similarly, in accordance with the definition of food systems, food distribution is analysed with a clear understanding that, due to the integrated nature of food systems, focusing on how food is made accessible in the Tanzanian context will necessarily highlight connections to other areas, such as food production and consumption.

This aligns with the process and outcomes of "Pathways for sustainable food systems 2030" ("Pathways"), a project 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. We find from our qualitative and quantitative data that **investments in food distribution have the potential to increase profits and enable further financing** (item 2 in "Pathways") to strengthen production (item 1), which results in higher availa-

1 This report also includes scenarios that consider aggregation and processing.

bility of nutritious food (item 3), and the use of more climate-resilient infrastructure (item 4). The overall outcome is a food system that is more resilient to economic fluctuations, trade dynamics and climate change (item 5).[2]

Both qualitative and quantitative methods are used in this study, to first map and conceptualize the complexity of the food system in Tanzania, and then to quantify the likely impacts of scenarios of action and inaction. System dynamics modelling, the approach chosen for this study, is a methodology that allows the capture of many socio-economic and environmental links of production, distribution and consumption, and highlights the long-term impact of policy and programming decisions on the food system. It also allows us to estimate, analyse and present physical results alongside a cost–benefit analysis (CBA) for each scenario.

Our analysis suggests that using an integrated approach to food systems leads to the greatest gains, in terms of profitability for farmers, nutritional outcomes and efficiency in the use of production inputs (see Table ES1). While our analysis shows that investments in production, distribution and consumption are all economically viable, we find that while investing in production or consumption alone can generate benefits, it does not lead to a transformation of the market and does not trigger virtuous, self-sustaining, systemic dynamics. Specifically, investment in improved access to infrastructure, adequate storage and transport infrastructure results in lower distribution losses, while at the same time 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, investment in food distribution infrastructure triggers many of the 'game changers' listed in "Pathways", by generating this systemic change.

Table ES1: Overview of scenario impacts on key model indicators for all scenarios relative to the BAU scenario

Indicator	Scenario results compared to business as usual (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: ↑ large increase, ↗ mild increase, → no change, ↘ mild decline, ↓ large decline.

2 Resilience is defined as, "The ability of individuals, households, communities, cities, institutions, systems and societies to prevent, resist, absorb, adapt, respond and recover positively, efficiently and effectively when faced with a wide range of risks, while maintaining an acceptable level of functioning without compromising long-term prospects for sustainable development, peace and security, human rights and well-being for all." (United Nations, 2020, p.11).

The integrated scenario, in which investments are made in production, consumption and distribution, is the most viable and also the scenario that generates the greatest absolute benefits (USD 1,646.4 billion undiscounted and USD 319.0 billion discounted). The investment required in this scenario is USD 80.6 billion, which generates avoided costs of USD 74.2 billion, as well as between USD 644.7 billion and USD 1,638.8 billion in added benefits (between 2021 and 2050). When discounting of 10 percent is included, the benefit- to-cost ratio is between 2.1 and 5.0 in a pessimistic and an optimistic scenario respectively.

We find that investment in each area of the food system has its own benefits and responds to specific strategic needs – investing in production increases income via job creation, investing in distribution reduces costs and leads to higher profits, and investing in consumption curbs malnutrition costs. However, investing in distribution additionally unlocks the potential to maximize the effectiveness of investments in production and consumption, resulting in the greatest benefits and increased effectiveness.

Several systemic considerations emerge from the analysis, which can inform decision-making, with the aim of improving the sustainability of food systems:

- **Distribution is the key to addressing the main challenges faced by the Tanzanian food system**. Improvements in distribution networks and processes would reduce transport-related losses, so that greater quantities of food reach market, while also improving end-product quality. Improved profitability for producers and distributors would incentivize greater follow-on investment from the private sector. Investments in distribution require commitment over time in order to maintain both capital investment in roads and short-term, 'win–win' strategies in food storage via the creation of a cold chain. A virtuous cycle is then created, with growing demand for healthy diets further stimulating farmers to invest in the production of fresh and nutritious food.
- Infrastructure investments are required to enable this transition, and these opportunities already exist. Two thirds of rural villages are electrified, representing **considerable potential for the establishment of adequate storage infrastructure and food-processing facilities at the local level**. The road network is growing, and its quality is improving. More effort in rural areas is likely to deliver very positive outcomes for the sustainability of food systems, and may enable further development of the food-processing industry.

- A focus on either increasing the productivity of the primary sector or changing consumer preferences could facilitate a shift towards fresher produce, although in isolation, such approaches lead to large losses and sub-optimal product quality if challenges in distribution remain unaddressed. Investing in distribution, aggregation and processing can unlock progress in other areas and leverage existing as well as future investments.

A transition to sustainable food systems in Tanzania can deliver benefits for all economic actors. An effective distribution network that delivers the food demanded by the market, in a timely and cost-effective manner, can stimulate demand for a healthy and nutritious diet. If the demand is there, several advantages can be accrued:

- for citizens, by reducing malnutrition and improving health;
- for the Government, by requiring a lower budget for health expenditure (thus freeing up resources for other investments) and by increasing labour productivity and possibly also public revenues;
- for producers, by providing a stimulus for more diversified production, which guarantees higher profitability (due to the higher profit margin of fresh produce) and improved productivity of natural resources (due to reforestation, restoration of rangelands and marine resources, soil and water conservation, improved soil health, etc).

Infrastructure investments are essential to realizing the social, economic and environmental opportunities described above. Even more importantly, **when the synergies among production, aggregation, distribution and consumption are realized, self-reinforcing mechanisms will emerge, driven by higher profitability for producers, improved health for citizens and reduced costs for the Government**. In fact, nutrition and human health can only improve if the whole system is working in a coordinated and harmonized manner: Tanzania needs productive natural resources and minimal pre- and post-harvest losses to create economies of scale in the distribution of food. Using efficient food-storage and cold-storage facilities, the country's food-supply system can provide fresh, healthy, affordable food. These are the preconditions for creating demand for healthy products and reducing the consumption of imported, pre-packaged products. The result will be that **nutrition and human health will improve, thanks to a food system that is sustainably strengthened and managed**.

1. Overview of the project

1.1 INTRODUCTION

The fact that 811 million people are chronically hungry across the world suggests that food systems – the networks that are needed to produce and transform food, and ensure it reaches consumers – are not meeting the needs of large sections of society. Improving the performance of food systems and their ability to cater even for the poorest will therefore be key to achieving Zero Hunger.

With this goal in mind, the World Food Programme (WFP) Country Office for Tanzania and the WFP Regional Bureau for Southern Africa, in collaboration with several national and international stakeholders, have conducted a study analysing the Tanzanian food system, and specifically food distribution, where the latter enables investment in sustainable production and improves food security and nutritional outcomes.[3] The aim is to inform national discussions on the key issues and opportunities surrounding the Tanzanian food system. There are many food-system challenges in the country and within the greater sub-region that impact on food- and nutrition-security outcomes, and influence the opportunities for improved production and demand. Food distribution is an area that holds considerable potential in creating a systemic solution to many of these problems.

In this report, food distribution is analysed with a clear understanding that, due to the integrated nature of food systems, focusing on how food is made accessible in the Tanzanian context will necessarily highlight connections with other areas (such as production and consumption). It is expected that this study will provide entry points for further studies of food-system issues within the country that will affect progress towards the achievement of Sustainable Development Goal (SDG) 2.

Both qualitative and quantitative methods are used in this study, to first map and conceptualize the complexity of the food system in Tanzania, and then to quantify the likely impacts of scenarios of action and inaction. System dynamics modelling, the approach chosen for this study, is a methodology that allows the capture the many socio-economic and environmental links between production, distribution and consumption, and highlights the long-term impact of policy and programming decisions on the food system.

3 This report also includes scenarios that consider aggregation and processing.

1.2 RESEARCH METHOD

Owing to the complexity of food systems and their integrated nature, traditional methods of research, such as value-chain analysis, supply-chain assessments and field-based interviews, are not able to represent the dynamics of a complex system characterized by feedback loops, delays and non-linearity, as well as the non-rationale elements and policy-path dependency that characterize sustainable development.[4] This study therefore uses system dynamics modelling to identify the complexity involved in the design and evaluation of distribution interventions. It presents a custom-built system dynamics model that illustrates some of the issues arising from an integrated, systems-oriented analysis of a concrete food system.

The study follows best practice in the system dynamics field, with a five-step modelling process. The following tasks have been performed:

- **Problem identification**: also called agenda-setting, this task focuses on the identification of the problem to be modelled. For the food system of Tanzania, this includes issues with land productivity and pre- and post-harvest losses, the time required to reach market and the resulting distribution food losses, which all affect farmers' profitability and consumer access to fresh and nutritious food through markets. This is presented in Section 2.
- **Dynamic hypothesis**: this task consists of the creation of a system map (also called a causal loop diagram, or CLD) that supports the identification of key variables, their interconnections and the feedback loops that causes changes in the system. This task has been carried out with the WFP team and external stakeholders. It supports knowledge integration, and the creation of a shared understanding of the dynamics of the system and the causes of the problem. Section 2 present the results of this step in the modelling process.
- **Model formulation**: this task involves the creation of the mathematical model, using the CLD as a blueprint. The model uses semi-continuous time and is built using a stock-and-flow structure to capture feedback loops, delays and non-linearity. The data used and the structure of the model are presented in Section 4.
- **Model validation**: this step consists of two main types of validation, structural and behavioural. The former pertains the validation of variables, equations and units. The latter regards the results of the model, considering both historical and future trends. Section 4 illustrates the extent to which the model is able to reproduce historical trends, based on the use of data (for model parametrization) and equations (for model customization).
- **Policy analysis**: in this final step using the validated model and accurate representation of historical trends, a future baseline scenario and intervention options (e.g. policies, targets, investments) are used to estimate effectiveness and efficiency, through indicators of social, economic and environmental outcomes. The result of scenarios of inaction (BAU) and action (for production, distribution, consumption and all these areas combined) are presented in Section 5, with biophysical and economic indicators.

4 'Policy-path dependency' may be defined as the ways in which present policy choices are constrained or shaped by institutional paths that have resulted from decisions made in the past.

1.3 ANALYSIS

This study aims to deliver several types of assessment, resulting in an improved understanding of the current issues, the identification of opportunities, quantification of the benefits to be realized, and the economic viability of intervention options. Specifically, this report aims to deliver the following:

- a clear analysis of the production, aggregation, processing, distribution and consumption of agricultural produce in Tanzania and the links with other elements of the food system. This task is carried out through the creation of CLDs, using a multi-stakeholder, shared model-building approach, complemented by a literature review.
- an understanding of the leverage points and the constraints these generate in the food system, particularly for food and nutrition security of the most vulnerable. This task is carried out using CLDs and the feedback loops (reinforcing and balancing) that are most likely to support the changes and transformations required.
- a simulation of how changes in production, aggregation, processing and distribution may affect leverage points in order to maintain the system in as productive a condition as possible. This task is performed through the creation of a stock-and-flow system dynamics model based on the CLDs co-created earlier in the project. Model development also implies the identification of data needs, and data-collection and data-consistency checks.
- an analysis of the trade-off between different investment options and the synergies that can be created when using a systems approach. This task analyses alternative scenarios and describes their outcomes across the food value-chain, identifying direct, indirect and induced impacts of actions and inaction. The goal is to identify potential areas of synergy and trade-offs for a stronger policy or strategy.
- identification of entry points for policymaking around food and nutrition security and provision of the indicative cost associations of current and adjusted approaches. This task consists of the assessment of selected intervention options aimed at increasing the sustainability of agri-food value-chains. As far as possible, this analysis includes an integrated cost–benefit analysis that is system-wide, and takes into account both tangible and intangible outcomes (i.e., it includes an economic valuation of externalities to better assess the societal outcomes of various scenarios).


ONGA
ONGA
ONGA

2. Setting the Context: Food Systems in Tanzania

2.1 OVERVIEW

Over the past 20 years, Tanzania has achieved significant improvements in terms of socio-economic and human development (WFP, Tanzania, 2020). On the other hand, such progress has not benefited all sectors to the same extent and inequality has increased (WFP, Tanzania, 2020).

Agriculture, which is mostly represented by smallholder farmers (but includes pastoralists, fishers and forest users), represents around 25 percent of national gross domestic product (GDP) (WFP, Tanzania, 2020). Since different climatic and geographical zones can be found within the country, producers can grow a large variety of annual and permanent crops, including fruits and vegetables, cash crops, coffee, cotton, cashew nuts, tobacco and tea (ITA, 2021). However, while Tanzania currently grows enough food to satisfy the needs of its population, the poorest have limited access to it (WFP, Tanzania, 2020). Furthermore, harvests are vulnerable to rain scarcity; in 2019 in some regions, maize production was 20–55 percent below the output obtained during 2018 due to low rainfall (FAO, 2020a).

With production being stagnant despite the many efforts to improve productivity and climate resilience, and with the expectation that the population will double by 2050, effective action is needed (WFP, Tanzania, 2020). More than 34 percent of children under five years of age are suffering from stunting, and overall chronic malnutrition rates are above average, compared with most countries in the African continent (WFP, Tanzania, 2020). Other nutritional challenges include anaemia, which particularly affects women of reproductive age and children, as well as overweight and obesity (MoHCDGEC, MoH, TFNC, NBS, OCGS, and UNICEF, 2018).

The challenges of Tanzania are not unique and can be found in other countries in the region and the continent. Africa holds the largest amount of untapped agricultural potential in the world, which could be used to increase production and improve nutrition (Goedde, Ooko-Ombaka, & Pais, 2019). Estimates range between 480 million ha to 850 million ha. However, much of this land is unreachable due to lack of infrastructure, conflict, or because it is found within forested/protected areas. In other words, only 20–30 million ha may be used to increase agricultural production in Sub-Saharan Arica, which would correspond to an increase of 10 percent in cultivated land.

Nevertheless, there is potential to reduce pre- and post-harvest and distribution losses, which average well above 50 percent for fresh and nutritious food in Tanzania (The United Republic of Tanzania, Ministry of Agriculture, 2019). Infrastructure plays a critical role in this, both to increase access to suitable land (and hence increase production), and to reduce time to market, so increasing the number of products sold, and generating income and improving nutrition.

Post-harvest (PH) losses pose a serious threat to food security in Tanzania, as well as to the economy of the country (The United Republic of Tanzania, Ministry of Agriculture, 2019). It is widely accepted that mitigating PH losses that occur between harvesting and consumption can offer the single largest opportunity to alleviate hunger and nutrition problems in the country. It has been estimated that Tanzanian farmers lose up to 40 percent of their harvest due to PH losses, with fresh products such as fruits and vegetables incurring losses above average because they are particularly vulnerable to transportation delays and conditions. Improved transport practices, such as the use of reinforced re-usable crates on trucks, have been shown to be a viable practice to reduce fruit damage during transportation (FAO, 2019). Improving rural infrastructure and distribution practices holds considerable potential to increase the speed of delivery to local markets and thus to satisfy the quality expected by consumers. Further, it increases revenues for producers, with the potential to create important synergies between sustainable production and nutritious, healthy consumption.

2.2 LAND PRODUCTIVITY CHALLENGES AND CLIMATE VULNERABILITY

Between 85 and 90 percent of the total cultivated land (13 million ha) is farmed by smallholders, who on average cultivate fewer than 5 ha a year, with subsistence farming as their main goal (WFP, 2021a). Cereals (maize, rice, sorghum) and pulses (beans) are some of the most important crops in Tanzania, representing around 40 percent of the total share of arable land in the country.

Several challenges affect the agricultural sector in Tanzania. For example, rudimentary farming practices (farmers largely rely on hand-hoes) and lack of access to modern technologies and production inputs are among the factors that affect land productivity and production (IFAD, 2017). The absence of agricultural extension services, such as access to training, technical advice and information, and the lack of farmers' organization for collective action keep productivity low and hinder the implementation of improved practices. This has led to a situation in which agricultural systems and farmers across Tanzania operate in a context of high vulnerability and variability (Tripathi, et al., 2021). Sudden and uncontrollable crop pests and diseases are not unusual in Tanzania (as well as in other regions of Sub-Saharan Africa), with their frequency on the rise as a result of climate change. Food crises, civil unrest and economic depression frequently affect the whole region, while health systems are also under pressure due to high rates of infectious diseases, such as malaria and HIV/AIDS. The COVID-19 pandemic represents an additional shock that is challenging the population.

In addition to these difficulties, one of the most pressing challenges affecting farming in Tanzania is the fact that it is largely rainfall dependent (WFP, 2021a). Changes in climate and weather conditions experienced in the past decades have increased the vulnerability of smallholder farmers, especially since less than 2 percent of their farmland is under irrigation (WFP, 2021a). Practically, smallholder farmers are already vulnerable to changes in weather: both excessive rainfall and droughts contribute to a higher prevalence of pests and diseases, severely affecting production and hence income and livelihoods. For instance, it has been estimated that due to droughts, the agricultural sector in Tanzania loses USD 200 million annually (WFP, 2021a). The severity and frequency of extreme events are increasing, as observed during the last 40 years, further threatening the already precarious livelihood of smallholder farmers. It is also worth mentioning that unstainable land management practices, such as frequent rangeland burning, overgrazing, continuous mono-cropping and forest clearance, reinforce the severity of climate-change impacts and deplete Tanzania's carbon sinks. In the long run, practices such as burning rangelands and mono-cropping lead to a loss of soil nutrients, increase erosion and hence negatively affect soil fertility. Altogether, the consequences of poor farmland management drive the decline of agricultural production, as observed in recent years (The United Republic of Tanzania, 2018).

It has been estimated in 2020 that around one third of all districts in Tanzania regularly report food shortages, even during years of surplus at the national level (WFP, 2021a). On average, agricultural and livestock production are below optimal levels. An assessment of land-use/land-cover data, land productivity and soil organic carbon, identifies hotspots of land degradation in Tanzania (see Figure 1; (The United Republic of Tanzania, 2018)). Drivers of such degradation are, among others, population growth, poverty, overgrazing, firewood and charcoal scarcity, land-tenure systems, poor farming practices and extreme weather events (see Table 1).

Figure 1: Hotspots of land degradation in Tanzania (The United Republic of Tanzania, 2018)

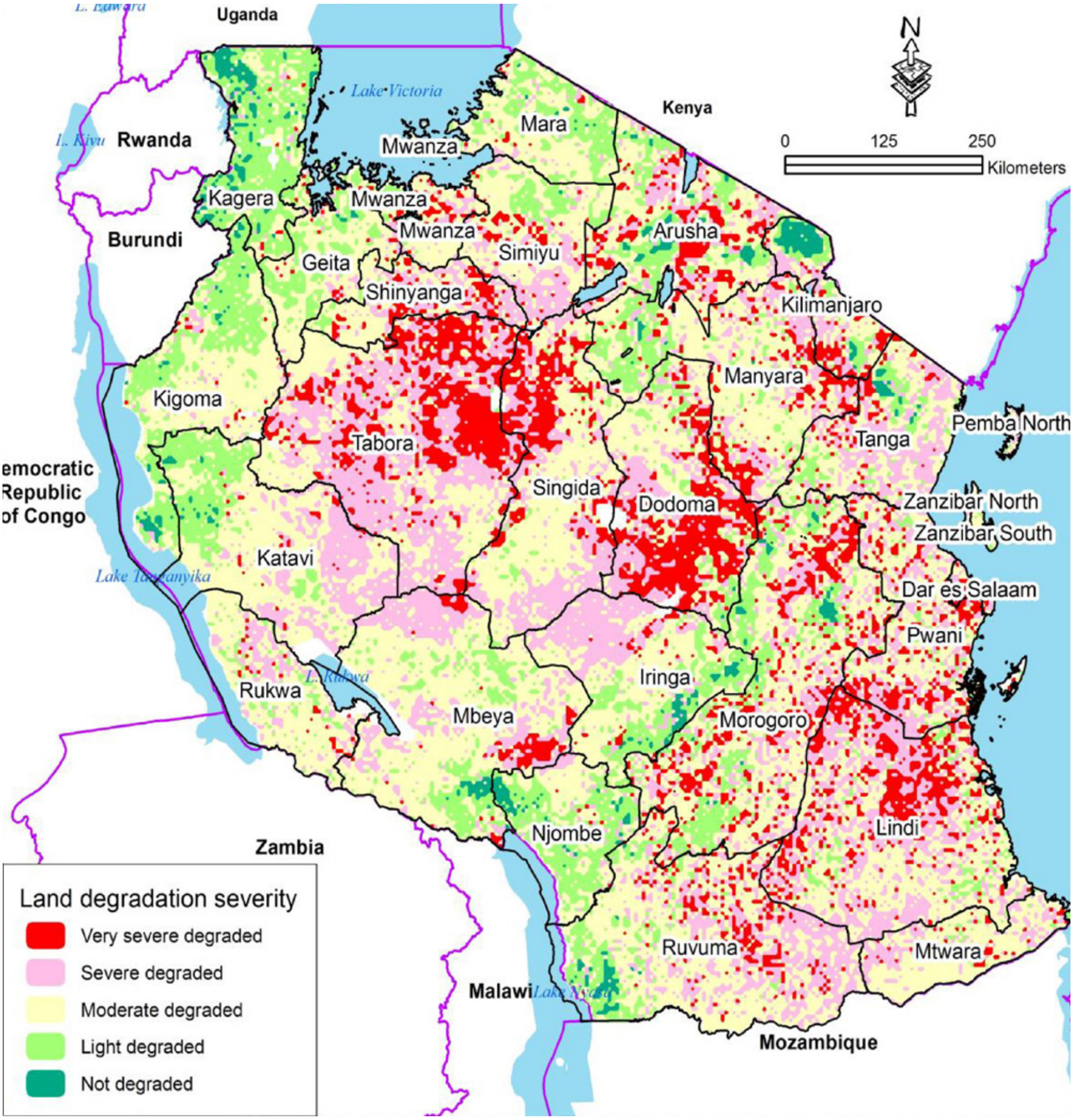


Table 1: Drivers and indicators of land degradation in hotspot areas (The United Republic of Tanzania, 2018)

Hotspot area	Zone	Indicators	Driver
Dodoma	Semi arid central	Decline in Productivity High soil erosion (high gullies) Bare lands (signs of desertification)	Agricolture i.e. convention of forest land to cropland
Lindi	Semi arid southern coast	Large area very, severely degraded	Livestock keeping, expansion of agricolture, uncontrolled fire, deforestation
Tabora	Semi arid western	Large area severely degraded canopy cover reduced	Agricolture i.e. tobacco farming Grazing i.e. large herds of cattle Shifting cultivation
Singida	Semi arid central	Very severe, severe degraded, moderate degraded	Agricolture i.e. convention of forest land to cropland
Shinyanga	Semi arid lake zone	Very severe degraded, moderate degraded	Agricolture i.e. cotton, rice farming Grazing i.e. large herds of cattle
Arusha	Northern highland	Bare lands, soil erosion and gullies	Agricolture i.e. maize, farming Grazing i.e. large herds of cattle

Weather variability and climate change are decreasing water volumes in many water bodies such as the Ruvuma and Ruaha Rivers, challenging irrigation and contributing to increased livestock migration (World Bank, 2017). High risks linked with weather variability have also hindered private-sector investments in agriculture, especially in infrastructure, such as for efficient irrigation. Currently, agriculture in Tanzania represents more than 90 percent of total water use, with losses exceeding 45 percent due to inefficient methods and infrastructure, further exacerbating the country's vulnerability to climate change (Pham, 2018).

To date, poor access to, and adoption of, modern technologies and production inputs, and the absence of extension services in the agricultural sector have prevented the increase in production via improved land productivity. Production has grown, but only as a result of the expansion of the cultivated area, driving deforestation and land degradation (IFAD, 2017). It is worth noting that Tanzania shows one of the highest rates of forest loss in the world, with more than 420,000 ha of forest lost every year, or around 0.9 percent of all the forest cover in the country (FAO, 2020b). This threatens the livelihood of those who are forest dependent (e.g. through the sale of non-timber forest products), forcing them to look for alternative means of income generation, which may further accelerate the degradation of forests, if these means require land for productive purposes.

The economic impacts associated with forest loss were estimated at USD 2.3 billion every year between 2000 and 2010 (Reith, Ghazaryan, Muthoni, & Dubovyk, 2021). Moreover, just five regions (Pwani, Lindi, Morogoro, Tabora and Mtwara) account for more than half of the overall country's forest loss. Supporting fuel-switching from biomass to electricity and addressing the underlying causes and effects of land degradation are intervention options that are needed to reduce these impacts (The United Republic of Tanzania, 2018).

2.3 POST-HARVEST AND DISTRIBUTION LOSSES, CAUSES AND EFFECTS

2.3.1 Current losses

In Tanzania, the monetary value of cereal production is estimated to be TZS 3.92 trillion for maize (with losses amounting to TZS 601 billion), TZS 767 billion for sorghum (with estimated losses amounting to TZS 95 billion) and TZS 2.58 trillion for rice (with estimated losses amounting to TZS 276 billion) (The United Republic of Tanzania, Ministry of Agriculture, 2019).

Currently, the magnitude of PH losses is estimated to be 30–40 percent for cereals and up to 100 percent higher for perishable crops. However, there is little data available to precisely estimate PH losses in Tanzania and also to break down the causes of such losses. For reference purposes, the estimated PH losses for different crops in East Africa (The United Republic of Tanzania, Ministry of Agriculture, 2019) are:

- Tomatoes: 20/50 percent
- Bananas: 20/80 percent
- Papayas: 40/100 percent
- Other fruits and vegetables: 18/32 percent
- Roots and tubers: 12/27 percent
- Maize: 15.5 percent
- Paddy rice: 10.7 percent
- Sorghum: 12.5 percent

Overall, it has been estimated that the monetary value of PH losses of grains amounts to more than USD4 billion (Mutungi & Affognon, 2013). Even though the country can produce enough food for its population when this food is well managed, the national Government of Tanzania spends USD 200 million each year to import food to mitigate the impacts of such losses.

2.3.2 Causes of post-harvest losses in the food supply chain

The causes of PH losses are many and occur at various different stages of the food supply chain. The following sections provide an overview of the causes and related impacts of PH losses at producer, distribution and retail level.

Post-harvest losses at the producer level

In developing countries, including Tanzania, smallholder farmers dominate production. Production, harvesting and post-harvesting technologies and methods are usually outdated. Moreover, smallholder farmers are also particularly vulnerable to natural disasters and climatic conditions, as well as to market variability (The United Republic of Tanzania, Ministry of Agriculture, 2019). PH losses at producer level are mainly attributable to inappropriate storage after harvest, the quality of storage equipment and packaging for transport and the absence of best practice in maintaining product quality before the harvest is picked up for transport (The United Republic of Tanzania, Ministry of Agriculture, 2019).

Almost all farmers (98 percent) rely exclusively on local markets, but sell only 35–48 percent of their produce, which is in part related to self-sufficiency, but also to the losses incurred at farm level or during distribution (FAO, 2018) (see Table 2). Furthermore, most of the harvest is sold via informal channels on local markets, which is in part attributable to the absence of farmers' organizations to pool resources and share knowledge, and to inadequate or absent distribution options.

At the same time, the fact that only 56 percent of smallholder and 67 percent of commercial producer income is generated at farm level suggests that farmers need to take a second job in order to survive (FAO, 2018). There is a high probability that this reduces the time available for the implementation of best practice and product maintenance after harvest, and this lies at the root of the losses incurred at producer level.

Table 2: Data portrait of smallholder farms in Tanzania (FAO, 2018)

Small family farms in Tanzania		Small Farms	Other Farms
Farm aspects	Average farm size (ha)	1.2	5.3
	% of smallholders on total farmers	83	17
	% female headed households	26.2	27.3
Income and poverty	Household income (const. 2009 Int. $)	5032	6918
	% of income from crop production	47	54
	% of income from on-farm income	56	67
	% of income from agricoltural wage labour	7	3
	% of income from non-agricoltural wages and self-employment	30	26
	Smallholder poverty rate (national poverty line)	39	40
Labour	Family labour-days supplied on farm over a day period (person days)	0.56	0.99
	Family labour-days supplied off-farm over a day period (person days)	0.14	0.11
Production	Value of crop production (const. 2009 Int. $)	895	2549
	Amount of food produced (const. 2009 Int. $)	639	1876
	Value of food production per ha (const. 2009 Int. $)	1103	505
Capital and inputs	Livestock (TLU; pastoral households only)	2.8	4.8
	% of households using motorized equipment	1.4	10.4
	% of households using fertilizer	15.5	4.6
	Felrtilizer per hectare (kg)	39	8
	Seed per hectare (kg)	80	23
	Irrigation (% of land)	1.9	1.7
Markets	% of households selling crops through informal channels*	98	98
	% of households selling crops in the local markets* *73 percent of households reported this information	98	98
	% of households buying ag. inputs in the local markets *57 percent of households reported this information	99	99
Innovation and technology	% of households using improved seeds	41	45
	% of households recipient of extension services	9	17
Constraints	% of agricoltural production sold	35	48
	% of expenditure for inputs on value of production	7	5
	% of credit beneficiary households	6	9
	Credit (const. 2009 Int. $)	1036	1243
	Distance of land from road (km)	1.3	1.4

The lack of agricultural extension services related to knowledge-sharing and skill-building hampers the uptake of best practice for pre-harvest treatments, and the alignment of harvest time with the time when produce is shipped, as well as product treatments between harvest and shipment. According to the FAO (2018), only 7 percent of smallholder farmers and 17 percent of commercial farmers are recipients of agricultural extension services, indicating the vast potential for improvement across all components that extension services entail.

Most smallholder producers cannot purchase their own transport vehicles, although in some instances, farmer organizations and market cooperatives have been able to do so (Kiaya, 2014). This alleviates some of the pressure, allows farmers to plan their harvest in accordance with available shipments and highlights not just the value but the necessity of agricultural extension services that facilitate farmers' organization in collaboratives or collectives.

One of the prime examples for the value of farmers' organizations is the Tanzania Horticultural Association (TAHA). TAHA, in existence since 2004, is a member-based trade association representing around 42,000 farmers, with membership also including producers, exporters, processors and suppliers. TAHA has helped to reduce PH losses of horticultural products by 40–50 percent (USAID, 2020). Its strategies include improved capacity-building of farmers, supporting farmers to connect with markets, and developing infrastructure throughout the value-chain at critical loss points. TAHA's documented experience highlights the value of agricultural extension services that aim to organize farmers and provide them with both financial means and negotiation power. The benefits resulting from farmers' organization are likely to apply across all production sectors, especially fruit and vegetable producers, as well as livestock and fish farmers.

A large variety of technologies and methods for reducing PH losses are available in Tanzania, such as hermetic storage technologies and high-density polyethylene (The United Republic of Tanzania, Ministry of Agriculture, 2019). Nevertheless, these are often ineffective in reducing such losses due to a variety of reasons, such as the high price of spare parts or limited knowledge of using such technologies. It is worth noting that simply providing technological solutions for a problem causing PH losses (such as inadequate storage) is insufficient to achieve sustainable, permanent loss reductions. PH losses occur from field to table, and even pre-harvest decisions can affect the degree of loss. More emphasis should be given to integrated approaches to creating efficient food systems that entail limited losses.

Post-harvest losses in the distribution sector

Distribution is the most prevalent cause of PH losses in the agricultural supply chain in Tanzania. Specifically, losses related to the handling of produce during transportation, often incurred due to rough handling of goods during trans-shipment, in combination with fragile packaging materials, are the most relevant, accounting for 16 percent and 12 percent respectively of all PH losses, according to producers' perception (The United Republic of Tanzania, Ministry of Agriculture, 2019).

Roads

Rural roads are essential to kick start agriculture in Sub-Saharan Africa (Neubert, 2016). While highways and other primary roads have been supported by growing investment in the past decade and tend to be in good condition, the same does not apply to rural roads. The Rural Access Index (RAI) in Tanzania is estimated at 24.6 percent, with rural roads failing to connect 33 million people to roads in good or fair condition (Transport & ICT, 2016). Moreover, access to post-harvest facilities in Tanzania is virtually unavailable to most horticultural producers (Netherlands Enterprise Agency, 2015).

The quality of infrastructure in Tanzania differs greatly across different modes of transport (PwC, 2015): while the country is well served by domestic and international air transport, the low level of rural connectivity poses an obstacle to the development of certain sectors, one of which is agriculture. The density of the total network of trunk and regional roads is relatively low, at 3.7 percent, with paved trunk-road density occupying only 0.7 percent of the total land area (Region, 2017). Only around 30 percent of the total classified road network in Tanzania is paved, resulting in high vulnerability to extreme weather events (TANROADS, 2021). In the rural context, the share of paved roads is even lower, with only 8 percent of roads in rural areas being paved (TANROADS, 2021). Furthermore, previous estimates indicate that nearly 90 percent of all rural roads are in poor condition (Transport & ICT, 2016) (see Table 3).

Table 3: Road condition by pavement type in Tanzania (TANROADS, 2021)

Paved truck roads	8,658
Unpaved Trunk Roads	3,518
Total Trunk Roads	**12,176**
Paved Regional Roads	1,963
Unpaved Regional Roads	21,559
Total Regional Roads	**23,523**
Paved District Designated Roads	45
Unpaved District Designated Roads	515
Total District Designated Roads	**560**
Total Road Network	**36,258**

The fact that only around 8 percent of rural roads are paved and 90 percent are in poor condition highlights both the challenges of food distribution and the observation that the benefits that can be derived from the existence of the road network are undermined. Underdeveloped infrastructure severely affects access to both domestic and international markets in Tanzania (Mutungi & Affognon, 2013). Transportation of horticultural products is particularly challenging in Tanzania, where the logistics performance index is lower than that of neighbouring countries, such as Uganda and Kenya (USAID, 2019). Transportation time and the loss of trans-shipment opportunities in particular increase PH losses, and contribute to a deterioration in product quality over time, and hence decreased revenues.

The issue of connectivity and access to producer sites and markets should also be considered. While the overall road network delivers good connectivity between urban areas, it fails to provide adequate connections between crop production sites and markets (ADB, 2013). The development of the transport network should integrate rural communities with the country's economy by providing fast and reliable access to main producer regions. It has been estimated that in Tanzania, the average distance of small farms to the nearest road is 1.3 km, which is a much lower value than for other African countries, where farmers have to travel distances up to 40 times higher (FAO, 2018). Yet, despite better average proximity of producers to road infrastructure, considerable losses occur during shipment. During the rainy season, rural roads in Tanzania are predominantly impassable, for example (Temu, Nyange, Mattee, & Kashasha, 2005; Jalango, Begasha, & Kweka, 2019).

To further explore the challenges related to market access, we carried out a spatial analysis to understand the percentage of total agricultural areas that can be found within 1.3 km of roads (FAO, 2018). This analysis is presented in Text Box 1.

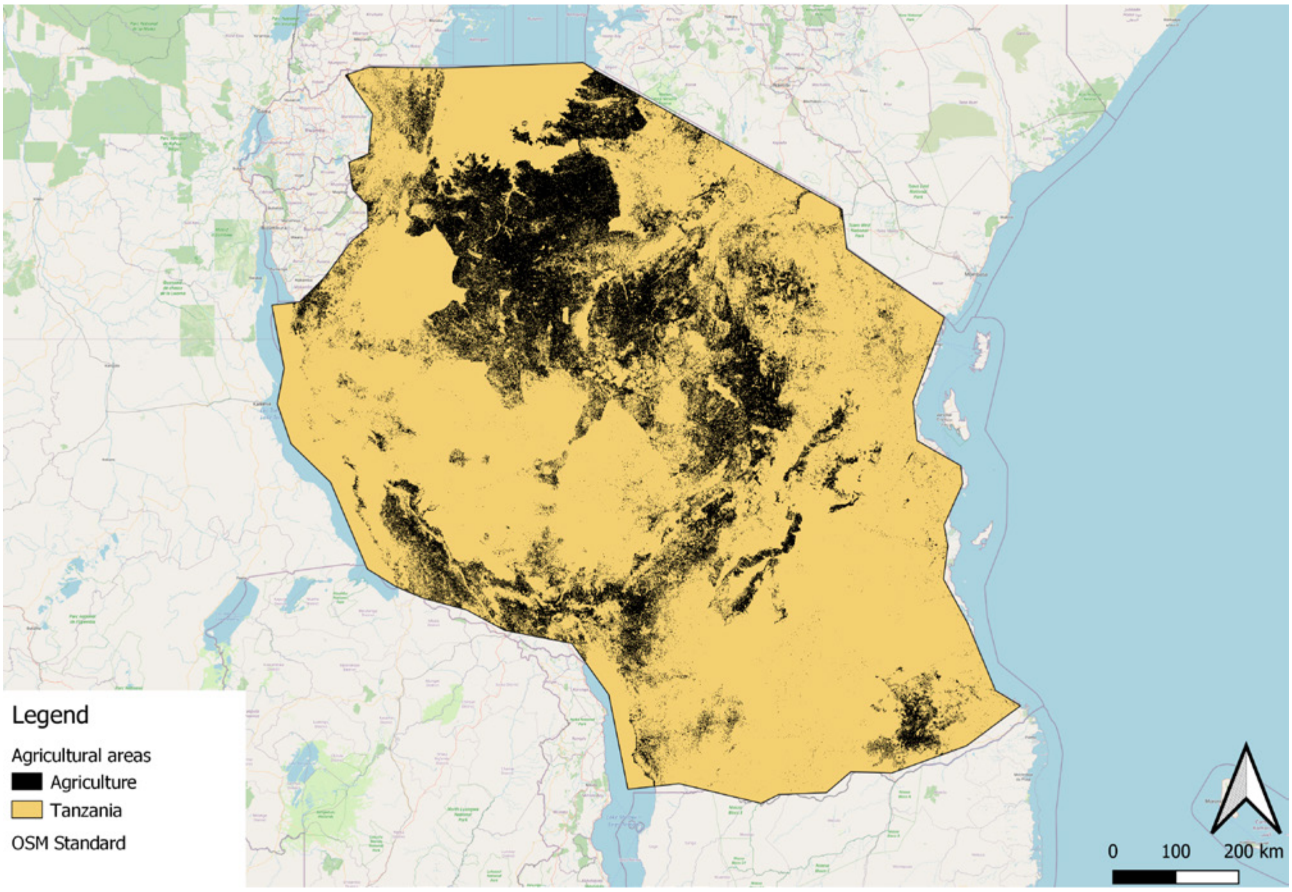
Text Box 1

Assessing access to roads for agriculture activities

In order to assess the amount of agricultural land in the proximity of roads, we first downloaded the 2019 land-use/land-cover (LULC) map of Tanzania from the Copernicus Global Land Service (100 m of resolution).[5] Second, we selected only the agricultural areas in the map (see Figure 2).

Next, we downloaded primary (including trunk), secondary and tertiary roads, with a buffer of 1.3 km around them, using Geofabrik.[6] We clipped the agricultural areas using a buffer of only primary roads (see Figure 3), then of primary and secondary roads (see Figure 4) and finally also including tertiary roads (see Figure 5). Through this process, it was possible to calculate the number of square metres of agricultural area within each buffer and to compare these with the total agricultural area.[7] Table 4 shows the number of square metres of agricultural area within each buffer.

Figure 2: Agricultural areas in Tanzania – 2019 LULC map



5 https://land.copernicus.eu/global/products/lc

6 https://www.geofabrik.de/

7 This calculation was done using in QGIS3: https://qgis.org/en/site/forusers/download.html

Figure 3: Buffer of 1.3 km around only primary roads (left); Agricultural areas within the buffer (right)

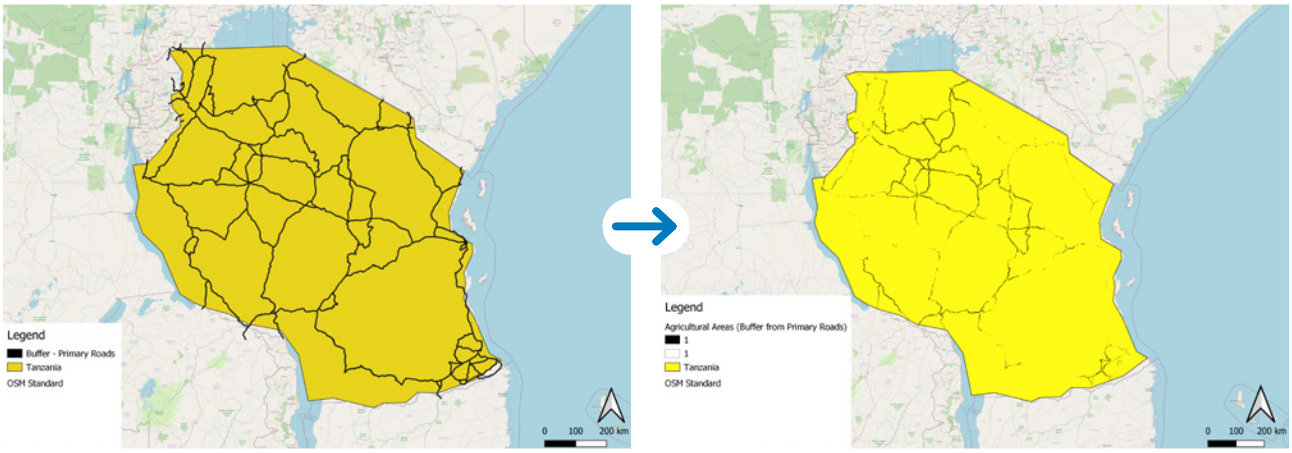


Figure 4: Buffer of 1.3 km around only primary and secondary roads (left); Agricultural areas within the buffer (right)

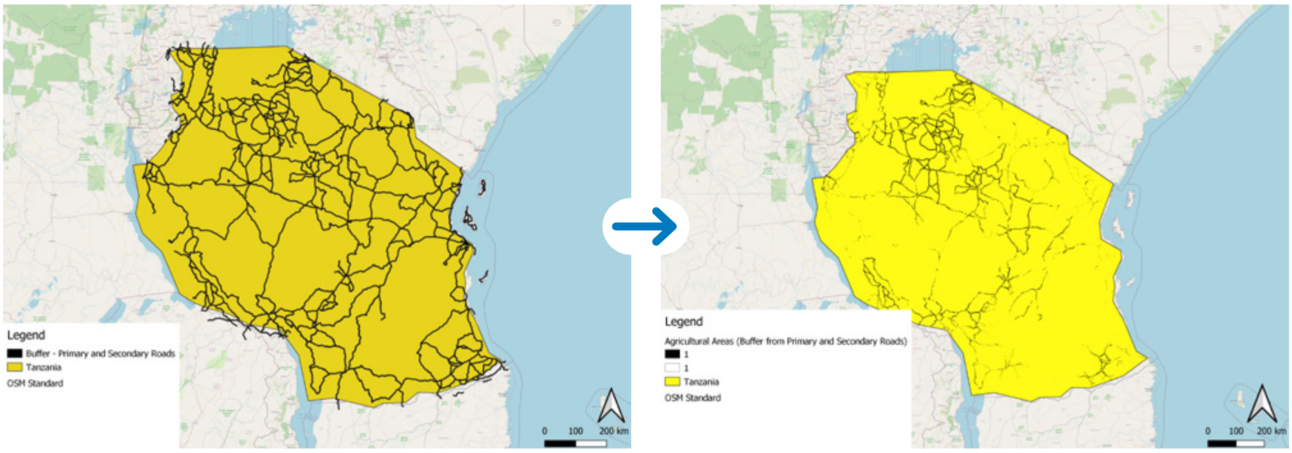


Figure 5: Buffer of 1.3 km around primary, secondary and tertiary roads (left); Agricultural areas within the buffer (right)

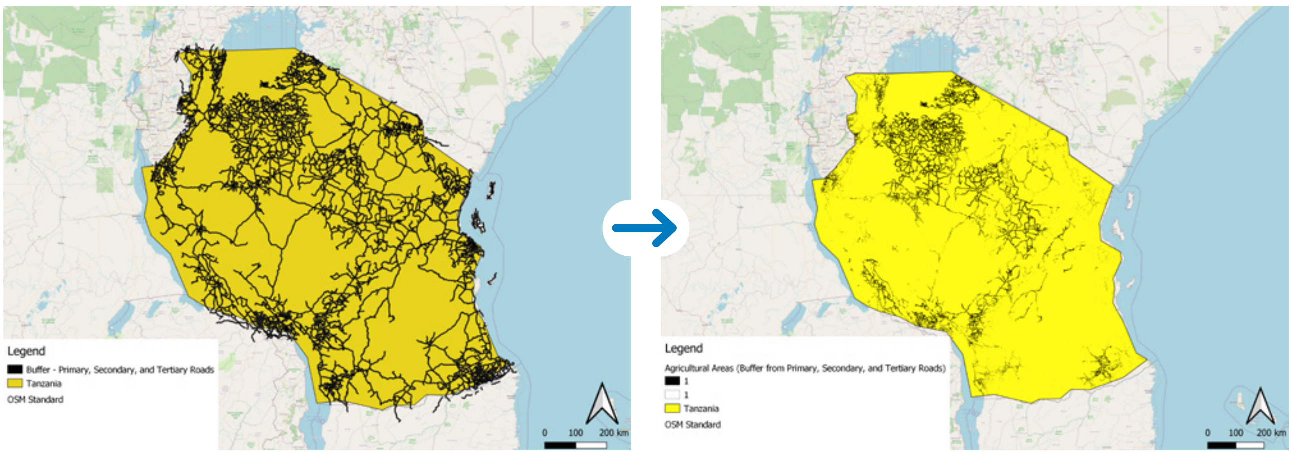


Table 4: Number of agricultural areas (m^2) within selected buffers.

	Agricultural areas within buffer (m2)	Agricultural areas outside the buffer compared to the total
Total agricultural areas	**195,697,270,969.84**	
Buffer (1.3 km – primary roads (including trunk)	12,313,888,548.61	94%
Buffer (1.3 km - primary & secondary roads)	26,686,785,486.46	86%
Buffer (1.3 km - primary, secondary & tertiary roads)	58,903,946,159.83	70%

94%

of agricultural areas in Tanzania can be found outside a buffer of 1.3 km of primary roads

30%

of all agricultural areas are located within the proximity of any road

As shown in Table 4, 94 percent of all agricultural areas in Tanzania can be found outside a buffer of 1.3 km of primary roads. In other words, almost every farm is unconnected to the primary road network, which is assumed to be the most frequently paved and also the most accessible road network during the rainy season. Furthermore, 85 percent of all agricultural areas can be found outside the buffer if we consider both primary and secondary roads, while 70 percent of all crop fields are located beyond 1.3 km of any road, including tertiary roads. Therefore, from our analysis, we conclude that only 30 percent of all agricultural areas are located within proximity of any road, and only a fraction (6 percent) can be found close to primary roads, which may not be paved either (Region, 2017). Nevertheless, it is worth noting that other types of roads, such as paths, residential roads and unclassified roads, have not been considered in this assessment.

Distribution practices and distribution infrastructure

Aside from the challenges related to the quality and proximity of roads and therefore access to markets, another significant challenge of distribution is the lack of proper packaging materials and the absence or inadequate quality of storage facilities. Examples include a lack of cold-storage facilities, lack of refrigerated transport vehicles (particularly relevant for horticultural products) and lack of appropriate transport systems (Kiaya, 2014). The electrification of rural villages has increased in recent years, with now almost two thirds of villages having access to electricity. The presence of a power supply in rural areas provides one of the key enabling conditions for the implementation of food storage, especially cold storage, as well as local processing facilities. However, to date, the potential for establishing these facilities has not been realized, indicating significant potential for improvements at the local level and beyond.

The lack of adequate food storage facilities and infrastructure means that many farmers leave agricultural products on the ground or in rudimentary storage facilities until these are picked up. This increases the risk of deterioration and loss by the time they are shipped and further exposes the harvest to moulds, insect infestations and other animals feeding on the produce. For example, a meta-analysis of measurements based on grain samples in Sub-Saharan Africa indicated that maize PH losses of more than 25 percent on average were due to insect infestation and mould damage (Brander, Bernauer, & Huss, 2018).

Since only products of high initial quality can be stored successfully, the lack of storage capacity and poor storage conditions lead to significant PH losses (Kiaya, 2014). During transportation, perishable agricultural products need to be kept cool. However, the lack of refrigerated (or at least ventilated) vehicles further hinders the transport of fresh, perishable products, such as fruits and vegetables (Kiaya, 2014). In addition to the road-related challenges discussed above, vehicles and other modes of transport are often not widely available for reaching local and international markets. The uncertain availability of adequate transport increases the uncertainty for farmers in choosing the best time to harvest, and long waiting times induced by shipment delays contribute to unnecessary deterioration and loss of quality in produce before shipments, for which farmers bear the brunt in the form of reduced revenues.

2.3.3 Effects of post-harvest losses on producers and consumers

As highlighted in the previous sections, the underlying dynamics of PH losses have several far-reaching impacts on all actors in the food supply chain. PH losses pose a food security threat in a country in which the population is projected to grow, and also have detrimental effects on environmental quality and the natural capital it represents. In recent years, Tanzania has followed a strong path of urbanization, accompanied by a growth in income among the middle-class (Mutungi & Affognon, 2013). Consequently, food chains have extended to longer distances, from farms to urban areas, accompanied by a growing demand for high-quality produce, primarily in terms of safety and convenience. Given the difficulties related to roads and transport described above, these longer distances, and protracted travel times entail a greater risk of damage during transport and trans-shipment and consequently, higher losses throughout the supply chain.

The increase in demand from potential consumers who are at a greater distance from agricultural areas requires solutions for reducing PH losses and addressing the economics of production, if local food production is to play a strong role in the development of the country. Solutions to manage and reduce PH losses cannot only concentrate at the farm level, as was the case in the past. Instead, an integrated approach that also addresses challenges related to distribution infrastructure and the development of an extended value-chain for food processing is needed.

Overall, the main impacts of PH losses include (The United Republic of Tanzania, Ministry of Agriculture, 2019):

- reduced monetary value, and hence revenues for producers, due to decreased quality and/or quantity of the products sold;
- less food available, affecting food security; and
- increased pressure on the environment, due to the use of production inputs that are used for food that is not even consumed, and agricultural expansion into fragile ecosystems.

Reductions in revenue

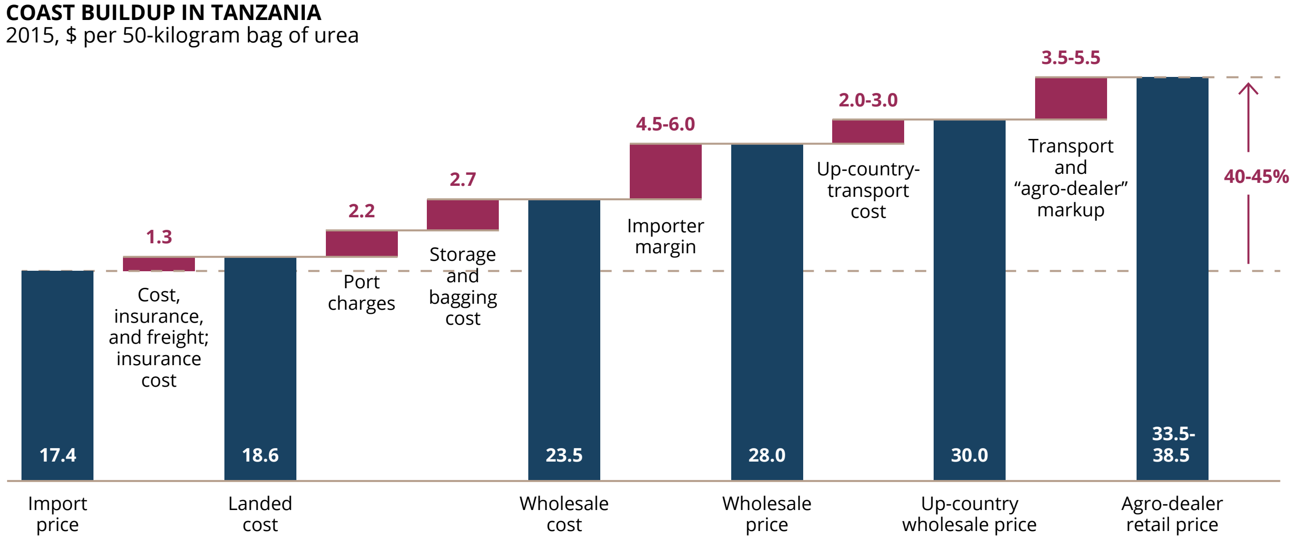
Many smallholder producers remain cut off from the economic life of their country, mainly as a consequence of the distribution-related challenges highlighted above. This is especially true during the rainy season, when people cannot reach markets to sell their products (Neubert, 2016). If produce is harvested too close to the rainy season, impassable roads lead to transport delays, which in turn increases the time for produce to reach the market. While grains, if properly dried and stored, are less susceptible to deterioration during storage, more perishable products such as fruit and vegetables, but also meat and fish, are more likely to deteriorate by the time shipment occurs. This loss in quality translates into a reduction in the sale price, or renders produce unsaleable by the time it reaches the market. This increases the monetary risk for farmers who decide to engage in the production of these products, as well as for the wholesalers and retailers who buy these products at the farm gate.

A second aspect relates to the accessibility of markets and the impacts of PH losses on the food supply chain as a whole. If farmers cannot get their products to market, or deliver produce at sub-par quality relative to that of other producers, they will earn less revenue and potentially have no resources to reinvest. A lack of ability to invest does not only slow down technological improvements, such as mechanization or the adoption of sustainable practices, but may imperil the purchase of basic production inputs such as seeds, fertilizers and in some instances, water, all of which results in a reduction of total sectoral productivity, putting both financial performance as well as future food security at risk (Region, 2017). In other words, the ripple effects are multi-dimensional, incurring in terms of economic activity (and hence national GDP) as well as having effects on nutritional outcomes and livelihoods. The above is supported when reviewing cases studies that focus on assessment of the impacts of road improvements on rural areas and the financial performance of farmers. For instance, when rural smallholder farmers in South Western Kenya were connected with improved roads, they adopted sustainable and more effective farming practices, such as hybrid seeds or fertilizer intensification (Kiprono & Matsumoto, 2018).

Furthermore, poor-quality roads and the resulting longer transportation times have been linked to higher transport prices for both production inputs and outputs (Fungo, 2018; OCED, 2007). For example, the price of chemical fertilizers in the Kilimanjaro region is 8 percent higher than in other, better connected areas. This is also a problem in other parts of the country: in Southern Tanzania, smallholder farmers buy fertilizers and hybrid seeds every two to three years due to poor market access and low crop prices, resulting in a decline in agricultural yields (Goedde, Ooko-Ombaka, & Pais, 2019). On average, the fragmented supply chains in Africa led to a 20–50 percent mark-up over import price across relevant agricultural inputs, with roughly between one third and one half of that captured as margin by distributors and retailers in the chain (see Figure 6).

In addition to the above, this increase in costs translates into the cost of living for final consumers. Higher input prices, in part induced by higher transport costs, lead to an increase in the cost of a healthy diet. For example, the average cost of food in regions such as Kilimanjaro and the city of Dar es Salaam, which are located further from production zones, ranges between USD 2.54 per person/per day and USD 2.83 per person/per day (FAO, IFAD, UNICEF, WFP and WHO, 2020). In comparison with the average national cost of a healthy diet of USD 2.33 per person/per day, this indicates that the daily cost of food is between 9 percent (Kilimanjaro) and 21.5 percent (Dar es Salaam) higher.

Figure 6: Import and distribution mark-ups in fertilizer prices in Tanzania (Goedde, Ooko-Ombaka, & Pais, 2019)



McKinsey&Company | Source: IFDC; interviews with local fertilizer importers and distributors

Food security and loss of resources

One of the most important impacts of PH losses is that they reduce the food supply available for consumption, especially for fresh and nutritious products. In a developing country such as Tanzania, which has seen rapid urbanization in recent years, the quality of life is expected to increase, but this depends on the availability of fresh produce and nutritious diets. With current PH losses of approximately 30–40 percent for cereals and even higher for perishable crops (The United Republic of Tanzania, 2018), there is considerable potential to increase the available food supply and to provide sufficient food for a growing population, today and in the future. Yet if PH losses are not addressed, there is a high probability that food scarcity will be more prevalent in the future, forcing the Government to import food from other countries in which agricultural production is less affected by, or more resilient to, climate change.

Environmental impacts

Last but not least, one issue related to PH losses is that they cause a wasteful use of production inputs, including natural resources. For producers, this means that the seeds, fertilizers and water required for production are wasted, representing costs that do not turn into revenues. For the actors working on distribution, this means that both the energy required for transport as well as the wear and tear on vehicles and the materials used for shipments incur unnecessary costs. If cold storage chains are available, the energy used to cool produce that is ultimately lost is wasted as well. The waste of resources across all actors of the supply chain comes in addition to the threat to food security, which is an issue that many countries in Sub-Saharan Africa are already facing and which, in the face of population growth and the growing impacts of climate change, will become worse in the future. Furthermore, the energy used and waste generated lead to additional greenhouse gas emissions, compared to a situation in which PH losses are reduced or avoided.

PH losses, low revenues and the resulting lack of investment also contribute to land-cover changes in expanding the harvested area. This expansion usually comes at the expense of natural capital such as forests, fallow land and in some instances, peatland, as has been observed in Tanzania over the last decades. The map in Figure 1 showing land degradation in Tanzania clearly shows that deforestation and degradation of other, potentially productive areas, are ongoing.

2.4 MALNUTRITION AND HEALTH IMPACTS

It has been estimated that between 2017 and 2019, 13 million Tanzanians were severely food insecure, and 31 million moderately food insecure (WFP, 2021a). The second Tanzania National Nutrition Survey (TNNS), conducted in 2018, found high malnutrition rates among children aged under five years, with stunting affecting 32 percent of children and the proportion who were underweight reaching 15 percent. Overall, it is estimated that 420,000 children were affected by acute malnutrition.

Micronutrient insufficiencies are also severe: anaemia affects 45 percent of women of child-bearing age, and 60 percent of children. Additionally, 32 percent of women between 15 and 49 years of age are overweight, and 11.5 percent are obese (WFP, 2021a). A WFP study (2021b) showed that high and very high prevalence of stunting is present in most regions in Tanzania (see Figure 7).

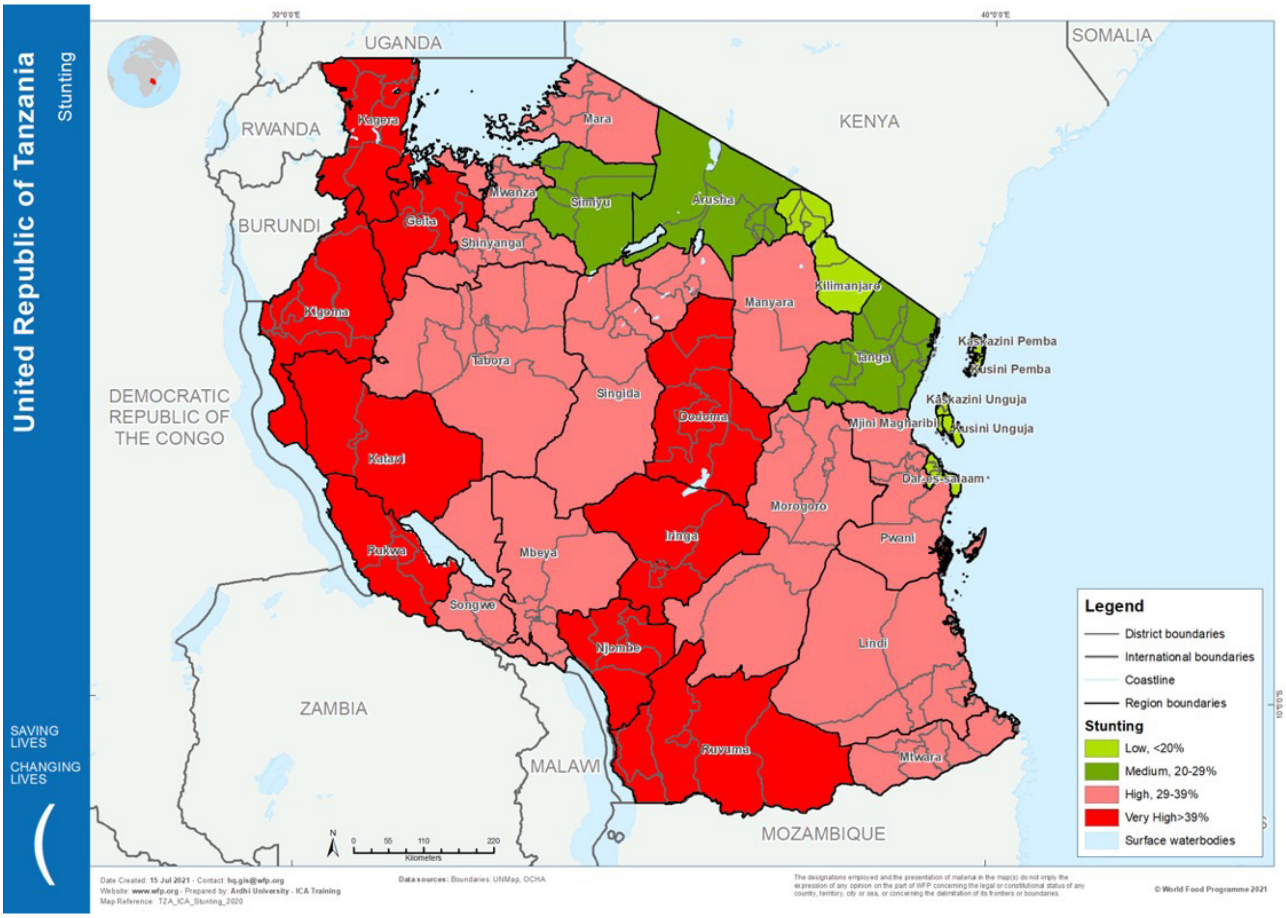
45%

of women of child-bearing age affected by anaemia

32%

of women between 15 and 49 years old are overweight

Figure 7: Stunting in Tanzania (WFP, 2021b)

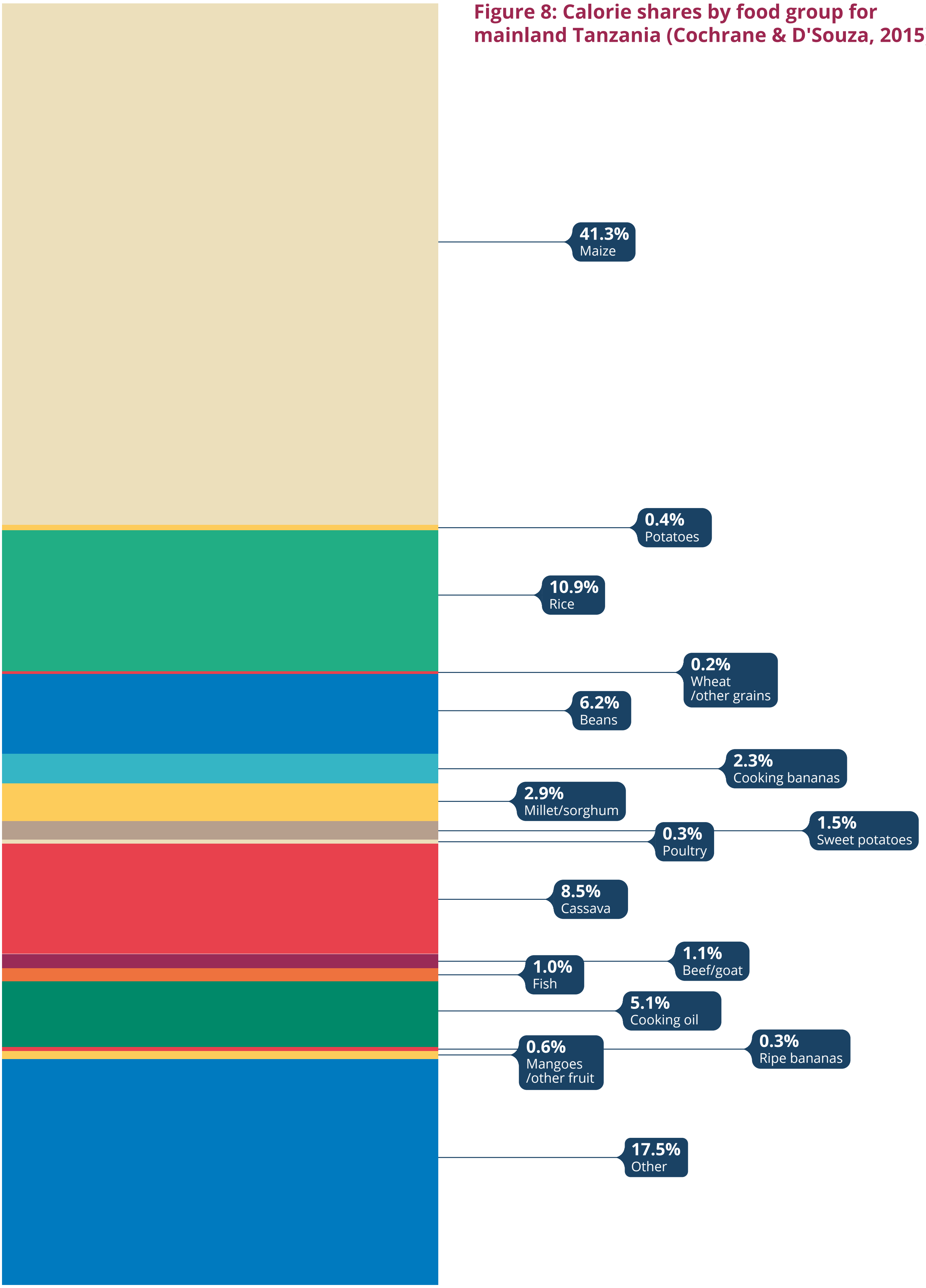


The severity of micronutrient deficiencies can be explained by the fact that diets in mainland Tanzania are heavily dependent on unfortified staple foods (WFP, 2017), with 40 percent and 11 percent of calories derived from maize and rice respectively. This means that more than half the calories in the average diet come from two types of cereals (see Figure 8). Moreover, contrary to the common assumption that in Africa, processed food is predominantly an urban, middle-class phenomenon, a study found that in Tanzania, processed food has penetrated diets in rural areas as well (Sauer, et al., 2021). In particular, the study found that 60 percent of food consumed in rural areas is purchased, while the residual 40 percent is grown, harvested and consumed locally (i.e., self-sufficiently by the local population). Out of the 60 percent of food that is purchased, processed food accounts for almost half (47 percent) and this share is likely to increase in the future as the population becomes more affluent (Sauer, et al., 2021). Since processed food is high in salt, sugar and oils, it raises health concerns, increasing the risk of illnesses such as cardiovascular disease, cancer and obesity.

Another pattern of food consumption in rural settings is the fact that family members eat from the same pot: this can have a negative effect on the nutrient intake of those who do not eat quickly enough, such as children (FAO, 2008). In some communities, men and women eat separately and often the latter eat only once the men are satisfied.

Traditional and common food preparation techniques can decrease the nutritional value of food (FAO, 2008). For example, cooking vegetables for a long time and removing the cooking water can lead to a significant loss of nutrients such as heat-sensitive vitamins (carotene and vitamin C) and water-soluble vitamins (especially those of the B group). In other words, inadequate knowledge of food and nutrition contributes to poor diets.

Figure 8: Calorie shares by food group for mainland Tanzania (Cochrane & D'Souza, 2015)



3. An integrated view at the food systems in Tanzania

The causal loop diagrams (CLDs) in Figure 9 and Figure 10 show the main dynamics influencing the food system in Tanzania.[8] These include the key drivers of change in production, distribution and access to food, and resulting impacts on producers (e.g. on income creation and the potential to invest in improved production practices) and citizens (e.g. concerning food affordability and nutrition).

Figure 9 presents the full CLD and Figure 10 highlights the main thematic areas. These figures present the final, most complete CLD created during two group model-building session.

3.1 IDENTIFICATION OF THE MAIN DRIVERS OF CHANGE

Tanzania's food system 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.

Overall, the CLDs show that food distribution and the lack of aggregation, local food processing and adequate transport and storage systems play a crucial role in the food system (see Figure 10). This finding emerges from analysis of the circular relations, or feedback loops, included in the diagram. The role of feedback loops in shaping historical trends and determining the success of policy implementation is presented in more detail below.

On the one hand, the performance of food distribution (considering its cost, speed and reliability) determines the extent to which the full potential of investments in production can be realized. Practically, if investments are implemented to increase production, but there isn't enough capacity to deliver all the food produced (e.g. due to limitations related to the road network in rural areas), the return on investment for farmers will be smaller than expected – or even negative. This reduces the appeal of investment in production (e.g. in technology adoption and improved production practices). Further, if investments are made to diversify production towards fresh produce, and distribution is untimely or ineffective, resulting in food losses, producers will be stimulated to only produce non-perishable food (e.g. grains), rendering the initial investment highly ineffective. This leads to a variety of outcomes, including market concentration, increased vulnerability to market dynamics and extreme weather events, and the impoverishment of natural capital, seen, for example, as soil infertility and erosion.

8 The CLDs were prepared in two group model-building sessions with internal WFP experts and Government stakeholders. The sessions took place on 31 May (internal consultation) and 15 June 2021 (external consultation) respectively.

On the other hand, the performance of food distribution can enable or trigger changes on the consumer side, having positive impacts on citizens, producers and government. As indicated above, an effective distribution network that delivers food to the market, in a timely and cost-effective manner, can stimulate demand for a healthy and nutritious diet. If demand is in place, several advantages can be accrued:

- for citizens, by reducing malnutrition and improving human health;
- for government, by requiring a lower budget for health expenditure (and freeing up resources for other investments) and by increasing labour productivity and possibly also public revenues; and
- for producers, by providing a stimulus for a more diversified production, which guarantees higher profitability (due to the higher profit margin of fresh produce) and improved productivity of natural resources (due to reforestation, restoration of rangelands and marine resources, soil and water conservation, improved soil health, etc.).

There are several other considerations, which are presented in more detail below – for instance, the extent to which access to nutritious food and improved productivity can improve gender balance and female empowerment; or the fact that changes in consumer demand, which would affect production choices, will improve the diversity of crop choices and improve the performance of the agricultural sector, while making it more climate-resilient.

Investments are required for the country to realize this potential. Two main areas that have emerged from the group model-building exercise are:

- infrastructure; and
- consumer behaviour.

Infrastructure investments relate to road construction and maintenance, with challenges existing for the perceived low economic appeal of investment in rural areas, as well as in food storage (both for post-harvest storage and the cold-chain distribution). Additional investments, with the potential for co-financing from the private sector, could emerge to expand the value-chain by adding local food processing. This would, on the one hand, reduce the pressure on distribution by producing food that can last longer, and on the other hand, increase the convenience of nutritious food and further stimulate demand. Investments to influence consumer behaviour include education and awareness-raising for consumers (including mothers and caregivers), as well as investment in school feeding programmes. Infrastructure investments are essential to realizing the social, economic and environmental opportunities described above. Even more importantly, when the synergies among production, aggregation, distribution and consumption are realized, self-reinforcing mechanisms will emerge, driven by higher profitability for producers, improved health among citizens and reduced costs for the Government. These dynamics are represented by reinforcing feedback loops (R) in the CLD. Practically, infrastructure for reducing pre- and post-harvest and delivery losses, is an enabler of more economically, socially and environmentally sustainable strategies for the food system. In fact, nutrition and human health can only improve if the whole system is working in a coordinated and harmonized manner: Tanzania needs productive natural resources and minimal pre- and post-harvest losses to create economies of scale in the distribution of food. With food- and cold-storage facilities, the country's supply system can provide fresh and healthy food to market, in a more affordable way. These are the preconditions to create demand for healthy products and to reduce the consumption of imported, pre-packaged products. The result will improved nutrition and human health, as a result of a food system that is sustainably strengthened and managed.

3.2 MAIN DYNAMICS EMERGING OVER TIME AND REQUIRED ACTIONS

First, the study identified that a producer's decision on what crops to grow depends on potential profitability and the extent to which they require a nutritious and diversified diet, taking into account cultural considerations.[9] The presence of a large number of women in the workforce of the agricultural sector could be used to create a positive, reinforcing feedback loop (R1) (see Figure 9). Women are more aware of the need to have a varied diet that comprises both grains and vegetables, and animal and/or fish products. If awareness is raised further, and women empowered, there is an opportunity to increase the sustainability of food production and the food system itself.

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, improved soil health and increased water harvesting and management would increase land productivity and also require smaller quantities of fertilizers. This higher productivity would stimulate more investment in diversified production, creating a second reinforcing loop, R2.

Third, if efforts in diversifying production are accompanied by investments in food processing, the number of products sold (and hence the revenues accrued by producers) will increase. This, represented by R3 in the CLD, provides a further stimulus for producers to diversify production. The advantage created by increasing food processing is twofold: it reduces the potential amount of food losses (increasing revenues and profitability for producers) and makes nutritious food more accessible, thus increasing demand, and indirectly increasing revenues for producers.

Fourth, building on the above, additional production of diversified and nutritious food and the expansion of the value-chain to food processing will increase the availability of non-perishable nutritious food in local markets. Processed food will also increase the convenience of consuming nutritious food, stimulating demand especially in urban areas or in contexts where there is little time for preparing food. 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).

Fifth, there are a few options to reduce food losses from distribution. On the one hand, as discussed earlier, food processing reduces the risk of losses. On the other hand, if the transport network becomes more effective, delivering food in a timelier manner and by storing food until demand emerges (e.g. through cold storage), more of the fresh produce can reach the market and generate revenues. 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 (and reduced pre- and post-harvest losses) could make distribution more effective, by allowing producers to fill trucks, rather than below-capacity trucks transporting produce.

Considering all the above, the study identified four main incentives for producers to invest in diversified production:

- the needs of producers and their families, for food security and nutrition, and income for basic needs;
- increased profitability from having reduced distribution losses (via an improved road network, food-storage infrastructure and expanded food processing);
- increased consumer demand resulting from improved education and access to nutritious food; and
- potentially higher demand for exportable commodities, resulting from export promotion activities.

9 This could also apply to animal, fish, forest and home-based processed products

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 characterized by reinforcing loops, which when triggered tend to be self-maintaining, creating virtuous cycles. On the other hand, historical data shows that past developments have been less effective. In fact, there are many challenges that 'break' the positive, desirable feedback loops described above. Two of these challenges are connected: 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 in areas that are more densely populated. This has resulted in unequal development, with comparatively lower investment in rural roads and 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 do more damage to unpaved roads and bridges). If roads are blocked, the time to reach market could increase by hours if not days. When the time to reach market increases, the incentive to produce fresh produce declines, because there is no certainty that fruits and vegetables will reach the market on time and in good condition, and so generate revenue. As a result of the current condition of the road network, especially in rural areas, farmers are incentivized to produce grains rather than horticultural and animal products. Grains offer lower profitability, but have longer shelf lives and are more likely to generate revenue. However, the very existence of those lower profit margins discourages investment in the resources needed to introduce more sustainable, climate-resilient practices. Under these conditions, the production side of the food system is constrained, and remains locked into low productivity, limited diversification and a high reliance on grains and other commodities that are not so affected by delays in reaching the market. Further, the concentration of supply in a few products makes oversupply of grains an issue, possibly further compressing profit margins. A diversified supply would prevent this problem from emerging. Roads also affect decisions to invest in the expansion of agricultural land.

In conclusion, improvements in the sustainability of the food system are likely to generate benefits that reach beyond production and distribution, if known challenges are addressed well. Specifically, if better access to, and the affordability and desirability of, nutritious food translate 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, both for households and the Government. Further, the Government can expect to see an increase in revenues from improved economic performance. The combination of lower costs and higher revenues may then free up resources for new investment, such as improved food storage and road networks in rural areas, to create further synergies and maximize value for money (R7 in the CLD).

Figure 9. Full CLD, 15 June 2021 session. Intervention options are presented in orange; external drivers in red

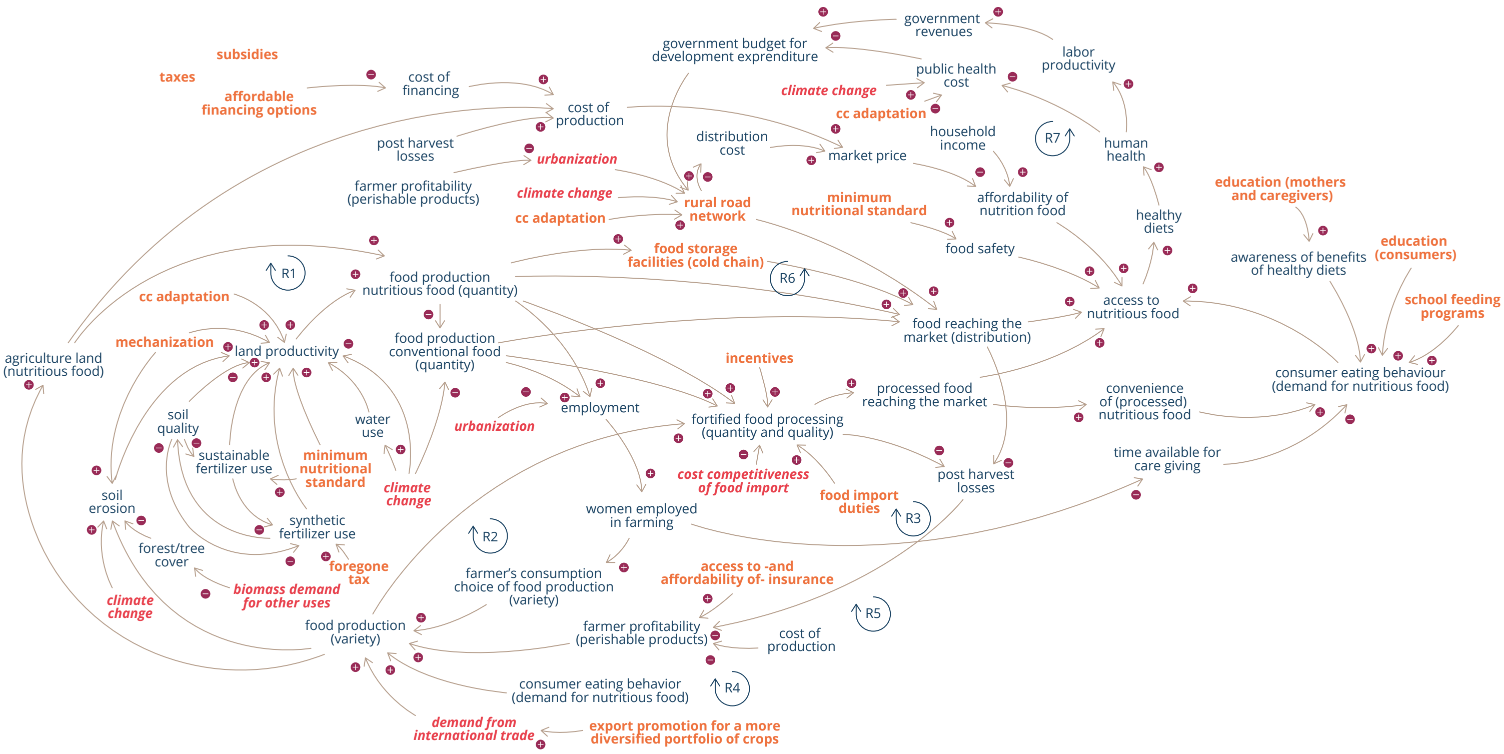
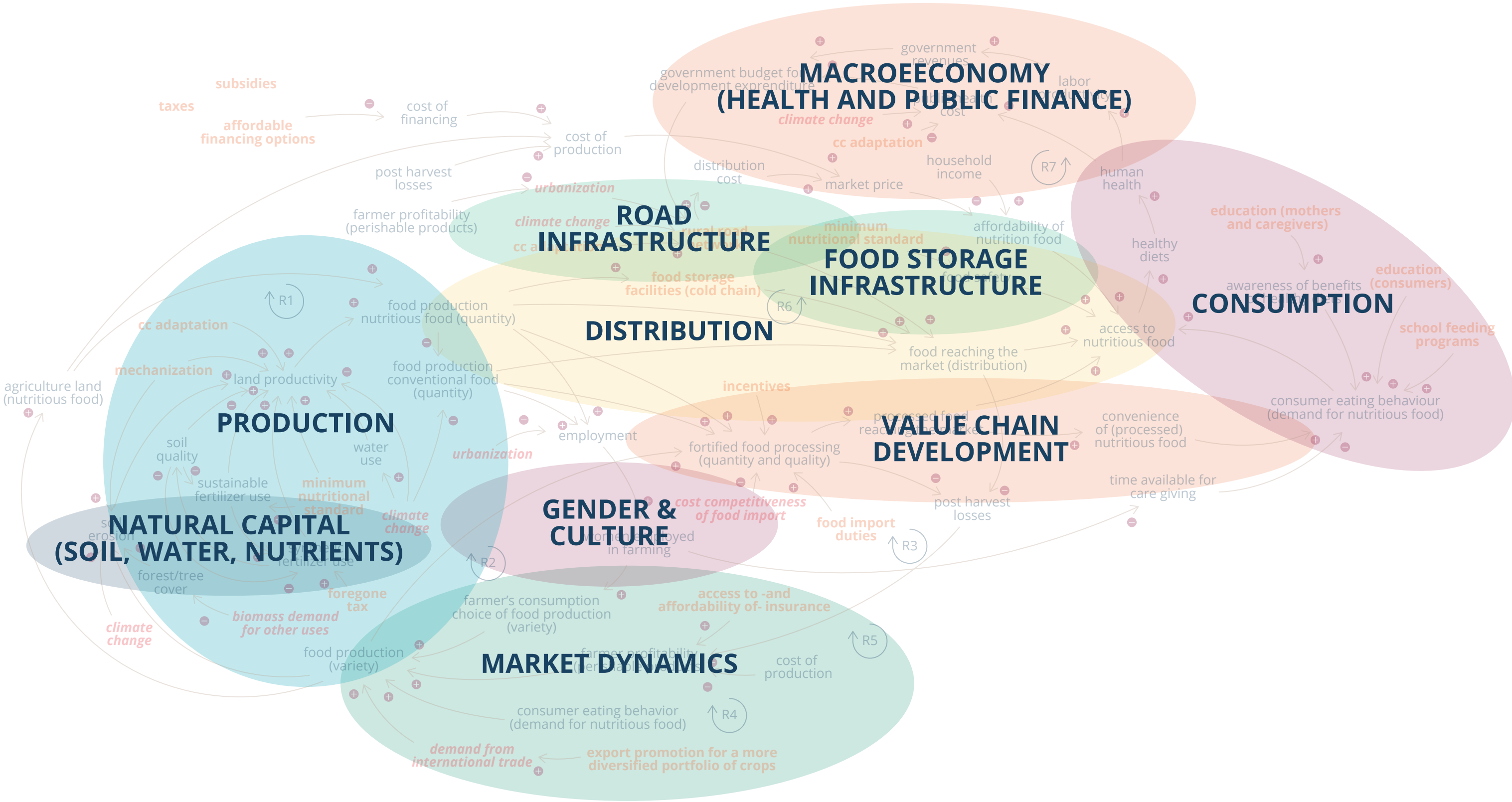


Figure 10. Thematic areas included in the full CLD 15 June 2021 session), including production, distribution, consumption and infrastructure (food storage and roads)



4. Quantitative analysis

4.1 SCENARIO DEFINITION

This section provides an overview of five scenarios:

- business as usual (BAU)
- production
- distribution
- awareness-raising (consumption); and
- all production, distribution and consumption combined (in synergy)

Table 5: Overview of scenarios

Scenario	Description
BAU	The BAU scenario assumes a continuation of historical trends observed for the crop-production, distribution and consumption sectors between 2000 and 2018. This assumes no changes related to the production of crops nor consumer preferences. Furthermore, no improvements are foreseen for the distribution system, which hence exhibits the same losses as observed in the past, or higher due to climate change. In essence, the BAU scenario represents the no-action scenario and constitutes the baseline against which the impacts of various policies targeting production, distribution and consumption are assessed.
Improved production	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 agricultural extension services. Land under sustainable management practices is assumed to be 20 percent more productive and to use 50 percent less synthetic fertilizer input. The assumptions used for the improved production scenario are presented in Table 9.
Improved distribution	The improved distribution scenario combines a range of interventions aiming to reduce losses during transport to market. The interventions envisaged are: (i) availability of cooled transport; (ii) processing of products to reduce perishability; (iii) expansion of the road network; and (iv) improvement of road quality in rural areas. The assumptions used for each of these policies are summarized in Table 16.
Consumer awareness	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. This shift is simulated by changing the consumer preference index, which in turn affects the choice of crops for farmers, practically allocating more land to fruits and vegetables to follow demand. The assumptions used for the consumer awareness index are presented in Table 23 .
Integrated supply chain management (improved production and distribution; raised consumer awareness)	This more integrated scenario assumes that all the interventions mentioned above for production, distribution and consumer awareness are implemented simultaneously. The policy assumptions for the full integration scenario are identical to the assumptions listed for the improved production scenario, the improved distribution scenario and the consumer awareness scenario.

4.2 RESULTS

This section presents the results of the analysis performed for the five scenarios simulated. Table 6 illustrates the trends observed for key indicators in the improved production, improved distribution, consumer awareness and full integration scenario, each compared to BAU.

The results suggest that the integrated approach leads to the largest gains, both concerning farmer profitability and nutrition. Improved access to infrastructure, adequate storage and suitable transport infrastructure result in lower distribution losses while at the same time 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.

Table 6: 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: ↑ large increase, ↗ mild increase, → no change, ↘ mild decline, ↓ large decline.

These results are also reflected also in the cost benefit analysis (CBA) (see Table 5; all assumptions are presented in Annex 1). The economic analysis compared the investment required under different scenarios with the resulting avoided costs and added benefits emerging over time, until 2050.

The investments considered are for:

- sustainable agriculture
- food-storage infrastructure
- expansion and upgrade (refrigeration) of the vehicle fleet
- road network expansion
- road quality improvements
- food-storage facilities
- consumer awareness programmes

Avoided costs include:

- reduction in the use of synthetic fertilizer
- reduced cost of malnutrition
- expected increases in the cost of healthy diets

Added benefits include:

- additional carbon sequestration from sustainable agriculture practices
- income generation from farming and food processing
- additional profit generated in farming activities

The analysis shows that investments in production, distribution and consumption are all economically viable. The integrated scenario, where investments are implemented for production, consumption and distribution, is the most viable and also the scenario that generates the largest absolute benefits (USD 1,652.7 billion undiscounted and USD 319.0 billion discounted). The investment required in this scenario is USD 93.9 billion and generates avoided costs of USD 74.2 billion, as well as between USD 638.9 billion and USD 1,633.04 billion in added benefits between 2021 and 2050. Practically, when considering discounting of 10 percent, the benefit-to-cost ratio is between 1.8 and 4.3 in a pessimistic and an optimistic scenario respectively.

We note that the results for investment in production are unviable under the most pessimistic assumptions (i.e. there is no premium price for sustainable products, and without the increased quality of products as a result of improved distribution, investment in production would not be rewarded with higher prices). Investing in production alone can generate benefits, but, under all assumptions, it does not lead to a transformation of the market and does not trigger virtuous and self-sustaining dynamics. Still, if consumers recognize the improved quality of fresh products with a premium price, investing in food supply leads to net benefits in the range of USD 21 billion (discounted) and USD 182 billion (undiscounted) between 2021 and 2050.

Investments in distribution and aggregation instead better leverage the current level of production, making it more profitable and hence stimulating both additional investments and consumer demand for healthier products. The benefit-to-cost ratio in the distribution scenario ranges between 1.4 and 3.7, indicating that, even under the most pessimistic assumptions, the investment is economically viable and more profitable than only investing in production. It is worth noting that, while investments in production lead to the largest income creation, investments in distribution generate higher profits.

Finally, the highest return per dollar invested is observed for investments in consumption, provided these are effective in changing consumer behaviour (the benefit-to-cost ratio in this case is between 11.2 and 13.9). However, the effectiveness of investment in consumer awareness is highly unpredictable and absolute impact is rather small when compared with investment in distribution, which is three times as large. The model forecasts an increase in the cost of fresh products, up to 26 percent of the current (BAU) price. This reduces affordability and would limit the effectiveness of awareness-raising activities, hence rendering the results of the consumption scenario overly optimistic. This is not the case for the integrated scenario, where an increase in the cost of diets is accompanied by an increase in farmer income and profits for producers.

In summary, as indicated above, strong synergies emerge when considering the possibility of simultaneously implementing all investments. While investing in each area of the food systems has its own benefits (e.g. investing in production increases income via job creation, investing in distribution reduces costs and leads to higher profits, and investing in consumption curbs malnutrition costs), investing in distribution unlocks the potential to maximize the effectiveness of investments in production and consumption, resulting in the largest benefits of all scenarios analysed (Table 6) and greater effectiveness than investing in production alone, which is often seen as the preferred intervention option.

Table 6: Cost–benefit analysis (CBA) comparing the economic performance of alternative scenarios with BAU. Cumulative values up to 2050

	Unit	Improved production scenario		Improved distribution scenario		Improved consumption scenario		Integrated supply chain scenario	
Investment and costs									
Sustainable agriculture	bn USD	26.81		0.00		0.00		26.81	
Investment in sustainable agriculture	bn USD	3.79		0.00		0.00		3.79	
O&M sustainable agriculture	bn USD	23.02		0.00		0.00		23.02	
Storage infrastructure	bn USD	0.00		13.51		0.00		23.26	
Capital investment storage infrastructure	bn USD	0.00		3.79		0.00		7.55	
O&M cost storage infrastructure	bn USD	0.00		9.72		0.00		15.72	
Vehicle fleet	bn USD	1.21		7.50		1.80		13.36	
Capital investment in trucks	bn USD	1.11		-3.33		1.64		-2.36	
Capital investment in refrigerated trucks	bn USD	0.00		10.27		0.00		14.74	
O&M cost conventional trucks	bn USD	0.10		-0.48		0.15		-0.34	
O&M cost refrigerated trucks	bn USD	0.00		1.04		0.00		1.33	
Road network expansion	bn USD	0.00		21.44		0.00		21.44	
Capital cost additional road construction	bn USD	0.00		5.76		0.00		5.76	
O&M cost of additional roads	bn USD	0.00		15.67		0.00		15.67	
Road network quality improvements	bn USD	0.00		3.24		0.00		3.24	
Capital cost road quality improvement	bn USD	0.00		2.43		0.00		2.43	
O&M cost road quality improvement	bn USD	0.00		0.81		0.00		0.81	
Food-processing facilities	bn USD	0.00		2.10		0.00		2.92	
Capital cost food processing	bn USD	0.00		0.98		0.00		1.36	
O&M cost food processing	bn USD	0.00		1.13		0.00		1.57	
Consumer awareness programmes for healthy nutrition	bn USD	0.00		0.00		2.89		2.89	
Capital cost of establishing awareness raising programmes	bn USD	0.00		0.00		2.89		2.89	
Running costs consumer awareness programmes	bn USD	0.00		0.00		0.00		0.00	
(1) Total investment and costs	**bn USD**	**28.02**		**47.79**		**4.68**		**93.93**	
Avoided costs									
Cost of synthetic fertilizers	bn USD	2.20		0.00		0.00		2.20	
Cost of organic fertilizers	bn USD	-0.21		0.00		0.00		-0.21	
Cost of malnutrition	bn USD	6.94		54.18		15.29		72.24	
Cost of healthy diets (% increase over baseline for fruits and vegetables)	bn USD	4.8%		20.4%		0.0%		26.2%	
(2) Total avoided costs	**bn USD**	**8.93**		**54.18**		**15.29**		**74.24**	
Added benefits									
Additional carbon sequestration from sustainable agriculture	bn USD	0.87		0.00		0.00		0.87	
Labour income from sustainable agriculture	bn USD	12.10		0.00		0.00		12.10	
Labour income from food processing	bn USD	0.00		0.71		0.00		0.99	
Labour income from storage facilities	bn USD	N/A		N/A		N/A		N/A	
Additional profits generated	bn USD	85.31	188.95	225.85	700.41	211.59	266.62	644.63	1,638.77
(3) Total added benefits	**bn USD**	**98.28**	**201.92**	**226.57**	**701.12**	**211.59**	**266.62**	**658.59**	**1,652.74**
Total net benefits (2)+(3)-(1)	**bn USD**	**79.20**	**182.84**	**232.95**	**707.51**	**222.20**	**277.23**	**638.90**	**1,633.04**
Benefit-to-cost ratio (BCR)		3.8	7.5	5.9	15.8	48.4	60.2	7.8	18.4
Discounted total net benefits (2)+(3)-(1)	bn USD	-3.2	20.8	17.2	127.0	47.8	60.5	75.6	305.7
Benefit-to-cost ratio (BCR)		0.9	1.7	1.4	3.7	11.2	13.9	1.8	4.3

5. Policy insights

The results of the multi-stakeholder consultations and of the quantitative assessment highlight the need for policy coherence, to create synergy across food production, distribution and consumption. The distribution of food represents a key inefficiency in the Tanzanian food system. Investments to improve distribution through better networks, infrastructure and processes could lead to improved access to nutritious foods, higher value-chain actor incomes and stronger market links for a more resilient food system.

It is therefore important that intervention options are envisaged to stimulate investments in distribution, as well as to leverage such investments to incentivize shifts in production and in consumption (e.g. via awareness-raising activities).

At the global level, the 2021 UN Food Systems Summit raised stakeholder awareness of the need to deal with the interconnected issues of hunger, nutrition, climate, environment and livelihoods through a food systems approach. The Summit has highlighted that investments are needed in all areas of the food system, including production, distribution and nutrition. It has also resulted in new or re-confirmed commitments from several countries, international organizations and multilateral development banks to support such processes. However, these commitments are focused on isolated areas of knowledge, specifically on production, distribution or consumption.

Effective translation of global food system commitments at the country level will require an integrated approach, leveraging the expertise and experience of multiple actors. The approach taken so far is understandable and justifiable, but represents a potential constraint to the effective implementation of investments towards the creation of a more resilient and equitable food system at country level.

It is therefore crucial that the Government of Tanzania, together with development partners and the private sector, embraces a transparent, coordinated policy effort, based on evidence and a shared understanding of development priorities.

In this respect, our study shows that:

- Distribution is the key to addressing the challenges faced by the Tanzanian food system. Improvements in distribution networks and processes would reduce transport-related losses, so that greater quantities of food reach the market, while also improving end-product quality. Improved profitability for producers and distributors would incentivize greater follow-on investment from the private sector.
- Improving production and demand for healthy foods without addressing the challenges in the distribution sector would lead to sub-optimal returns. Taking a multi-pronged approach to improving production, distribution and consumer behaviour provides for the greatest impact.
- Focusing on increasing the productivity of the primary sector or changing consumer preferences in isolation can facilitate a shift towards fresher produce. However, this leads to high losses and sub-optimal product quality as long as challenges in the distribution sector remain unaddressed. While efforts in these areas should continue, targeted additional efforts could be planned in conjunction with the strengthening of the food distribution infrastructure. It is expected that the effectiveness of these investments will increase when compared with that of past experience.
- The fact that around two thirds of rural villages are electrified represents considerable potential for the establishment of adequate storage infrastructure and food-processing facilities locally. This potential should be seized by both the Government and the private sector in order to improve product quality (across all crops, animal and fish products) and reduce post-harvest losses.
- Even in absence of cooling infrastructure or processing facilities, the improvement of rural roads leads to improvements in average delivery time, which translates into reduced losses and higher quality of products reaching the market. Additional positive outcomes emerging from this investment include providing improved access to public services and markets (other than food markets).
- In order to provide equal access to nutritious and healthy diets and to subsequently stimulate a shift in production methods and in the crop mix, support has to be provided to mitigate the increase in the cost of diets due to the higher quality of food becoming available in local markets. This effort should target the comparatively higher cost of fresh produce, via incentives to farmers or retailers, which would be mitigated by reduced losses in the distribution process, but may still be higher than imported packaged food or grains.

6. Conclusions

Food security is critical for achieving the national development goals of Tanzania. Access to healthy and nutritious food is an enabling factor for realizing the Sustainable Development Goals for a more equitable and resilient future.

This reports assesses the challenges and opportunities of Tanzania's food system. A systemic approach was used to study how production, distribution and nutrition interact with one another to shape the food system at the national level.

The Tanzanian food system is characterized by:

- production challenged by low soil productivity due to lack of knowledge, limited access to infrastructure and investment limited by low profitability;
- a distribution network that generates large losses due to the lack of aggregation, missing cold storage and refrigerated vehicles, and high travel time due to poor road infrastructure;
- persistent issues with malnutrition, associated with the high costs and comparatively lower desirability of nutritious diets.

Using qualitative and quantitative methods, we find that:

- transition to a sustainable food system in Tanzania can deliver benefits for all economic actors;
- infrastructure investments are essential to realizing the social, economic and environmental opportunities;
- with the synergies created by investments in food distribution, self-reinforcing mechanisms will emerge, driven by higher profitability for producers, improved health for citizens, and reduced costs for the Government;
- practically, investments in improving distribution enable progress to be made on production and nutrition as well.

This aligns with the process and outcomes of "Pathways for sustainable food systems 2030" ("Pathways"), a project 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. We find from our qualitative and quantitative data that investments in food distribution have the potential to increase profits and enable further financing (item 2 in "Pathways") to strengthen production (item 1), which results in higher availability of nutritious food (item 3), and the use of more climate-resilient infrastructure (item 4). The overall outcome is a food system that is more resilient to economic fluctuations, trade dynamics and climate change (item 5).

These findings emerge because of the use of an integrated approach to food systems that considers simultaneously the outcomes of investments on farmer profitability, nutrition and efficiency in the use of production inputs. Specifically, we find that investing in improved access to infrastructure, adequate storage and suitable transport infrastructure results in lower distribution losses, while at the same time 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 fruits and vegetables, which in turn leads to a change in the composition of crops grown, stimulated by higher demand and profitability.

In order to realize the opportunities identified in this study, the following recommendations are made:

- Since investments in production, distribution and consumption are all economically viable, it is important to compare options against the societal value they deliver and the contribution they bring to the Government's priorities. In this respect, while investing in production alone can generate benefits, it does not lead to a transformation of the market and does not trigger virtuous and self-sustaining dynamics. A simultaneous shift in current policy and approach to improving nutrition is needed to translate improved production and distribution to the increased consumption of healthy diets by the Tanzanian people.

- Investing in distribution unlocks the potential to maximize the effectiveness of investments in production and consumption, resulting in the largest benefits and higher effectiveness than investing in production alone. Investments in distribution should not be assessed in isolation. The cost should be considered against multiple returns, including job creation and improved human health, which more than outweigh the costs. Investing in distribution infrastructure should be considered a development strategy and not limited to the transport sector and mobility.
- When investments in distribution infrastructure are planned, a coordinated strategy that would leverage such investment is required to maximize benefits. As a result, incentives for improving agriculture practices and awareness-raising of the advantages of adopting a healthy and nutritious diet must accompany distribution investments.

In conclusion, this study highlights that there is potential to trigger systemic change in the Tanzanian food system through investment in food distribution. Policy change is required to take a more systemic approach and to create synergies among production, distribution and nutrition efforts, rather than treating them as isolated domains. It is our hope that this work will inform the creation of a strong action plan for realizing the 2030 pathways for sustainable food systems, which is a short-term priority of the Government of Tanzania's commitments at the Food Summit.

References

United Nations. 2020. *UN Common Guidance on Helping Build Resilient Societies*. New York, USA, United Nations.

Annex 1: CBA assumptions

INVESTMENT AND COSTS	UNIT	VALUE	SOURCE	COMMENT
Sustainable agriculture				
Investment in sustainable agriculture	USD/ha	476	USAID (2017) - Cost and benefit analysis for Climate-Smart Agricultural (CSA) practices in the coastal Savannah Agro-Ecological Zone (AEZ) of Ghana	
O&M sustainable agriculture	USD/ha/Year	281.7	USAID (2017) - Cost and benefit analysis for Climate-Smart Agricultural (CSA) practices in the coastal Savannah Agro-Ecological Zone (AEZ) of Ghana	
Storage infrastructure				
Capital investment storage infrastructure	USD/ton	4250	https://energypedia.info/images/2/2d/GIZ_%282016%29_-_Promoting_Food_Security_and_Safety_via_Cold_Chains.pdf	
O&M cost storage infrastructure	USD/ton/year	1062.5		Assumption
based on assumption of share OPEX over CAPEX	%	25%		Assumption, includes energy use and maintenance
Vehicle fleet				
Capital investment in trucks	USD/Truck	70000	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7195915/pdf/PAMJ-SUPP-35-1-11.pdf	
Capital investment in refrigerated trucks	USD/Truck	200000	https://static1.squarespace.com/static/52246331e4b0a46e5f1b8ce5/t/5e874c3113dcc50266606ee7/1585925176127/Vilakazi+%26+Paelo+%282017b%29.pdf	
O&M cost conventional trucks	USD/Truck/year	617.23	https://documents1.worldbank.org/curated/en/794251489201242940/pdf/TZ-PAD-02162017.pdf	
O&M cost refrigerated trucks	USD/Truck/year	1763.51	Sources above	estimation
based on assumption of share OPEX over CAPEX conventional trucks	%	0.9%		
Average lifetime per truck	Years	30		Assumption

INVESTMENT AND COSTS	UNIT	VALUE	SOURCE	COMMENT
Road network expansion				
Capital cost additional road construction	USD/km	385000	https://assets.publishing.service.gov.uk/media/57a08bd7e5274a27b2000dc3/TI_UP_HD_Feb2007_Cost_of_Roads_in_Africa.pd	Assuming 50% of the cost for the construction of roads in Ghana. Cost is indicated at 484,314 USD/km, corrected for the inflation factor 2000->2021, which is 1.59 Reference to calculate inflation: https://www.in2013dollars.com/us/inflation/2000?amount=1
O&M cost of additional roads	USD/km/Year	57750	https://assets.publishing.service.gov.uk/media/57a08bd7e5274a27b2000dc3/TI_UP_HD_Feb2007_Cost_of_Roads_in_Africa.pd	Reference to calculate inflation: https://www.in2013dollars.com/us/inflation/2000?amount=1
OPEX as share of CAPEX	%	15%		Assuming 15% of capital expenditure.
Road network quality improvements				
Capital cost road quality improvement	USD/km	98580	https://assets.publishing.service.gov.uk/media/57a08bd7e5274a27b2000dc3/TI_UP_HD_Feb2007_Cost_of_Roads_in_Africa.pd	Reference to calculate inflation: https://www.in2013dollars.com/us/inflation/2000?amount=1
O&M cost road quality improvement	USD/km/Year	2815	https://assets.publishing.service.gov.uk/media/57a08bd7e5274a27b2000dc3/TI_UP_HD_Feb2007_Cost_of_Roads_in_Africa.pd	Reference to calculate inflation: https://www.in2013dollars.com/us/inflation/2000?amount=1
Food processing facilities				
Capital cost food processing	USD/ton (annualized over 10 years)	8.958	http://www.agripunjab.gov.pk/system/files/Feasibility%20Study%20FCKJ%20Vol.%202.pdf	Costs are based on a fruit processing plant in Pakistan with a capacity to process 600 tons per day and an operating time of 110 days per year. The costs are 5,912,290 USD (total including land and cost of capital), with an annual processing capacity of 66,000 tons per year (based on daily capacity and capacity utilization). This results in an average cost per ton of 89.58 USD/ton input, annualized over 10 years, this results in around 9 USD/ton processed in capital expenditure
O&M cost food processing	USD/ton/year	10.35	http://www.agripunjab.gov.pk/system/files/Feasibility%20Study%20FCKJ%20Vol.%202.pdf	The operating cost for the fruit processing plant correspond to around 683,013 USD/Year inlcuding electricity and labor; based on a capacity of 66,000 tons, the average OPEX per ton is 10.35 USD/ton processed.
Consumer awareness programs for healthy nutrition				
Capital cost of establishing awareness raising programs	USD/Household	5		Assumption
Running costs consumer awareness programs	USD/Household/Year	0		

INVESTMENT AND COSTS	UNIT	VALUE	SOURCE	COMMENT
Avoided costs				
Cost of synthetic fertilizers	USD/Ton	1350		
Cost of organic fertilizers	USD/Ton	675	https://glopan.org/sites/default/files/pictures/CostOfMalnutrition.pdf	Assumed 50% of synthetic fertilizer per ton, also assumes that 50% of organic fertilizer is provided through manure.
Cost of malnutrition	USD/Person/Year	50	https://www.wfp.org/publications/cost-hunger-africa-series; https://glopan.org/sites/default/files/pictures/CostOfMalnutrition.pdf	Avoided cost of malnutrition was estimated based on the average sufficiency indicators for each of the scenarios and the assumption that 100% sufficiency removes 75% of malnutrition cost due to access
Cost of healthy diets (% increase over baseline for vegetables and fruits)	%			Calculated based on the average price per ton across all products for each scenario
Added benefits				
Additional carbon sequestration from sustainable agriculture	Ton/ha/Year	0.342	USAID (2017) - Cost and benefit analysis for Climate-Smart Agricultural (CSA) practices in the coastal Savannah Agro-Ecological Zone (AEZ) of Ghana	
Social cost of carbon per ton CO2e avoided	USD/Ton	31	Nordhaus (2017) - Revisiting the social cost of carbon	
Labor income from sustainable agriculture	TSH/Person/Year	540000		
Labor income from food processing	TSH/Person/Year	540000		
Labor intensity food processing	Person/(Ton/Year)	0.00424242	http://www.agripunjab.gov.pk/system/files/Feasibility%20Study%20FCKJ%20Vol.%202.pdf	The plant employs 280 people based on an annual production capacity of 66,000 tons.
Minimum salary in Tanzania	TSH/Person/Year	540000		
Additional profits generated	USD/ton	forecasted by model dynamics	forecasted by model dynamics	forecasted by model dynamics
Exchange rate	TSH/USD	350	Oanda	

Annex 2: model description

This annex includes a description of the model, and how it focuses on 3 main building blocks: consumption, distribution and consumption.

MODEL STRUCTURE: PRODUCTION

The choice of crops included in the production module was informed by data availability on crop production by type of produce and the composition of "traditional" foods (crops and dishes) in Tanzania. Both are relevant to identify specific food choices that drive the current demand for main staples and to inform the selection of how production can be aggregated. In addition to consumer preferences, the nutritional values of the main crops produced (Lukmanji, et al., 2008) determined the extent to which crop categories can be aggregated. Based on this review, the following crops are included in the analysis:

- Maize
- Sorghum
- Millet (bulrush & finger millet)
- Potatoes (sweet & round potato)
- Cassava
- Beans
- Peas (cowpeas & pigeon peas)
- Bananas
- Tomato

The production module keeps track of the total cropland required for realizing the forecasted production. The demand for agriculture land is driven by the development of total population and an average agriculture land per capita multiplier. In the context of this study, total agriculture land used for crop production refers to the total area used for abovementioned crops, not the total amount of land used for crop production in Tanzania. The fractions used to determine land allocation are driven by an index consisting of (i) demand for products, (ii) the profitability of products for farmers, (iii) export demand for crops and (iv) farmers' own demand for subsistence.

Crop production is estimated using the number of hectares used for each crop, the respective production yield per hectare and the share of pre-harvest losses. The average yield per hectare is hereby a function of the initial yield, the use of synthetic and organic fertilizers and soil erosion. Climate change impacts are also considered, as is the availability of infrastructure (e.g. irrigation). Based on the above, total crop production represents the total amount of crops produced.

MODEL STRUCTURE: DISTRIBUTION

The distribution module provides an overview of the total road infrastructure, farmers' access to roads, and hence markets, storage facilities and transport vehicles. As highlighted above, having timely access to markets is a crucial precondition for incentivizing farmers to grow fresh, and more nutritional produce. While this modeling assessment does not consider meat and fish production, the same considerations could be made. The two main obstacles highlighted are access to markets and the quality of produce that reaches the market.

Access to markets is captured using the size of the transport network, specifically in rural areas, farm distance to the closest road and the availability of suitable modes of transport. The quality of produce reaching the market will be a function of the time required for delivering food from the farm gate to the market and the availability of cold chains and food storage facilities.

The key parameters determining distribution losses, such as farmers' distance to roads and the time required to reach the market are variables subject to policy interventions. For example, the farm distance to the closest road can be reduced through the construction of additional roads in rural areas. In the same vein, product quality issues can be addressed by either reducing the time to market (e.g. expanding and upgrading roads) or by improving storage along the supply chain (e.g. include cold storage).

MODEL STRUCTURE: CONSUMPTION

The consumption module captures the demand for and consumption of agriculture products and the nutrient uptake per capita. The demand for products is determined by the following four key drivers: (i) affordability, how much does the food cost, (ii) accessibility, is the product accessible in nearby markets, (iii) availability, is the product physically present in nearby markets, and (iv) consumer awareness, hence the consumer preferences for cereals or fresh food.

The table of nutritional values for all crops considered from Lukmanji (2008) is used for the estimation of nutrient availability and nutrient uptake. The study provides data on nutritional values for all crops and main meals in Tanzania and hence allows for estimating the amount of nutrients that are provided/taken up by consumers, which drive the composition of the food production system. Table 8 presents the macronutrients, vitamins, minerals and amino acids considered in this study, based on Lukmanji et al. (2008).

Table 8: Macronutrients, vitamins, minerals and amino acids considered for the food consumption module

Macronutrients	Vitamins	Minerals	Amino Acids
Energy	Vitamin A	Calcium	Tryptophan
Total protein	Vitamin D	Phophorus	Threonin
Total Fat	Vitamin C	Magnesium	Isoleucine
Sucrose	Vitamin E	Potassium	Leucine
Saturated fats	Thiamine	Sodium	Lysine
Monounsaturated fats	Riboflavin	Iron	Valine
Polyunsaturated fats	Niacin	Zinc	Methionine
Cholesterol	Folate	Copper	Cystine
Fiber	Vitamin B6	Manganese	Tyrosine
Phytic acid	Vitamin B12		Phenylalanine
	Pantothenic Acid		Arginine
			Histidine

For all of the nutrients indicated in Table 8, the nutritional balance before and after cooking food is estimated. Especially for heat and water labile vitamins, any form of further preparation (e.g. cooking, boiling and frying) leads to a loss of up to 55 percent that must be considered in the estimation of nutrient sufficiency. For this purpose the model distinguishes between the foods can be consumed raw (e.g. fruits and vegetables), while others need preparation in form of frying, boiling or cooking, which will cause a change in the nutritional balance opposed to the raw produce.

Annex 3: detailed model results

SCENARIO 1: IMPROVED PRODUCTION

The improved production scenario assumes the introduction of sustainable agriculture practices. Land under sustainable management practices is assumed to be more productive and to use less synthetic fertilizer inputs. The assumptions used for the improved production scenario are presented in Table 9.

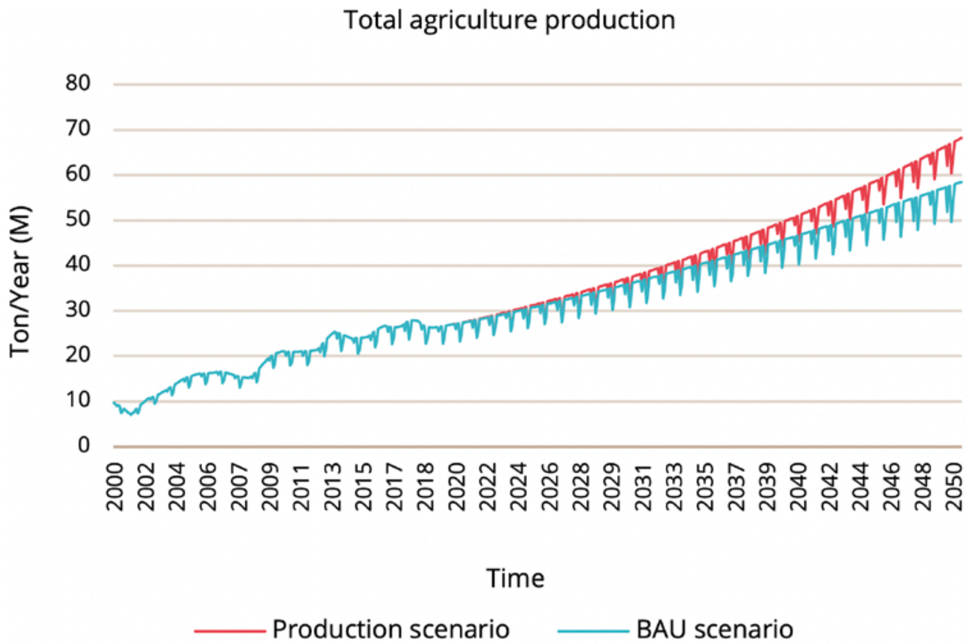
Table 9: Overview of assumptions improved production scenario

Parameter	Assumption
Adoption rate sustainable agriculture practices	The adoption rate of sustainable practices is applied to all crops. By 2030, 12.5% of total cropland are assumed to be under sustainable management. By 2040 and 2050, the adoption rate increases to 30% and 50% of total cropland respectively.
Additional productivity of sustainable agriculture	It is assumed that land under sustainable management practices has 20% higher yields, which is assumed across all production.
Premium prices sustainable produce	It is assumed that sustainable produce generates 10% more revenues compared to conventional produce.
Synthetic fertilizer inputs	Land under sustainable management practices uses 50% less synthetic fertilizers.

Production

The higher productivity of sustainable practices contributes to an increase in crop production relative to the BAU scenario. Total crop production in the BAU scenario is projected to increase from 26.63 million tons in 2020 to 35.2 million tons in 2030, and is projected to reach 58.5 million tons by 2050. In the improved production scenario, total crop production increases to 36.58 million tons and 68.21 million tons by 2030 and 2050 respectively, which is 3.9% and 16.6% higher relative to the BAU scenario. The projected development of total agriculture production in the BAU and improved production scenario is presented in Figure 11, compared to historical data.

Figure 11: Total crop production BAU and improved production scenario



The choice of crops in the BAU and improved production scenario remains unchanged, given that production increases, but there are no changes to distribution nor consumer preferences. In essence, it is a continuation of BAU land use dynamics, however, with more productive land. The choice of crops is reflected in the share of land used by crop type. Table 10 illustrates the land use by type of crop for the BAU and improved production scenario, for selected years. The shares of land used by crop are identical in both scenarios.

Table 10: Shares of land used by crop BAU and improved production scenario

Crop type	Unit	2020	2030	2040	2050
Maize					
Production scenario	%	45.3%	45.3%	45.3%	45.3%
BAU scenario	%	45.3%	45.3%	45.3%	45.3%
Sorghum					
Production scenario	%	8.5%	8.5%	8.5%	8.5%
BAU scenario	%	8.5%	8.5%	8.5%	8.5%
Millet					
Production scenario	%	3.6%	3.6%	3.6%	3.6%
BAU scenario	%	3.6%	3.6%	3.6%	3.6%
Potato					
Production scenario	%	14.4%	14.4%	14.4%	14.4%
BAU scenario	%	14.4%	14.4%	14.4%	14.4%
Cassava					
Production scenario	%	13.5%	13.5%	13.5%	13.5%
BAU scenario	%	13.5%	13.5%	13.5%	13.5%
Beans					
Production scenario	%	7.1%	7.1%	7.1%	7.1%
BAU scenario	%	7.1%	7.1%	7.1%	7.1%
Peas					
Production scenario	%	2.6%	2.6%	2.6%	2.6%
BAU scenario	%	2.6%	2.6%	2.6%	2.6%
Banana					
Production scenario	%	4.0%	4.0%	4.0%	4.0%
BAU scenario	%	4.0%	4.0%	4.0%	4.0%
Mango					
Production scenario	%	0.4%	0.4%	0.4%	0.4%
BAU scenario	%	0.4%	0.4%	0.4%	0.4%
Tomato					
Production scenario	%	0.5%	0.5%	0.5%	0.5%
BAU scenario	%	0.5%	0.5%	0.5%	0.5%

Distribution

Distribution losses in the BAU and improved production scenario are summarized in Table 11, for selected years. While the total amount of produce lost in the BAU scenario increases from 2.21 million tons in 2020 to 2.85 million tons by 2030 and 4.24 million tons in 2050, the losses observed in the improved production scenario are higher. By 2030 and 2050, projections indicate distribution losses of 2.28 million tons per year (+3% vs BAU) and 4.9 million tons per year (+16% vs BAU) respectively. The reason for the increase in losses is that, while total production increases, the capacity of the distribution sector does not, indicating that distribution losses increase at least proportionally to total agriculture production.

Table 11: Produce lost during distribution BAU and improved production scenario

Produce lost during distribution	Unit	2030	2040	2050
BAU scenario	mn ton/year	2.21	2.85	4.24
Production scenario	mn ton/year	2.28	3.08	4.90
vs BAU scenario	%	3%	8%	16%

Losses during distribution are related to the availability of transport vehicles as well as to the quality of roads, given that fresh produce perishes if it is transported uncooled for too long. The average time to market in the BAU and improved production scenario is presented in Figure 12. It slightly increases until 2020, after which the average time to reach the market remains constant around 4.7 days in both scenarios. The spikes observed in the average time to reach the market represent occasions in which floods force carriers to make a detour as the shortest routes may be damaged and unavailable due to flood damages.

In the absence of cooled transport and storage, product quality, especially the quality of fresh produce, declines (i.e. the longer the time to reach the market, the lower the quality of products). The average product quality in the improved production scenario remains unchanged when compared to the BAU scenario, as indicated by the results for product quality presented in Table 12. The relative quality of products is an index that measures the quality of products relative to the year 2000 (year 2000 = 100%). A value below 100% indicates that overall food quality has deteriorated relative to the year 2000, while a value above 100% indicates an improvement in overall product quality.

Figure 12: Average time to market BAU and improved production scenario

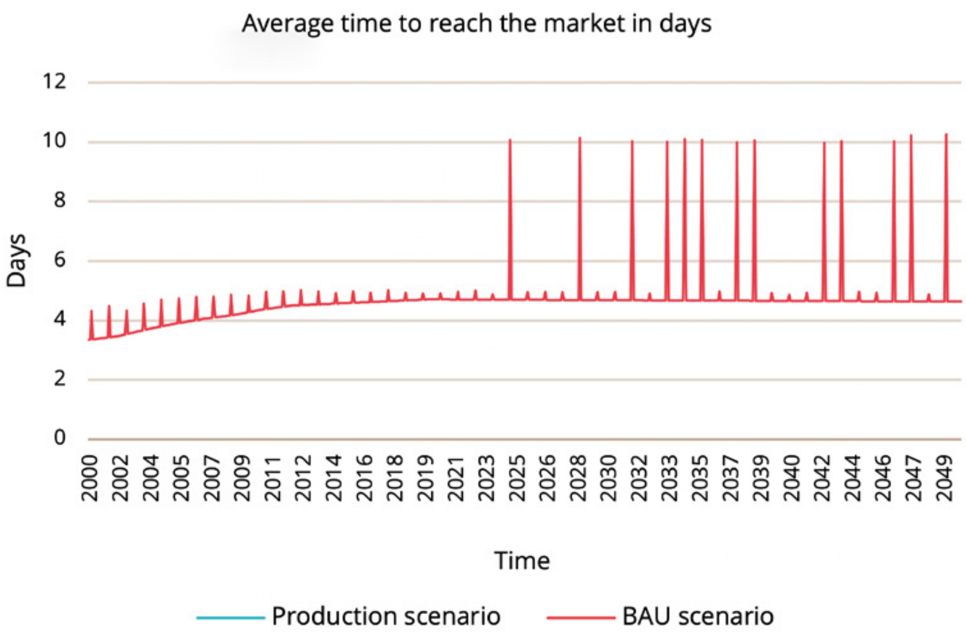


Table 12: Relative product quality BAU and improved production scenario

Relative product quality	Unit	2020	2030	2040	2050
Maize					
Production scenario	%	98.6%	98.6%	98.6%	98.7%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Sorghum					
Production scenario	%	98.6%	98.6%	98.6%	98.7%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Millet					
Production scenario	%	98.6%	98.6%	98.6%	98.7%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Potato					
Production scenario	%	97.1%	97.1%	97.2%	97.2%
BAU scenario	%	97.1%	97.1%	97.2%	97.2%
Cassava					
Production scenario	%	97.1%	97.1%	97.2%	97.2%
BAU scenario	%	97.1%	97.1%	97.2%	97.2%
Beans					
Production scenario	%	98.6%	98.6%	98.6%	98.7%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Peas					
Production scenario	%	98.6%	98.6%	98.6%	98.7%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Banana					
Production scenario	%	89.8%	90.0%	90.2%	90.3%
BAU scenario	%	89.8%	90.0%	90.2%	90.3%
Mango					
Production scenario	%	89.8%	90.0%	90.2%	90.3%
BAU scenario	%	89.8%	90.0%	90.2%	90.3%
Tomato					
Production scenario	%	89.8%	90.0%	90.2%	90.3%
BAU scenario	%	89.8%	90.0%	90.2%	90.3%

Consumption

The dietary composition per person in the BAU and improved production scenario is presented in Table 13, for cereals, fruit, pulses, roots and tubers, and vegetables respectively. Results indicate that, compared to the baseline, there are no or only minor changes in the choice of crops. The underlying reason for this is that the production sector, in absence of adequate distribution measures for perishable products, keeps producing staple crops that guarantee sufficient income to maintain self-sufficiency.

Table 13: Produce shares in the average per capita diet by type of produce BAU and improved production scenario

Type of produce	Unit	2020	2030	2040	2050
Cereals					
Production scenario	%	30.2%	29.7%	29.6%	29.4%
BAU scenario	%	30.2%	29.7%	29.7%	29.6%
Fruit					
Production scenario	%	13.1%	12.5%	12.2%	12.1%
BAU scenario	%	13.1%	12.7%	12.8%	12.8%
Pulses					
Production scenario	%	4.1%	3.5%	3.5%	3.5%
BAU scenario	%	4.1%	3.5%	3.5%	3.5%
Roots and tubers					
Production scenario	%	50.6%	52.3%	52.6%	53.0%
BAU scenario	%	50.6%	52.1%	52.1%	52.1%
Vegetables					
Production scenario	%	2.0%	2.0%	2.0%	2.0%
BAU scenario	%	2.0%	2.0%	2.0%	2.0%

The composition of the diet has an impact on the nutrients that are consumed. The average nutrient sufficiency per capita indicates whether, based on the current composition of crop production, there are sufficient nutrients per capita available (100% = full sufficiency). The average nutrient sufficiency per capita is calculated by dividing per capita consumption of nutrients by the average daily intake requirements for each nutrient. The results projected for nutrient sufficiency per capita for the BAU and improved production scenario are presented in Table 14 below.

Table 14: Nutrient sufficiency per capita indicators BAU and improved production scenario

Nutrient by type	Unit	2020	2030	2040	2050
Amino acid sufficiency per capita					
Tryptophan					
Production scenario	%	197%	161%	140%	127%
BAU scenario	%	197%	155%	128%	108%
Threonine					
Production scenario	%	81%	64%	56%	50%
BAU scenario	%	81%	62%	51%	43%
Isoleucine					
Production scenario	%	63%	50%	44%	39%
BAU scenario	%	63%	49%	40%	34%
Leucine					
Production scenario	%	74%	59%	51%	46%
BAU scenario	%	74%	57%	47%	40%
Lysine					
Production scenario	%	51%	40%	35%	31%
BAU scenario	%	51%	39%	32%	27%
Methionine					
Production scenario	%	56%	45%	39%	35%
BAU scenario	%	56%	44%	36%	31%
Cystine					
Production scenario	%	111%	90%	78%	70%
BAU scenario	%	111%	87%	72%	61%
Phenylalanine					
Production scenario	%	9214%	7295%	6324%	5675%
BAU scenario	%	9214%	7077%	5848%	4934%
Tyrosine					
Production scenario	%	6247%	4999%	4335%	3890%
BAU scenario	%	6247%	4847%	4005%	3379%
Valine					
Production scenario	%	64%	51%	44%	40%
BAU scenario	%	64%	49%	41%	34%
Arginine					
Production scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Histidine					
Production scenario	%	200%	158%	135%	120%
BAU scenario	%	200%	155%	128%	108%
Macronutrient sufficiency per capita					
Energy					
Production scenario	%	98%	80%	70%	62%
BAU scenario	%	98%	78%	64%	54%
Total protein					
Production scenario	%	89%	72%	62%	56%
BAU scenario	%	89%	70%	58%	49%
Total fat					
Production scenario	%	17%	13%	12%	10%
BAU scenario	%	17%	13%	11%	9%
Total carbohydrates					
Production scenario	%	149%	123%	106%	95%
BAU scenario	%	149%	119%	98%	83%

Saturated fatty acids					
Production scenario	%	2%	2%	1%	1%
BAU scenario	%	2%	2%	1%	1%
Monounsaturated fatty acids					
Production scenario	%	14%	11%	10%	9%
BAU scenario	%	14%	11%	9%	8%
Polyunsaturated fatty acids					
Production scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Cholesterol					
Production scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Fiber					
Production scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Total sugar					
Production scenario	%	79%	64%	55%	49%
BAU scenario	%	79%	62%	52%	44%
Phytate					
Production scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Mineral sufficiency per capita					
Calcium					
Production scenario	%	22%	18%	16%	14%
BAU scenario	%	22%	18%	15%	12%
Phosphorus					
Production scenario	%	144%	116%	101%	90%
BAU scenario	%	144%	113%	93%	78%
Magnesium					
Production scenario	%	132%	108%	93%	83%
BAU scenario	%	132%	104%	86%	73%
Potassium					
Production scenario	%	148%	122%	106%	95%
BAU scenario	%	148%	119%	98%	83%
Sodium					
Production scenario	%	11%	9%	8%	7%
BAU scenario	%	11%	8%	7%	6%
Iron					
Production scenario	%	125%	102%	89%	79%
BAU scenario	%	125%	99%	82%	69%
Zinc					
Production scenario	%	76%	62%	54%	48%
BAU scenario	%	76%	60%	49%	42%
Copper					
Production scenario	%	197%	163%	142%	127%
BAU scenario	%	197%	158%	131%	111%
Manganese					
Production scenario	%	736%	603%	521%	464%
BAU scenario	%	736%	585%	483%	407%

Vitamin sufficiency per capita					
Vitamin A					
Production scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Vitamin D					
Production scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Vitamin E					
Production scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Vitamin C					
Production scenario	%	132%	112%	97%	88%
BAU scenario	%	132%	108%	89%	75%
Thiamin					
Production scenario	%	145%	118%	102%	92%
BAU scenario	%	145%	114%	94%	80%
Riboflavin					
Production scenario	%	91%	77%	66%	59%
BAU scenario	%	91%	74%	62%	52%
Niacin					
Production scenario	%	91%	75%	65%	58%
BAU scenario	%	91%	73%	60%	51%
Vitamin B6					
Production scenario	%	145%	119%	103%	92%
BAU scenario	%	145%	116%	96%	81%
Folate					
Production scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Vitamin B12					
Production scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Pantothenic					
Production scenario	%	51%	41%	36%	32%
BAU scenario	%	51%	40%	33%	28%

Economics

An additional aspect that drives the choice of crops are the profits generate, total (as absolute value) and per ton of produce. In the BAU scenario, total profits from crop production increase from around TSH 11.55 trillion in 2020 to TSH 15.24 trillion and TSH 24.04 trillion by 2030 and 2050 respectively. In the improved production scenario, total profits from crop production are projected to reach TSH 16.15 trillion (+6% vs BAU) and TSH 30.31 (+26.1% vs BAU), mainly as a result of premium prices received for sustainable produce and the higher amount of production sold. The development of total profits from crop production in the BAU and improved production scenario are presented in Figure 13.

Figure 13: Total profits from crop production BAU and improved production scenario

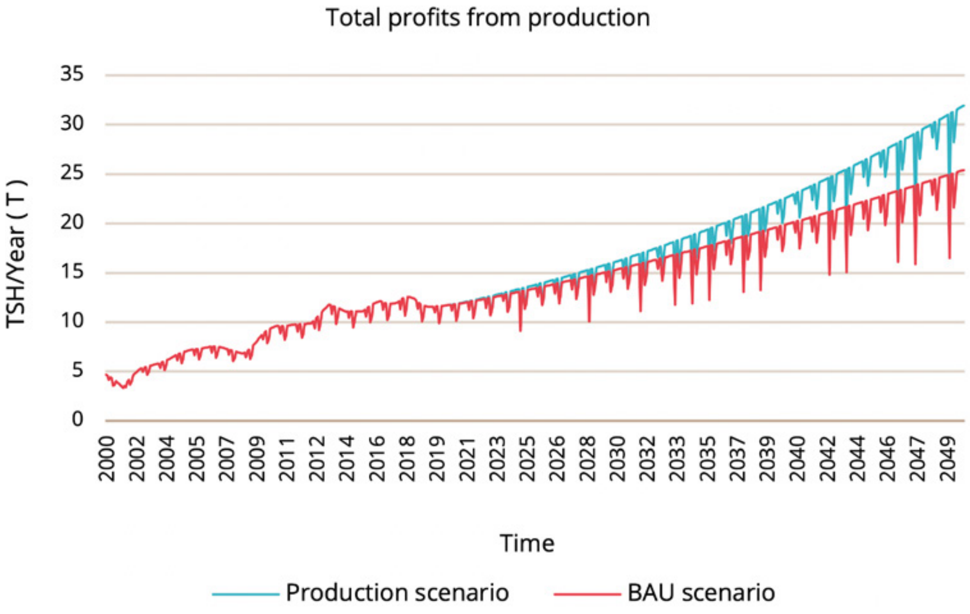


Table 15: Average profits per ton of produce sold BAU and improved production scenario

Crop type	Unit	2020	2030	2040	2050
Maize					
BAU scenario	TSH/ton	242,199	242,336	242,540	239,692
Production scenario	TSH/ton	242,564	250,649	261,853	270,156
vs BAU	%	0.2%	3.4%	8.0%	12.7%
Sorghum					
BAU scenario	TSH/ton	1,265,117	1,265,501	1,266,070	1,258,152
Production scenario	TSH/ton	1,266,161	1,289,270	1,321,294	1,345,261
vs BAU	%	0.1%	1.9%	4.4%	6.9%
Millet					
BAU scenario	TSH/ton	689,468	689,715	690,081	684,979
Production scenario	TSH/ton	690,135	704,901	725,362	740,630
vs BAU	%	0.1%	2.2%	5.1%	8.1%
Potato					
BAU scenario	TSH/ton	502,023	502,391	502,937	494,892
Production scenario	TSH/ton	502,472	512,632	526,738	532,265
vs BAU	%	0.1%	2.0%	4.7%	7.6%
Cassava					
BAU scenario	TSH/ton	216,505	216,705	217,000	212,342
Production scenario	TSH/ton	216,734	221,906	229,088	231,324
vs BAU	%	0.1%	2.4%	5.6%	8.9%
Beans					
BAU scenario	TSH/ton	1,131,614	1,132,031	1,132,650	1,123,921
Production scenario	TSH/ton	1,132,736	1,157,593	1,192,039	1,217,600
vs BAU	%	0.1%	2.3%	5.2%	8.3%
Peas					
BAU scenario	TSH/ton	1,192,206	1,192,637	1,193,275	1,184,301
Production scenario	TSH/ton	1,193,364	1,219,002	1,254,531	1,280,924
vs BAU	%	0.1%	2.2%	5.1%	8.2%
Banana					
BAU scenario	TSH/ton	547,095	548,498	550,577	531,583
Production scenario	TSH/ton	547,566	559,228	575,560	570,312
vs BAU	%	0.1%	2.0%	4.5%	7.3%
Mango					
BAU scenario	TSH/ton	948,879	950,965	954,057	926,272
Production scenario	TSH/ton	949,586	967,070	991,554	984,401
vs BAU	%	0.1%	1.7%	3.9%	6.3%
Tomato					
BAU scenario	TSH/ton	507,306	508,868	511,183	490,146
Production scenario	TSH/ton	507,832	520,847	539,073	533,383
vs BAU	%	0.1%	2.4%	5.5%	8.8%

SCENARIO 2: IMPROVED DISTRIBUTION

The improved distribution scenario combines a range of interventions aiming to reduce losses during the transport to the market. The interventions envisaged are (i) the availability of cooled transport, (ii) processing of products to reduce perishability, (iii) the expansion of the road network, and (iv) the improvement of road quality in rural areas. The assumptions used for each of these polices are summarized in Table 16.

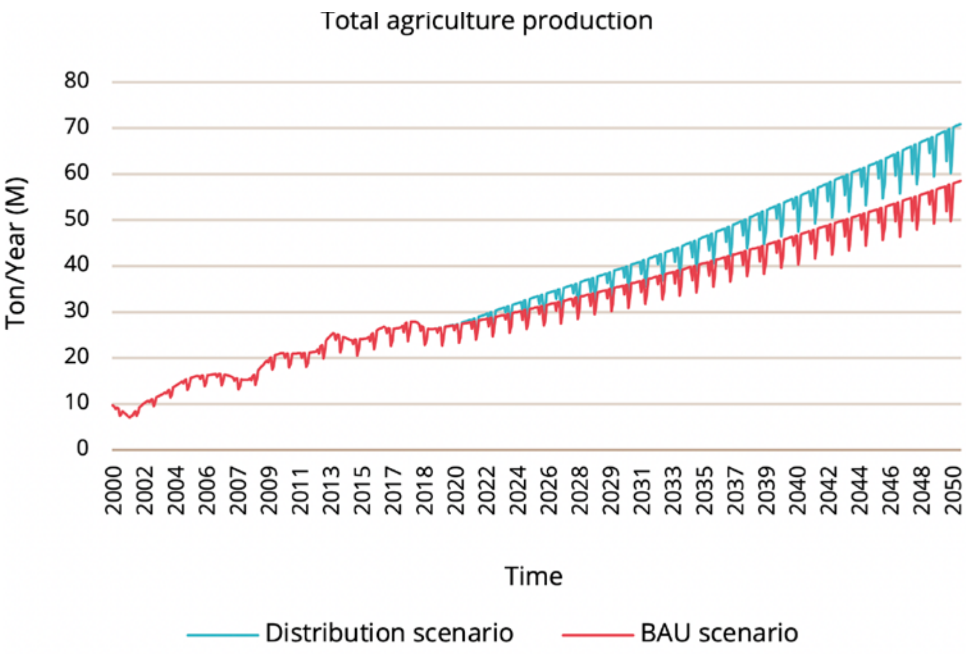
Table 16: Overview of policy assumptions for the improved distribution scenario

Parameter	Assumption
Cooled storage and transport	This intervention assumes that cooled transportation is available for a share of total crop production. Cooled transportation maintains product quality, especially for perishable products such as fruits and vegetables. Higher product quality translates into higher sales prices and hence higher profits. The share of total production for which cooled transport is available for the years 2030, 2040 and 2050 is presented below. • Share of transport cooled in 2020: 0% • Share of transport cooled in 2030: 20% • Share of transport cooled in 2040: 40% • Share of transport cooled in 2050: 60%
Processing of products	Food processing aims at reducing the perishability of products in order to reduce distribution losses and maintain product quality. Especially vegetables (tomatoes in this case) are well suited for processing. While processing increases availability and convenience, processed foods are assumed to be sold at a lower price relative to fresh produce. **Reduction in price for processed produce**: 10% The assumptions for the shares of produce processed are presented below. **Cereals** • % processed 2020: 0% • % processed 2030: 0% • % processed 2040: 0% • % processed 2050: 0% **Pulses** • % processed 2020: 0% • % processed 2030: 0% • % processed 2040: 0% • % processed 2050: 0% **Roots and tubers** • % processed 2020: 0% • % processed 2030: 5% • % processed 2040: 10% • % processed 2050: 15% **Fruits** • % processed 2020: 0% • % processed 2030: 2.5% • % processed 2040: 5% • % processed 2050: 7.5% **Vegetables** • % processed 2020: 0% • % processed 2030: 25% • % processed 2040: 50% • % processed 2050: 50%
Road network expansion	Road network expansion leads to improved accessibility of products for consumers and reductions in travel time. The expansion of the road network occurs between 2020 and 2030 and it is assumed that the total road network will be 10.6% higher by 2030 relative to the BAU scenario. After 2030, the road network will remain 10.6% larger relative to the BAU until 2050
Improvements of rural roads	Road quality is modeled using the IRI index, which is an index of road roughness and the main determinant for travel speed, especially in rural areas. The higher the index value, the lower travel speed. The improvement in rural roads is assumed to occur between 2030 and 2040, and the simulated reduction (=improvement) in IRI index relative to the BAU scenario is 0% in 2030 and 50% in 2040.

Production

The improved distribution scenario shows the strongest overall impacts on the behavior of the system relative to the BAU scenario. Total crop production in the BAU scenario is projected to increase from 26.63 million tons in 2020 to 35.2 million tons in 2030 and is projected to reach 58.5 million tons by 2050. In the improved distribution scenario, improved access to markets and transport infrastructure (cooling trucks and facilities) as well as processing makes crop production more attractive, facilitating demand on the one hand. On the other hand, the provision of processing facilities contributes to reducing losses of perishable products and increases the total quantity reaching the market. Furthermore, the fact that fruits and vegetables generally have higher yields per hectare relative to cereals, the shift in the choice of crops contributes to increasing production. As a result, stimulated by increased demand, total crop production in the improved distribution scenario increases to 36.6 million tons by 2030 and 68.2 million tons per year in 2050, which is 11.1% and 21.1% higher relative to the BAU respectively. The projected development of total agriculture production in the BAU and improved distribution scenario is presented in Figure 14, compared to historical data.

Figure 14: Total crop production BAU and improved distribution scenario



Overall, the improvements in distribution infrastructure lead to increased attractiveness for farmers to grow fruits and vegetables, due to the fact that the risk of losses during distribution are reduced. At the same time, fresher produce and the availability of processed products increase the convenience for consumers, as products are fresher and of better quality, facilitating demand. The increased demand for fresh produce, given the benefits described above, leads to a shift in land use away from cereal production, which has historically been the most "low-risk" option for farmers and contributed to the lack of fresh products in the market. The land use shares for the BAU and improved distribution scenario are presented in Table 17, for selected years. A decline in land used for cereals is observed, accompanied by an increase in land use for pulses, roots and tubers, fruits and vegetables, whereby the shares for fruits and vegetables increase the most.

Table 17: Shares of land used by crop BAU and improved distribution scenario

Crop type	Unit	2020	2030	2040	2050
Maize					
Distribution scenario	%	45.0%	41.7%	38.8%	37.4%
BAU scenario	%	45.3%	45.3%	45.3%	45.3%
Sorghum					
Distribution scenario	%	8.5%	8.0%	7.6%	7.4%
BAU scenario	%	8.5%	8.5%	8.5%	8.5%
Millet					
Distribution scenario	%	3.6%	3.3%	3.0%	2.9%
BAU scenario	%	3.6%	3.6%	3.6%	3.6%
Potato					
Distribution scenario	%	14.4%	14.3%	14.5%	14.8%
BAU scenario	%	14.4%	14.4%	14.4%	14.4%
Cassava					
Distribution scenario	%	13.5%	13.4%	13.7%	13.9%
BAU scenario	%	13.5%	13.5%	13.5%	13.5%
Beans					
Distribution scenario	%	7.2%	7.8%	8.5%	8.8%
BAU scenario	%	7.1%	7.1%	7.1%	7.1%
Peas					
Distribution scenario	%	2.6%	2.8%	3.0%	3.1%
BAU scenario	%	2.6%	2.6%	2.6%	2.6%
Banana					
Distribution scenario	%	4.1%	7.0%	8.7%	9.3%
BAU scenario	%	4.0%	4.0%	4.0%	4.0%
Mango					
Distribution scenario	%	0.4%	0.6%	0.7%	0.7%
BAU scenario	%	0.4%	0.4%	0.4%	0.4%
Tomato					
Distribution scenario	%	0.7%	1.1%	1.4%	1.4%
BAU scenario	%	0.5%	0.5%	0.5%	0.5%

Distribution

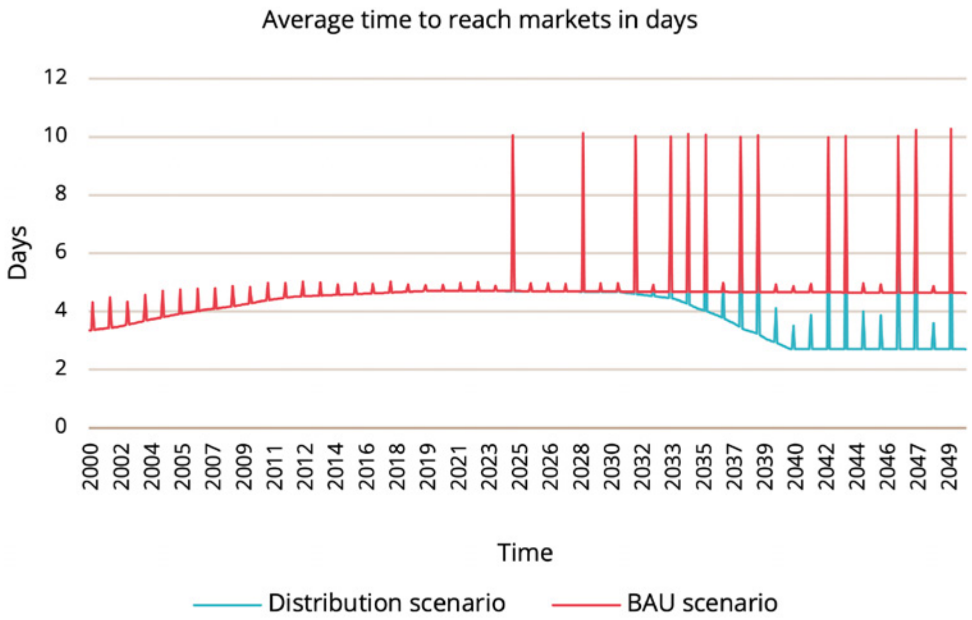
In addition to facilitating demand, the improvements in distribution infrastructure and processing facilities contribute to a reduction in losses during food transport. In the BAU scenario, distribution losses increase from 2.21 million tons in 2020 to 2.85 million tons by 2030 and 4.24 million tons per year in 2050. In the improved distribution scenario, the losses are projected to first increase to 2.74 million tons per year by 2030, which is 24% higher relative to the baseline, and then decline once the improvement of rural transport infrastructure (roads) occurs after 2030. This highlights the importance of improving rural transportation infrastructure. In other words, the expansion of the road network is insufficient to reduce losses, given that most of the roads in rural area are deteriorated, which forces carriers to drive slower and contributes to additional damage to produce during transport. The combination of road network expansion and the improvement of existing main roads used to transport produce to the markets are projected to reduce losses in 2040 and 2050 by 26% and 18% relative to the BAU scenario, despite the simultaneous increase in production.

Table 18: Produce lost during distribution BAU and improved distribution scenario

Produce lost during distribution	Unit	2030	2040	2050
BAU scenario	mn ton/year	2.21	2.85	4.24
Distribution scenario	mn ton/year	2.74	2.10	3.47
vs BAU scenario	%	24%	-26%	-18%

In the improved distribution scenario, the improvement of rural roads leads to the highest impacts on the average time to reach the market. The average time to reach the market in the BAU and improved distribution scenarios is presented in Figure 15 below. The graph shows that, despite the increase in total road network between 2020 and 2030, there are barely impacts on the time to reach the market, assuming that most roads will be of mediocre quality (gravel or worse). The improvement of road quality (IRI index), on the other hand, is projected to reduce the average time to market from around 4.7 days to 2.7 days, a reduction of 42.5% in total time to reach the market. The spikes observed in the average time to reach the market represent occasions in which floods force carriers to make a detour as the shortest routes may be partially damaged due to floods.

Figure 15: Average time to market BAU and improved distribution scenario



The establishment of processing facilities and refrigerated transport and storage infrastructure in the improved distribution scenario contributes to significant improvements in average product quality relative to the baseline. In this scenario, it is assumed that the government and the private sector seize the potential that emerged from the electrification of rural villages with renewable energy to establish adequate storage and local food processing facilities, which leads to improved product quality and reduces post-harvest losses. The relative product quality by 2050 is projected to improve by around 3.7% for cereals, 16.9% for roots and tubers, 34.8% for pulses, 31.6% for fruits and 68.6% for vegetables, relative to the BAU scenario in 2050. The projected relative average product quality for the BAU and improved distribution scenario is presented in Table 19 for selected years.

Table 19: Relative product quality BAU and improved distribution scenario

Relative product quality	Unit	2020	2030	2040	2050
Maize					
Production scenario	%	98.6%	99.6%	101.8%	102.4%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Sorghum					
Production scenario	%	98.6%	99.6%	101.8%	102.4%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Millet					
Production scenario	%	98.6%	99.6%	101.8%	102.4%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Potato					
Production scenario	%	97.1%	100.1%	107.8%	114.1%
BAU scenario	%	97.1%	97.1%	97.2%	97.2%
Cassava					
Production scenario	%	97.1%	100.1%	107.8%	114.1%
BAU scenario	%	97.1%	97.1%	97.2%	97.2%
Beans					
Production scenario	%	98.6%	105.5%	123.0%	133.5%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Peas					
Production scenario	%	98.6%	105.5%	123.0%	133.5%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Banana					
Production scenario	%	89.8%	97.5%	115.0%	121.9%
BAU scenario	%	89.8%	90.0%	90.2%	90.3%
Mango					
Production scenario	%	89.8%	97.5%	115.0%	121.9%
BAU scenario	%	89.8%	90.0%	90.2%	90.3%
Tomato					
Production scenario	%	89.8%	111.1%	144.4%	158.9%
BAU scenario	%	89.8%	90.0%	90.2%	90.3%

Consumption

Improvements in product quality increase the average price at which products can be sold; on the other hand, the reduced losses from distribution make so that production costs can be spread over a larger quantity. Overall, fresh products become more available for consumers as well as more affordable, creating a shift in consumer preferences. As a consequence, the projections for the improved distribution scenario indicate a shift in the composition of the average diet in Tanzania. While cereals and roots and tubers represent more than 80% of per capita consumption in the BAU scenario, the results for the improved distribution scenario indicate that vegetables and fruits become more prevalent in diets. The average shares by product category in the per capita diet in the BAU and improved distribution scenario are presented in Table 20.

Table 20: Produce shares in the average per capita diet by type of produce BAU and improved distribution scenario

Type of produce	Unit	2020	2030	2040	2050
Cereals					
Distribution scenario	%	30.1%	16.4%	10.5%	8.8%
BAU scenario	%	30.2%	29.7%	29.7%	29.6%
Fruit					
Distribution scenario	%	13.2%	33.2%	41.0%	44.5%
BAU scenario	%	13.1%	12.7%	12.8%	12.8%
Pulses					
Distribution scenario	%	4.1%	2.9%	2.7%	2.6%
BAU scenario	%	4.1%	3.5%	3.5%	3.5%
Roots and tubers					
Distribution scenario	%	50.4%	34.3%	27.5%	26.1%
BAU scenario	%	50.6%	52.1%	52.1%	52.1%
Vegetables					
Distribution scenario	%	2.2%	13.3%	18.3%	18.1%
BAU scenario	%	2.0%	2.0%	2.0%	2.0%

The projected shift in the composition of diets leads to an improvement in nutrient delivery and significantly improves nutrient sufficiency per capita relative to the BAU scenario. The improvement in nutrient sufficiency is driven by the shift in consumption away from conventional staples towards consuming more fresh produce, which is on average more nutritious relative to cereals and roots and tubers. The results for the average nutrient sufficiency in the BAU and improved distribution scenario are presented in Table 21 below.

Table 21: Nutrient sufficiency per capita indicators BAU and improved distribution scenario

Nutrient by type	Unit	2020	2030	2040	2050
Amino acid sufficiency per capita					
Tryptophan					
Distribution scenario	%	197%	194%	201%	189%
BAU scenario	%	197%	155%	128%	108%
Threonine					
Distribution scenario	%	81%	84%	90%	84%
BAU scenario	%	81%	62%	51%	43%
Isoleucine					
Distribution scenario	%	63%	65%	70%	66%
BAU scenario	%	63%	49%	40%	34%
Leucine					
Distribution scenario	%	74%	74%	77%	71%
BAU scenario	%	74%	57%	47%	40%
Lysine					
Distribution scenario	%	51%	58%	66%	63%
BAU scenario	%	51%	39%	32%	27%
Methionine					
Distribution scenario	%	56%	54%	55%	50%
BAU scenario	%	56%	44%	36%	31%
Cystine					
Distribution scenario	%	111%	110%	114%	106%
BAU scenario	%	111%	87%	72%	61%
Phenylalanine					
Distribution scenario	%	9222%	9733%	10593%	9991%
BAU scenario	%	9214%	7077%	5848%	4934%
Tyrosine					
Distribution scenario	%	6249%	5976%	6064%	5551%
BAU scenario	%	6247%	4847%	4005%	3379%
Valine					
Distribution scenario	%	64%	67%	72%	68%
BAU scenario	%	64%	49%	41%	34%
Arginine					
Distribution scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Histidine					
Distribution scenario	%	201%	502%	725%	760%
BAU scenario	%	200%	155%	128%	108%
Macronutrient sufficiency per capita					
Energy					
Distribution scenario	%	98%	100%	104%	97%
BAU scenario	%	98%	78%	64%	54%
Total protein					
Distribution scenario	%	89%	87%	88%	81%
BAU scenario	%	89%	70%	58%	49%
Total fat					
Distribution scenario	%	16%	15%	14%	13%
BAU scenario	%	17%	13%	11%	9%
Total carbohydrates					
Distribution scenario	%	149%	156%	165%	156%
BAU scenario	%	149%	119%	98%	83%

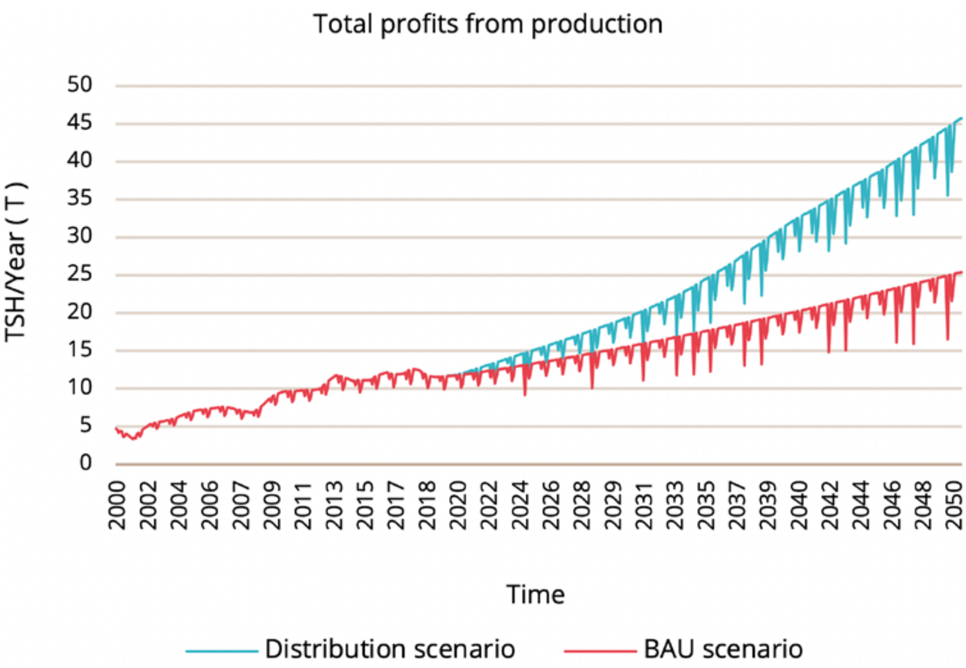
Saturated fatty acids					
Distribution scenario	%	2%	2%	2%	2%
BAU scenario	%	2%	2%	1%	1%
Monounsaturated fatty acids					
Distribution scenario	%	14%	12%	10%	9%
BAU scenario	%	14%	11%	9%	8%
Polyunsaturated fatty acids					
Distribution scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Cholesterol					
Distribution scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Fiber,					
Distribution scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Total sugar					
Distribution scenario	%	79%	199%	287%	302%
BAU scenario	%	79%	62%	52%	44%
Phytate					
Distribution scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Mineral sufficiency per capita					
Calcium					
Distribution scenario	%	22%	23%	25%	24%
BAU scenario	%	22%	18%	15%	12%
Phosphorus					
Distribution scenario	%	144%	135%	133%	121%
BAU scenario	%	144%	113%	93%	78%
Magnesium					
Distribution scenario	%	132%	137%	143%	134%
BAU scenario	%	132%	104%	86%	73%
Potassium					
Distribution scenario	%	148%	205%	250%	247%
BAU scenario	%	148%	119%	98%	83%
Sodium					
Distribution scenario	%	11%	10%	10%	9%
BAU scenario	%	11%	8%	7%	6%
Iron					
Distribution scenario	%	125%	119%	118%	107%
BAU scenario	%	125%	99%	82%	69%
Zinc					
Distribution scenario	%	76%	72%	71%	65%
BAU scenario	%	76%	60%	49%	42%
Copper					
Distribution scenario	%	197%	225%	251%	239%
BAU scenario	%	197%	158%	131%	111%
Mangan					
Distribution scenario	%	735%	638%	578%	508%
BAU scenario	%	736%	585%	483%	407%

Vitamin sufficiency per capita					
Vitamin A					
Distribution scenario	%	0.21%	0.18%	0.16%	0.14%
BAU scenario	%	0.21%	0.18%	0.15%	0.12%
Vitamin D					
Distribution scenario	%	0.00%	0.00%	0.00%	0.00%
BAU scenario	%	0.00%	0.00%	0.00%	0.00%
Vitamin E					
Distribution scenario	%	0.07%	0.06%	0.06%	0.05%
BAU scenario	%	0.07%	0.06%	0.05%	0.04%
Vitamin C					
Distribution scenario	%	132%	202%	257%	253%
BAU scenario	%	132%	108%	89%	75%
Thiamin					
Distribution scenario	%	146%	138%	137%	123%
BAU scenario	%	145%	114%	94%	80%
Riboflavin					
Distribution scenario	%	91%	115%	134%	129%
BAU scenario	%	91%	74%	62%	52%
Niacin					
Distribution scenario	%	91%	96%	101%	94%
BAU scenario	%	91%	73%	60%	51%
Vitamin B6					
Distribution scenario	%	145%	223%	282%	283%
BAU scenario	%	145%	116%	96%	81%
Folate					
Distribution scenario	%	0.21%	0.16%	0.14%	0.13%
BAU scenario	%	0.21%	0.16%	0.13%	0.11%
Vitamin B12					
Distribution scenario	%	0.00%	0.00%	0.00%	0.00%
BAU scenario	%	0.00%	0.00%	0.00%	0.00%
Pantothenic					
Distribution scenario	%	51%	68%	82%	80%
BAU scenario	%	51%	40%	33%	28%

Economics

Compared to the BAU scenario, total profits from crop production in the improved distribution scenario are projected to be 25.4% higher by 2030 and 81.1% higher by 2050. While profits from crop production in the baseline scenario are projected to increase from around TSH 11.55 trillion in 2020 to TSH 15.24 trillion and TSH 24.04 trillion by 2030 and 2050 respectively, total profits in the improved distribution scenario are projected to increase to TSH 19.11 trillion in 2030 and TSH 43.55 trillion in 2050 respectively. The development of total profits from crop production in the BAU and improved production scenario are presented in Figure 16 below.

Figure 16: Total profits from crop production BAU and improved distribution scenario



The average profits per ton of produce sold are projected to increase between 5.6% and 124.7%, depending on the type of produce (see Table 22). The increase in profits earned per ton occurs as a consequence of a combination of factors. On the one hand, cooled transportation and the availability of processing infrastructure improve product quality, which increases the availability in the market and the average price at which fresh products can be sold. At the same time, fresh produce has higher profits margins relative to cereals, benefiting farmers by increasing their income. The increased accessibility and convenience that comes with processed foods makes purchasing them more attractive for consumers, which increases demand and in turn affects the crop choice of farmers, as described above (see Table 17).

Table 22: Average profits per ton of produce sold BAU and improved distribution scenario

Crop type	Unit	2020	2030	2040	2050
Maize					
BAU scenario	TSH/ton	242,199	242,336	242,540	239,692
Distribution scenario	TSH/ton	242,519	249,675	263,165	265,235
vs BAU	%	0.1%	3.0%	8.5%	10.7%
Sorghum					
BAU scenario	TSH/ton	1,265,117	1,265,501	1,266,070	1,258,152
Distribution scenario	TSH/ton	1,265,976	1,285,137	1,323,638	1,328,446
vs BAU	%	0.1%	1.6%	4.5%	5.6%
Millet					
BAU scenario	TSH/ton	689,468	689,715	690,081	684,979
Distribution scenario	TSH/ton	690,028	702,522	727,133	730,420
vs BAU	%	0.1%	1.9%	5.4%	6.6%
Potato					
BAU scenario	TSH/ton	502,023	502,391	502,937	494,892
Distribution scenario	TSH/ton	502,523	522,573	578,757	616,495
vs BAU	%	0.1%	4.0%	15.1%	24.6%
Cassava					
BAU scenario	TSH/ton	216,505	216,705	217,000	212,342
Distribution scenario	TSH/ton	216,729	226,439	255,337	274,020
vs BAU	%	0.1%	4.5%	17.7%	29.0%
Beans					
BAU scenario	TSH/ton	1,131,614	1,132,031	1,132,650	1,123,921
Distribution scenario	TSH/ton	1,130,696	1,212,391	1,481,741	1,655,572
vs BAU	%	-0.1%	7.1%	30.8%	47.3%
Peas					
BAU scenario	TSH/ton	1,192,206	1,192,637	1,193,275	1,184,301
Distribution scenario	TSH/ton	1,191,271	1,275,742	1,553,609	1,732,921
vs BAU	%	-0.1%	7.0%	30.2%	46.3%
Banana					
BAU scenario	TSH/ton	547,095	548,498	550,577	531,583
Distribution scenario	TSH/ton	549,933	618,489	773,458	817,284
vs BAU	%	0.5%	12.8%	40.5%	53.7%
Mango					
BAU scenario	TSH/ton	948,879	950,965	954,057	926,272
Distribution scenario	TSH/ton	953,136	1,055,728	1,286,177	1,352,001
vs BAU	%	0.4%	11.0%	34.8%	46.0%
Tomato					
BAU scenario	TSH/ton	507,306	508,868	511,183	490,146
Distribution scenario	TSH/ton	513,727	696,182	977,311	1,101,272
vs BAU	%	1.3%	36.8%	91.2%	124.7%

SCENARIO 3: JIGHER DEMAND FOR NUTRITIOUS FOOD (AWARENESS RAISING)

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. This shift is simulated by changing the consumer preference index in the consumption sketch, which in turn affects the choice of crops for farmers towards using more land for fruits and vegetables. The assumption used for the consumer awareness index are presented in Table 23.

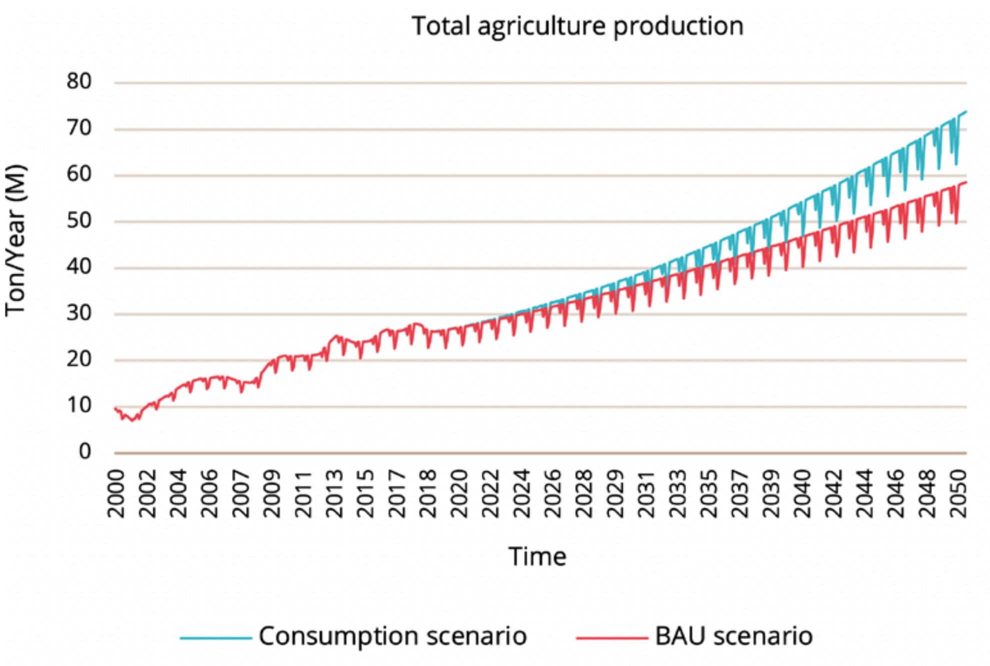
Table 23: Overview of assumptions for the consumer awareness scenario

Parameter	Assumption
Consumer awareness index value	An index value of 1 indicates that there is no change in consumer preferences for this specific produce category. An increase of the index value above 1, indicates increased consumer demand for the respective product category. The consumer price index values for the years 2030, 2040 and 2050 for all crop categories are presented below. **Cereals** • Index value 2020: 1 • Index value 2030: 1 • Index value 2040: 1 • Index value 2050: 1 **Pulses** • Index value 2020: 1 • Index value 2030: 1.05 • Index value 2040: 1.1 • Index value 2050: 1.15 • Roots and tubers • Index value 2020: 1 • Index value 2030: 1.05 • Index value 2040: 1.1 • Index value 2050: 1.15 **Fruits** • Index value 2020: 1 • Index value 2030: 1.2 • Index value 2040: 1.35 • Index value 2050: 1.5 **Vegetables** • Index value 2020: 1 • Index value 2030: 1.2 • Index value 2040: 1.35 • Index value 2050: 1.5

Production

The change of consumer preferences contributes to a shift in land use patters, away from cereals and towards pulses, roots and tubers, and especially crops and vegetables. Given that fruits and vegetables generally have higher yields per hectare, total agriculture production is projected to increase relative to the BAU scenario. While total crop production in the BAU scenario increases from 26.63 million tons in 2020 to 35.2 million tons in 2030 and 58.5 million tons in 2050, total crop production in the consumer awareness scenario increases to 37.29 million tons by 2030 (+5.9% vs BAU) and 73.79 million tons per year in 2050 (+26.1% vs BAU). The forecasted total agriculture production in the BAU and consumer awareness scenario is presented in Figure 17, compared to historical data.

Figure 17: Total crop production BAU and consumer awareness scenario



The assumed changes in consumer preferences lead to a shift in land use towards pulses, roots and tubers, fruits and vegetables. This development is similar to the improved distribution scenario, however the differences relative to the BAU scenario are less marked. The change in crop choice leads to a reduction in land used for cereals accompanied by an increased use of cropland to grow other products. The highest relative increase is observed for tomatoes and bananas, followed by mango. The projected shares of land used by type of crop in the BAU and consumer awareness scenario are presented in Table 24, for selected years.

Table 24: Shares of land used by crop BAU and consumer awareness scenario

Crop type	Unit	2020	2030	2040	2050
Maize					
Consumer awareness	%	45.2%	43.0%	40.1%	37.4%
BAU scenario	%	45.3%	45.3%	45.3%	45.3%
Sorghum					
Consumer awareness	%	8.5%	8.2%	7.8%	7.4%
BAU scenario	%	8.5%	8.5%	8.5%	8.5%
Millet					
Consumer awareness	%	3.6%	3.4%	3.1%	2.9%
BAU scenario	%	3.6%	3.6%	3.6%	3.6%
Potato					
Consumer awareness	%	14.4%	14.8%	14.8%	14.8%
BAU scenario	%	14.4%	14.4%	14.4%	14.4%
Cassava					
Consumer awareness	%	13.5%	13.8%	13.8%	13.7%
BAU scenario	%	13.5%	13.5%	13.5%	13.5%
Beans					
Consumer awareness	%	7.1%	7.3%	7.3%	7.3%
BAU scenario	%	7.1%	7.1%	7.1%	7.1%
Peas					
Consumer awareness	%	2.6%	2.7%	2.7%	2.7%
BAU scenario	%	2.6%	2.6%	2.6%	2.6%
Banana					
Consumer awareness	%	4.1%	5.6%	8.7%	11.7%
BAU scenario	%	4.0%	4.0%	4.0%	4.0%
Mango					
Consumer awareness	%	0.4%	0.5%	0.7%	0.9%
BAU scenario	%	0.4%	0.4%	0.4%	0.4%
Tomato					
Consumer awareness	%	0.5%	0.6%	0.9%	1.1%
BAU scenario	%	0.5%	0.5%	0.5%	0.5%

Distribution

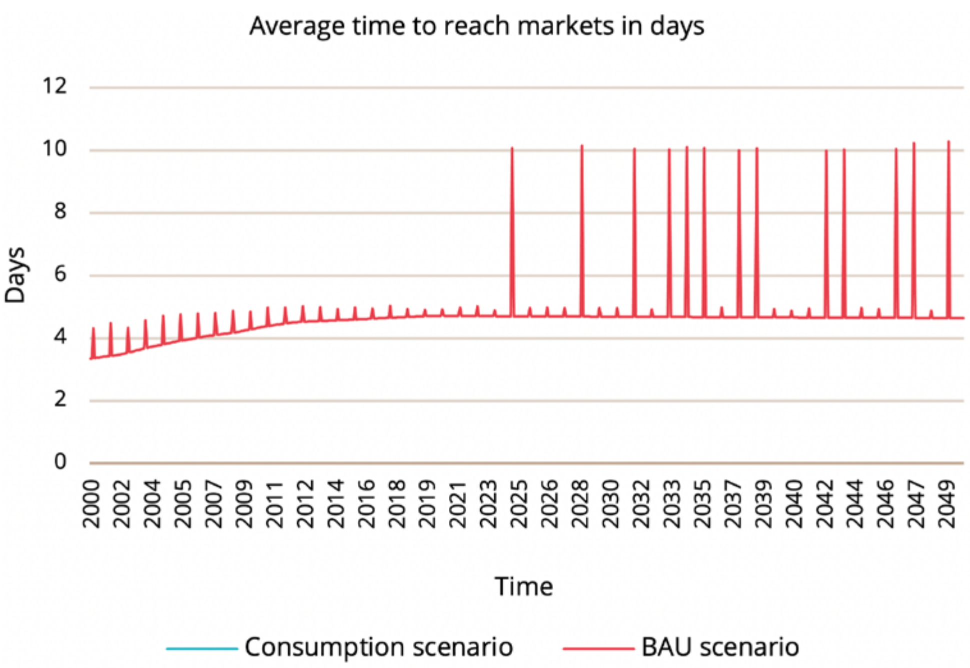
The results for distribution losses occurring in the BAU and consumer awareness scenario are presented in Table 25 below. While the overall output of the crop production sector increases, driven by higher yields of fruits and vegetables, the lack of adequate transport and processing infrastructure causes distribution losses in the consumer awareness scenario to be higher relative to the BAU scenario. While BAU projections indicate distribution of 2.21 million tons in 2020, increasing to 2.85 million tons by 2030 and 4.24 million tons per year by 2050, distribution losses in the consumer awareness scenario are projected to be 16% higher in 2030 (+0.35 million tons per year vs BAU) and 67% higher by 2050 (+2.84 million tons per year vs BAU).

Table 25: Produce lost during distribution BAU and consumer awareness scenario

Produce lost during distribution	Unit	2030	2040	2050
BAU scenario	mn ton/year	2.21	2.85	4.24
Consumer awareness	mn ton/year	2.57	4.17	7.07
vs BAU scenario	%	16%	47%	67%

The average time to market in the BAU and consumer awareness scenario is presented in Figure 18Figure 12. In absence of any measures targeting the distribution sector, the average time to reach the market in the BAU and consumer awareness scenario is the same. It slightly increases until 2020, after which the average time to reach the market remains constant around 4.8 days in both scenarios. The spikes observed in the average time to reach the market represent occasions in which floods force carriers to make a detour as the shortest routes may be partially damaged due to flood damages.

Figure 18: Average time to market BAU and consumer awareness scenario



Furthermore, the absence of cooled transport and storage causes product quality to decline the longer it takes to transport produce to the markets, especially in the case of fresh produce. In the consumer awareness scenario, the response of the distribution sector to the increase in total sectoral output would be buying more conventional trucks. As a result, the average product quality in the improved production scenario remains unchanged to the BAU scenario, as illustrated by the projected relative product quality presented in Table 26.

Table 26: Relative product quality BAU and consumer awareness scenario

Relative product quality	Unit	2020	2030	2040	2050
Maize					
Consumer awareness	%	98.6%	98.6%	98.6%	98.7%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Sorghum					
Consumer awareness	%	98.6%	98.6%	98.6%	98.7%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Millet					
Consumer awareness	%	98.6%	98.6%	98.6%	98.7%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Potato					
Consumer awareness	%	97.1%	97.1%	97.2%	97.2%
BAU scenario	%	97.1%	97.1%	97.2%	97.2%
Cassava					
Consumer awareness	%	97.1%	97.1%	97.2%	97.2%
BAU scenario	%	97.1%	97.1%	97.2%	97.2%
Beans					
Consumer awareness	%	98.6%	98.6%	98.6%	98.7%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Peas					
Consumer awareness	%	98.6%	98.6%	98.6%	98.7%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Banana					
Consumer awareness	%	89.8%	90.0%	90.2%	90.3%
BAU scenario	%	89.8%	90.0%	90.2%	90.3%
Mango					
Consumer awareness	%	89.8%	90.0%	90.2%	90.3%
BAU scenario	%	89.8%	90.0%	90.2%	90.3%
Tomato					
Consumer awareness	%	89.8%	90.0%	90.2%	90.3%
BAU scenario	%	89.8%	90.0%	90.2%	90.3%

Consumption

The simulated shift in consumer preferences and the induced shift to the crop production sector leads to a change in the composition of supply reaching the market relative to the BAU scenario. In the consumer awareness scenario, an increase in the average consumption of fruits and vegetables, roots and tubers and pulses is observed with a simultaneous decline in land used for cereals. The projected share of each produce category in the per capita diet in the BAU and consumer awareness scenario is presented in Table 27 below.

Table 27: Produce shares in the average per capita diet by type of produce BAU and consumer awareness scenario

Type of produce	Unit	2020	2030	2040	2050
Cereals					
Consumer awareness	%	30.2%	25.7%	20.9%	17.0%
BAU scenario	%	30.2%	29.7%	29.7%	29.6%
Fruit					
Consumer awareness	%	13.2%	18.2%	27.1%	35.3%
BAU scenario	%	13.1%	12.7%	12.8%	12.8%
Pulses					
Consumer awareness	%	4.1%	3.4%	3.1%	2.8%
BAU scenario	%	4.1%	3.5%	3.5%	3.5%
Roots and tubers					
Consumer awareness	%	50.6%	50.2%	45.4%	40.7%
BAU scenario	%	50.6%	52.1%	52.1%	52.1%
Vegetables					
Consumer awareness	%	2.0%	2.6%	3.5%	4.3%
BAU scenario	%	2.0%	2.0%	2.0%	2.0%

The shift in produce shares in the average per capita diet, away from cereals and towards more nutritious foods, leads to an overall improvement in nutrient sufficiency per capita. The projected nutrient sufficiency for all nutrients considered in this study is presented in Table 28, for the BAU and consumer awareness scenario and selected years.

Table 28: Nutrient sufficiency per capita indicators BAU and consumer awareness scenario

Nutrient by type	Unit	2020	2030	2040	2050
Amino acid sufficiency per capita					
Tryptophan					
Consumer awareness	%	197%	165%	144%	128%
BAU scenario	%	197%	155%	128%	108%
Threonine					
Consumer awareness	%	81%	66%	57%	51%
BAU scenario	%	81%	62%	51%	43%
Isoleucine					
Consumer awareness	%	63%	51%	45%	40%
BAU scenario	%	63%	49%	40%	34%
Leucine					
Consumer awareness	%	74%	59%	51%	45%
BAU scenario	%	74%	57%	47%	40%
Lysine					
Consumer awareness	%	51%	42%	38%	35%
BAU scenario	%	51%	39%	32%	27%
Methionine					
Consumer awareness	%	56%	45%	38%	33%
BAU scenario	%	56%	44%	36%	31%
Cystine					
Consumer awareness	%	111%	90%	77%	68%
BAU scenario	%	111%	87%	72%	61%
Phenylalanine					
Consumer awareness	%	9216%	7484%	6580%	5928%
BAU scenario	%	9214%	7077%	5848%	4934%
Tyrosine					
Consumer awareness	%	6247%	5007%	4228%	3644%
BAU scenario	%	6247%	4847%	4005%	3379%
Valine					
Consumer awareness	%	64%	52%	46%	41%
BAU scenario	%	64%	49%	41%	34%
Arginine					
Consumer awareness	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Histidine					
Consumer awareness	%	201%	212%	267%	318%
BAU scenario	%	200%	155%	128%	108%
Macronutrient sufficiency per capita					
Energy					
Consumer awareness	%	98%	81%	71%	64%
BAU scenario	%	98%	78%	64%	54%
Total protein					
Consumer awareness	%	89%	72%	61%	53%
BAU scenario	%	89%	70%	58%	49%
Total fat					
Consumer awareness	%	16%	13%	11%	9%
BAU scenario	%	17%	13%	11%	9%
Total carbohydrates					
Consumer awareness	%	149%	125%	110%	100%
BAU scenario	%	149%	119%	98%	83%

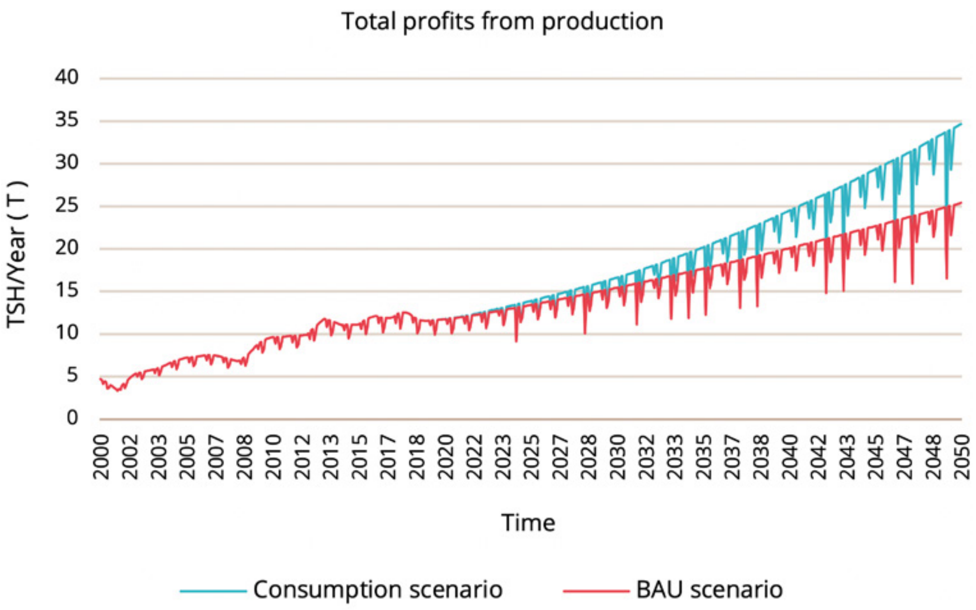
Saturated fatty acids					
Consumer awareness	%	2%	2%	1%	1%
BAU scenario	%	2%	2%	1%	1%
Monounsaturated fatty acids					
Consumer awareness	%	14%	11%	9%	7%
BAU scenario	%	14%	11%	9%	8%
Polyunsaturated fatty acids					
Consumer awareness	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Cholesterol					
Consumer awareness	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Fiber,					
Consumer awareness	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Total sugar					
Consumer awareness	%	79%	86%	108%	128%
BAU scenario	%	79%	62%	52%	44%
Phytate					
Consumer awareness	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Mineral sufficiency per capita					
Calcium					
Consumer awareness	%	22%	19%	17%	15%
BAU scenario	%	22%	18%	15%	12%
Phosphorus					
Consumer awareness	%	144%	115%	96%	83%
BAU scenario	%	144%	113%	93%	78%
Magnesium					
Consumer awareness	%	132%	108%	94%	85%
BAU scenario	%	132%	104%	86%	73%
Potassium					
Consumer awareness	%	148%	133%	128%	126%
BAU scenario	%	148%	119%	98%	83%
Sodium					
Consumer awareness	%	11%	9%	7%	6%
BAU scenario	%	11%	8%	7%	6%
Iron					
Consumer awareness	%	125%	102%	86%	74%
BAU scenario	%	125%	99%	82%	69%
Zinc					
Consumer awareness	%	76%	61%	52%	45%
BAU scenario	%	76%	60%	49%	42%
Copper					
Consumer awareness	%	197%	170%	153%	140%
BAU scenario	%	197%	158%	131%	111%
Mangan					
Consumer awareness	%	735%	581%	475%	399%
BAU scenario	%	736%	585%	483%	407%

Vitamin sufficiency per capita					
Vitamin A					
Consumer awareness	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Vitamin D					
Consumer awareness	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Vitamin E					
Consumer awareness	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Vitamin C					
Consumer awareness	%	132%	124%	120%	118%
BAU scenario	%	132%	108%	89%	75%
Thiamin					
Consumer awareness	%	145%	116%	96%	81%
BAU scenario	%	145%	114%	94%	80%
Riboflavin					
Consumer awareness	%	91%	81%	74%	70%
BAU scenario	%	91%	74%	62%	52%
Niacin,					
Consumer awareness	%	91%	76%	66%	59%
BAU scenario	%	91%	73%	60%	51%
Vitamin B6					
Consumer awareness	%	145%	133%	135%	139%
BAU scenario	%	145%	116%	96%	81%
Folate					
Consumer awareness	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Vitamin B12					
Consumer awareness	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Pantothenic					
Consumer awareness	%	51%	44%	42%	40%
BAU scenario	%	51%	40%	33%	28%

Economics

Total profits from crop production in the consumer awareness scenario are projected to reach TSH 16.46 trillion (+8% vs BAU) and TSH 32.49 (+35.1% vs BAU), driven by the higher profit margins of fresh produce. This is compared to total profits of TSH 15.24 trillion and TSH 24.04 trillion by 2030 and 2050 respectively for the BAU scenario. The development of total profits from crop production in the BAU and improved production scenario are presented in Figure 19. On the other hand, it should be noted that the cost of production increases considerably, given the high transportation losses occurring in this scenario.

Figure 19: Total profits from crop production BAU and consumer awareness scenario



The lack of cooled transport and processing facilities impedes increase in product prices observed in the improved distribution scenario, indicating that the system is performing below optimum performance. Consequently, the increase in profits is driven by total output (driven by higher yields of 'preferred products') rather than improvements in product quality. The projected average profitability per ton of produce sold in the BAU and consumer awareness scenario is presented in Table 29.

Table 29: Average profits per ton of produce sold BAU and consumer awareness scenario

Crop type	Unit	2020	2030	2040	2050
Maize					
BAU scenario	TSH/ton	242,199	242,336	242,540	239,692
Consumer awareness	TSH/ton	242,199	242,336	242,540	239,692
vs BAU	%	0.0%	0.0%	0.0%	0.0%
Sorghum					
BAU scenario	TSH/ton	1,265,117	1,265,501	1,266,070	1,258,152
Consumer awareness	TSH/ton	1,265,117	1,265,501	1,266,070	1,258,152
vs BAU	%	0.0%	0.0%	0.0%	0.0%
Millet					
BAU scenario	TSH/ton	689,468	689,715	690,081	684,979
Consumer awareness	TSH/ton	689,468	689,715	690,081	684,979
vs BAU	%	0.0%	0.0%	0.0%	0.0%
Potato					
BAU scenario	TSH/ton	502,023	502,391	502,937	494,892
Consumer awareness	TSH/ton	502,023	502,391	502,937	494,892
vs BAU	%	0.0%	0.0%	0.0%	0.0%
Cassava					
BAU scenario	TSH/ton	216,505	216,705	217,000	212,342
Consumer awareness	TSH/ton	216,505	216,705	217,000	212,342
vs BAU	%	0.0%	0.0%	0.0%	0.0%
Beans					
BAU scenario	TSH/ton	1,131,614	1,132,031	1,132,650	1,123,921
Consumer awareness	TSH/ton	1,131,614	1,132,031	1,132,650	1,123,921
vs BAU	%	0.0%	0.0%	0.0%	0.0%
Peas					
BAU scenario	TSH/ton	1,192,206	1,192,637	1,193,275	1,184,301
Consumer awareness	TSH/ton	1,192,206	1,192,637	1,193,275	1,184,301
vs BAU	%	0.0%	0.0%	0.0%	0.0%
Banana					
BAU scenario	TSH/ton	547,095	548,498	550,577	531,583
Consumer awareness	TSH/ton	547,095	548,498	550,577	531,583
vs BAU	%	0.0%	0.0%	0.0%	0.0%
Mango					
BAU scenario	TSH/ton	948,879	950,965	954,057	926,272
Consumer awareness	TSH/ton	948,879	950,965	954,057	926,272
vs BAU	%	0.0%	0.0%	0.0%	0.0%
Tomato					
BAU scenario	TSH/ton	507,306	508,868	511,183	490,146
Consumer awareness	TSH/ton	507,307	508,868	511,183	490,146
vs BAU	%	0.0%	0.0%	0.0%	0.0%

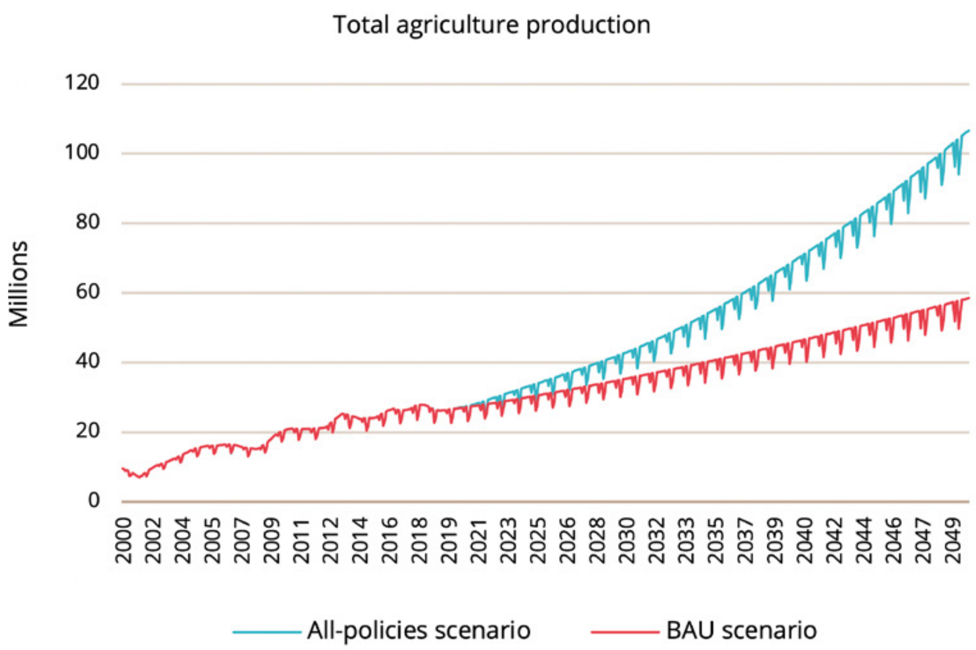
SCENARIO 4: IMPROVED PRODUCTION, DISTRIBUTION AND EFFORTS FOR AWARENESS RAISING

This scenario assumes all policy interventions presented in the scenario sections above. It represents an integrated approach to address several challenges of the food system simultaneously, including production, distribution and consumption interventions.

Production

In the integrated scenario, total agriculture production increases as a consequence of a combination of factors. The change in consumer preferences towards fresh produce, with higher yields per hectare relative to cereals, and the higher productivity of sustainable management practices drive the increase in total production. At the same time, higher product quality through improved transport and processing infrastructure increase the sales prices per ton of produce, which makes growing fresh produce even more attractive for farmers. While total crop production in the BAU scenario is projected to increase from 26.63 million tons in 2020 to 35.2 million tons in 2030 and is projected to reach 58.5 million tons by 2050, the projections for the integrated supply chain scenario increase total crop production to 43.32 million tons by 2030 (+23.1% vs BAU) and 106.63 million tons by 2050 (+82.3% vs BAU) respectively. The development of total agriculture production in the BAU and integrated supply chain scenario is presented in Figure 20, compared to historical data.

Figure 20: Total crop production BAU and integrated supply chain scenario



The shares of land used for the production of each crop in the BAU and integrated supply chain scenario is summarized in Table 30. The combination of higher margins for fresh produce, increased profitability from improved quality of products reaching the market, better transport and processing infrastructure as well as consumer preferences contributes to increased land use for fruits and vegetables, and, to a lesser extent, pulses and roots and tubers. The share of land used for cereal production is projected to decline for all cereals considered.

Table 30: Shares of land used by crop BAU and integrated supply chain scenario

Crop type	Unit	2020	2030	2040	2050
Maize					
All policies	%	44.9%	39.0%	32.3%	27.8%
BAU scenario	%	45.3%	45.3%	45.3%	45.3%
Sorghum					
All policies	%	8.5%	7.7%	6.8%	6.1%
BAU scenario	%	8.5%	8.5%	8.5%	8.5%
Millet					
All policies	%	3.6%	3.0%	2.4%	2.1%
BAU scenario	%	3.6%	3.6%	3.6%	3.6%
Potato					
All policies	%	14.4%	14.5%	14.2%	13.8%
BAU scenario	%	14.4%	14.4%	14.4%	14.4%
Cassava					
All policies	%	13.5%	13.7%	13.7%	13.5%
BAU scenario	%	13.5%	13.5%	13.5%	13.5%
Beans					
All policies	%	7.2%	7.9%	8.4%	8.3%
BAU scenario	%	7.1%	7.1%	7.1%	7.1%
Peas					
All policies	%	2.6%	2.9%	3.0%	3.0%
BAU scenario	%	2.6%	2.6%	2.6%	2.6%
Banana					
All policies	%	4.2%	9.1%	15.6%	20.8%
BAU scenario	%	4.0%	4.0%	4.0%	4.0%
Mango					
All policies	%	0.4%	0.7%	1.2%	1.6%
BAU scenario	%	0.4%	0.4%	0.4%	0.4%
Tomato					
All policies	%	0.7%	1.4%	2.3%	3.0%
BAU scenario	%	0.5%	0.5%	0.5%	0.5%

Distribution

The results suggest that distribution losses are higher relative to the baseline scenario. The distribution losses in the BAU and integrated supply chain scenario are presented in Table 31 below. Distribution losses are projected to be 48% higher in 2030 and 58% higher in 2050, with a temporary reduction to 20% in 2040, induced by the improvements of rural roads. Given that the improvement of roads is assumed to occur between 2030 and 2040, the share of losses increases again after 2040, reaching 58% by 2050, but absolute benefits accumulate over time.

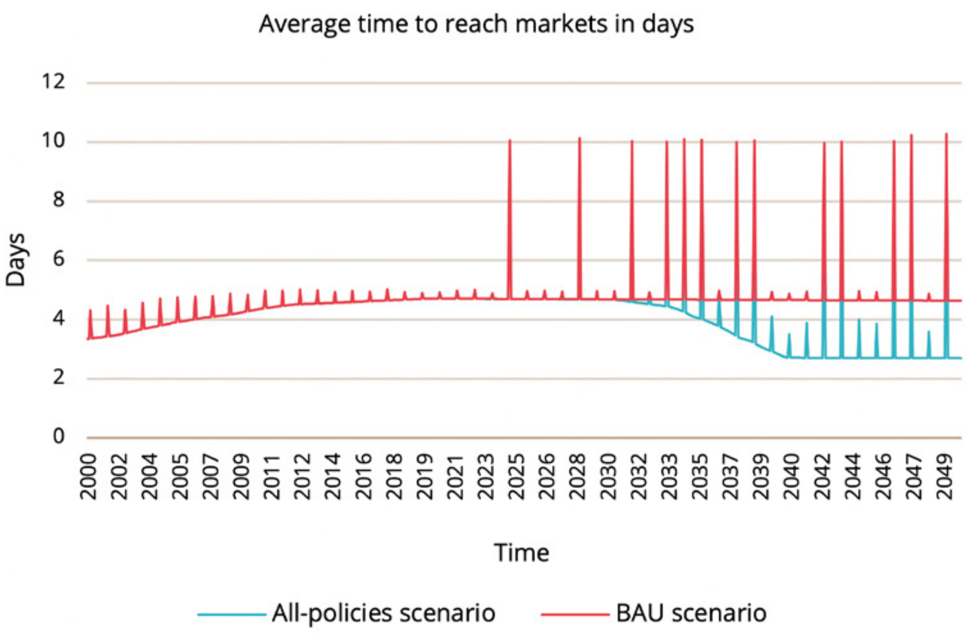
While total losses in the integrated supply chain scenario seem to be higher relative to the BAU scenario, these losses need to be put in context with the increase in production described above. While absolute losses increase, the share of losses in total production decline. In the BAU scenario, the share of distribution losses over total crop production increases slightly, from 6.3% in 2020 to 7.2% by 2050. In the integrated supply chain scenario a decline in distribution losses over total production from 6.3% in 2020 to 4.6% in 2050 is projected, indicating that the share of produce lost during distribution in the integrated supply chain scenario is 2.6% lower relative to the BAU scenario.

Table 31: Produce lost during distribution BAU and integrated supply chain scenario

Produce lost during distribution	Unit	2030	2040	2050
BAU scenario	mn ton/year	2.21	2.85	4.24
Integrated supply chain	mn ton/year	3.27	3.43	6.71
vs BAU scenario	%	48%	20%	58%

The average time to reach the market projected for the BAU and integrated supply chain scenario is presented in Figure 21. The average time to reach the market slightly increases until 2020, after which it constant at around 4.7 days between 2020 and 2030. After 2030, the improvement of rural roads leads to a reduction in the time to reach the market, reaching around 2.7 days by 2040 and thereafter in the integrated scenario. The reduction in transport time to market leads to improvements in product quality also for those perishable products that are transported uncooled. The spikes observed in the average time to reach the market represent occasions in which floods force carriers to make a detour as the shortest routes may be partially damaged due to flood damages.

Figure 21: Average time to market BAU and integrated supply chain scenario



The combination of interventions improves the overall quality of products reaching the markets above BAU levels. Improved road quality reduces transport time, reducing the fraction of produce lost during transport. As in the distribution scenario, the government and private sector seize the potential for establishing cold storate and local food processing facilities, which emerged from the electrification of rural villages. In addition to improvement in distribution infrastructure, the processing of products both maintains product quality and increases the convenience for consumers, because now also fresh products have a longer shelf life compared to the BAU scenario. The average relative product quality for all crops considered is presented in Table 32.

Table 32: Relative product quality BAU and integrated supply chain scenario

Crop type	Unit	2020	2030	2040	2050
Maize					
Production scenario	%	98.6%	99.6%	101.8%	102.4%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Sorghum					
Production scenario	%	98.6%	99.6%	101.8%	102.4%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Millet					
Production scenario	%	98.6%	99.6%	101.8%	102.4%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Potato					
Production scenario	%	97.1%	100.1%	107.8%	114.1%
BAU scenario	%	97.1%	97.1%	97.2%	97.2%
Cassava					
Production scenario	%	97.1%	100.1%	107.8%	114.1%
BAU scenario	%	97.1%	97.1%	97.2%	97.2%
Beans					
Production scenario	%	98.6%	105.5%	123.0%	133.5%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Peas					
Production scenario	%	98.6%	105.5%	123.0%	133.5%
BAU scenario	%	98.6%	98.6%	98.6%	98.7%
Banana					
Production scenario	%	89.8%	97.5%	115.0%	121.9%
BAU scenario	%	89.8%	90.0%	90.2%	90.3%
Mango					
Production scenario	%	89.8%	97.5%	115.0%	121.9%
BAU scenario	%	89.8%	90.0%	90.2%	90.3%
Tomato					
Production scenario	%	89.8%	111.1%	144.4%	158.9%
BAU scenario	%	89.8%	90.0%	90.2%	90.3%

Consumption

Driven by increased convenience (longer shelf life), availability (produce reaching the market and product quality), accessibility (road network expansion) and consumer preferences (preferred fresh foods) the dietary composition is forecasted to change. The projected shares of cereals, fruits, pulses, roots and tubers and vegetables in the average diet per capita in the BAU and integrated supply chain scenario is presented in Table 33. The share of cereals shows a strong decline in favor of all other crops, mainly fruits and vegetables, but also pulses and roots and tubers.

Table 33: Produce shares in the average per capita diet by type of produce BAU and integrated supply chain scenario

Type of produce	Unit	2020	2030	2040	2050
Cereals					
Integrated supply chain scenario	%	30.0%	12.6%	5.2%	3.0%
BAU scenario	%	30.2%	29.7%	29.7%	29.6%
Fruit					
Integrated supply chain scenario	%	13.3%	39.6%	52.7%	59.1%
BAU scenario	%	13.1%	12.7%	12.8%	12.8%
Pulses					
Integrated supply chain scenario	%	4.1%	2.5%	1.7%	1.2%
BAU scenario	%	4.1%	3.5%	3.5%	3.5%
Roots and tubers					
Integrated supply chain scenario	%	50.4%	29.7%	17.2%	12.6%
BAU scenario	%	50.6%	52.1%	52.1%	52.1%
Vegetables					
Integrated supply chain scenario	%	2.2%	15.6%	23.2%	24.2%
BAU scenario	%	2.0%	2.0%	2.0%	2.0%

This shift in dietary composition enabled through integrated supply chain management leads to a significant increase in the nutritional balance of the average diet relative to the BAU scenario. Nutrient sufficiency increases as a consequence of the increased availability and consumption of more nutritious foods relative to the current average diet projected in the BAU scenario. The per capita nutrient sufficiency indicators in the BAU scenario are presented in Table 34.

Table 34: Nutrient sufficiency per capita indicators BAU and integrated supply chain scenario

Nutrient by type	Unit	2020	2030	2040	2050
Amino acid sufficiency per capita					
Tryptophan					
Integrated Supply Chain scenario	%	197%	220%	271%	303%
BAU scenario	%	197%	155%	128%	108%
Threonine					
Integrated Supply Chain scenario	%	81%	95%	129%	154%
BAU scenario	%	81%	62%	51%	43%
Isoleucine					
Integrated Supply Chain scenario	%	63%	74%	100%	118%
BAU scenario	%	63%	49%	40%	34%
Leucine					
Integrated Supply Chain scenario	%	74%	83%	108%	127%
BAU scenario	%	74%	57%	47%	40%
Lysine					
Integrated Supply Chain scenario	%	51%	68%	100%	123%
BAU scenario	%	51%	39%	32%	27%
Methionine					
Integrated Supply Chain scenario	%	56%	60%	73%	82%
BAU scenario	%	56%	44%	36%	31%
Cystine					
Integrated Supply Chain scenario	%	111%	124%	159%	183%
BAU scenario	%	111%	87%	72%	61%
Phenylalanine					
Integrated Supply Chain scenario	%	9225%	11184%	15573%	18841%
BAU scenario	%	9214%	7077%	5848%	4934%
Tyrosine					
Integrated Supply Chain scenario	%	6250%	6544%	7745%	8393%
BAU scenario	%	6247%	4847%	4005%	3379%
Valine					
Integrated Supply Chain scenario	%	64%	77%	107%	129%
BAU scenario	%	64%	49%	41%	34%
Arginine					
Integrated Supply Chain scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Histidine					
Integrated Supply Chain scenario	%	202%	729%	1670%	2531%
BAU scenario	%	200%	155%	128%	108%
Macronutrient sufficiency per capita					
Energy					
Integrated Supply Chain scenario	%	98%	115%	159%	197%
BAU scenario	%	98%	78%	64%	54%
Total protein					
Integrated Supply Chain scenario	%	89%	97%	123%	143%
BAU scenario	%	89%	70%	58%	49%
Total fat					
Integrated Supply Chain scenario	%	16%	16%	20%	23%
BAU scenario	%	17%	13%	11%	9%
Total carbohydrates					
Integrated Supply Chain scenario	%	149%	182%	261%	330%
BAU scenario	%	149%	119%	98%	83%

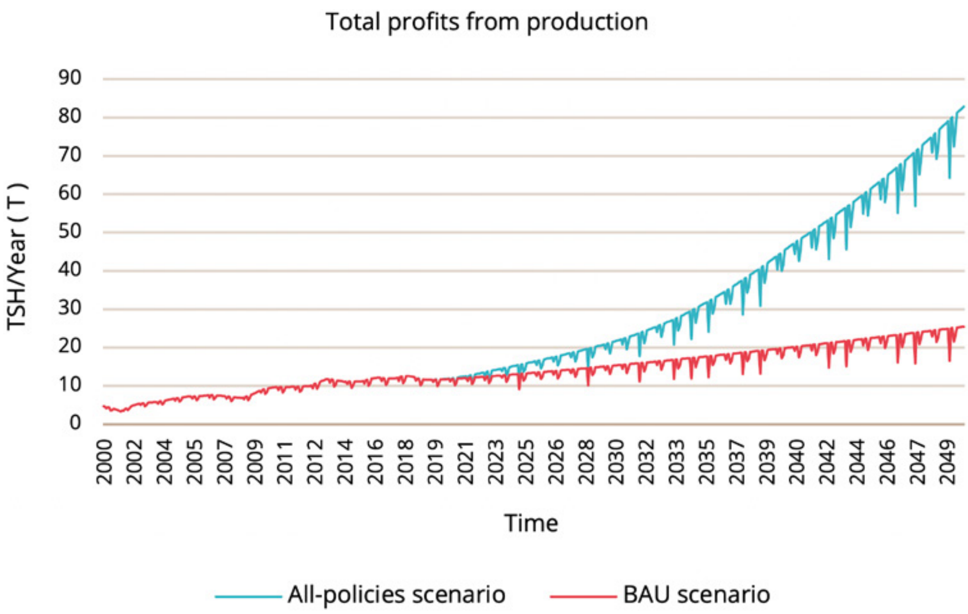
Saturated fatty acids					
Integrated Supply Chain scenario	%	2%	2%	3%	4%
BAU scenario	%	2%	2%	1%	1%
Monounsaturated fatty acids					
Integrated Supply Chain scenario	%	14%	12%	13%	13%
BAU scenario	%	14%	11%	9%	8%
Polyunsaturated fatty acids					
Integrated Supply Chain scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Cholesterol					
Integrated Supply Chain scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Fiber,					
Integrated Supply Chain scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Total sugar					
Integrated Supply Chain scenario	%	80%	291%	664%	1008%
BAU scenario	%	79%	62%	52%	44%
Phytate					
Integrated Supply Chain scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Mineral sufficiency per capita					
Calcium					
Integrated Supply Chain scenario	%	22%	27%	37%	44%
BAU scenario	%	22%	18%	15%	12%
Phosphorus					
Integrated Supply Chain scenario	%	144%	148%	180%	205%
BAU scenario	%	144%	113%	93%	78%
Magnesium					
Integrated Supply Chain scenario	%	132%	157%	222%	279%
BAU scenario	%	132%	104%	86%	73%
Potassium					
Integrated Supply Chain scenario	%	148%	261%	468%	644%
BAU scenario	%	148%	119%	98%	83%
Sodium					
Integrated Supply Chain scenario	%	11%	11%	14%	16%
BAU scenario	%	11%	8%	7%	6%
Iron					
Integrated Supply Chain scenario	%	125%	131%	158%	177%
BAU scenario	%	125%	99%	82%	69%
Zinc					
Integrated Supply Chain scenario	%	76%	79%	95%	108%
BAU scenario	%	76%	60%	49%	42%
Copper					
Integrated Supply Chain scenario	%	197%	267%	403%	512%
BAU scenario	%	197%	158%	131%	111%
Mangan					
Integrated Supply Chain scenario	%	735%	674%	720%	776%
BAU scenario	%	736%	585%	483%	407%

Vitamin sufficiency per capita					
Vitamin A					
Integrated Supply Chain scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Vitamin D					
Integrated Supply Chain scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Vitamin E					
Integrated Supply Chain scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Vitamin C					
Integrated Supply Chain scenario	%	132%	263%	496%	682%
BAU scenario	%	132%	108%	89%	75%
Thiamin					
Integrated Supply Chain scenario	%	146%	152%	189%	213%
BAU scenario	%	145%	114%	94%	80%
Riboflavin					
Integrated Supply Chain scenario	%	91%	141%	235%	314%
BAU scenario	%	91%	74%	62%	52%
Niacin					
Integrated Supply Chain scenario	%	92%	111%	160%	201%
BAU scenario	%	91%	73%	60%	51%
Vitamin B6					
Integrated Supply Chain scenario	%	146%	293%	567%	810%
BAU scenario	%	145%	116%	96%	81%
Folate					
Integrated Supply Chain scenario	%	0%	0%	0%	1%
BAU scenario	%	0%	0%	0%	0%
Vitamin B12					
Integrated Supply Chain scenario	%	0%	0%	0%	0%
BAU scenario	%	0%	0%	0%	0%
Pantothenic					
Integrated Supply Chain scenario	%	51%	85%	151%	206%
BAU scenario	%	51%	40%	33%	28%

Economics

In addition to improving food security as well as the nutritional balance per capita, the integrated scenario drastically increases profits for farmers. Profits from crop production in the baseline scenario are projected to increase from around TSH 11.55 trillion in 2020 to TSH 15.24 trillion and TSH 24.04 trillion by 2030 and 2050 respectively. In the integrated scenario, total profits generated are projected to be 45.1% and 227.1% higher compared to the BAU scenario in 2030 and 2050 respectively. This indicates total profits of TSH 22.11 trillion in 2030 and TSH 78.66 trillion by 2050, which is more than three times the profits generated in the BAU scenario. This increase in profits is driven by (i) increased product prices due to higher product quality, (ii) higher convenience for consumers due to improved shelf life of fresh and processed produce, (iii) improved access to fresh food as more produce reaches the market thanks to reduced perishability due to cooled transport and processing, (iv) increased consumer preference for fruits and vegetables, pulses and roots and tubers, and (v) improved access as a result of the expansion of the road network.

Figure 22: Total profits from crop production BAU and integrated supply chain scenario



The average profits realized per ton of produce sold in the market in the BAU and integrated scenario are presented in Table 35, for selected years. The increase in the average profits per ton sold range from 12.8% for sorghum to 139.6% for tomatoes and result from the combination of factors described above.

Table 35: Average profits per ton of produce sold BAU and integrated supply chain scenario

Crop type	Unit	2020	2030	2040	2050
Maize					
BAU scenario	TSH/ton	242,199	242,336	242,540	239,692
Integrated supply chain	TSH/ton	242,884	258,076	283,094	296,879
vs BAU	%	0.3%	6.5%	16.7%	23.9%
Sorghum					
BAU scenario	TSH/ton	1,265,117	1,265,501	1,266,070	1,258,152
Integrated supply chain	TSH/ton	1,267,020	1,309,159	1,380,621	1,418,929
vs BAU	%	0.2%	3.4%	9.0%	12.8%
Millet					
BAU scenario	TSH/ton	689,468	689,715	690,081	684,979
Integrated supply chain	TSH/ton	690,695	717,868	763,537	788,226
vs BAU	%	0.2%	4.1%	10.6%	15.1%
Potato					
BAU scenario	TSH/ton	502,023	502,391	502,937	494,892
Integrated supply chain	TSH/ton	502,973	533,096	604,916	659,832
vs BAU	%	0.2%	6.1%	20.3%	33.3%
Cassava					
BAU scenario	TSH/ton	216,505	216,705	217,000	212,342
Integrated supply chain	TSH/ton	216,958	231,784	268,624	296,031
vs BAU	%	0.2%	7.0%	23.8%	39.4%
Beans					
BAU scenario	TSH/ton	1,131,614	1,132,031	1,132,650	1,123,921
Integrated supply chain	TSH/ton	1,131,818	1,239,126	1,552,321	1,775,824
vs BAU	%	0.0%	9.5%	37.1%	58.0%
Peas					
BAU scenario	TSH/ton	1,192,206	1,192,637	1,193,275	1,184,301
Integrated supply chain	TSH/ton	1,192,428	1,303,318	1,626,407	1,856,954
vs BAU	%	0.0%	9.3%	36.3%	56.8%
Banana					
BAU scenario	TSH/ton	547,095	548,498	550,577	531,583
Integrated supply chain	TSH/ton	550,406	630,145	805,194	869,718
vs BAU	%	0.6%	14.9%	46.2%	63.6%
Mango					
BAU scenario	TSH/ton	948,879	950,965	954,057	926,272
Integrated supply chain	TSH/ton	953,846	1,073,223	1,333,810	1,430,700
vs BAU	%	0.5%	12.9%	39.8%	54.5%
Tomato					
BAU scenario	TSH/ton	507,306	508,868	511,183	490,146
Integrated supply chain	TSH/ton	514,258	710,714	1,019,845	1,174,614
vs BAU	%	1.4%	39.7%	99.5%	139.6%

Bibliography

ADB. (2013). 'TANZANIA Transport Sector Review'. African Development Bank.

Brander, M., Bernauer, T., & Huss, M. (2018). Improved on-farm storage reduces seasonal food insecurity of smallholder farmer households–Evidence from a randomized control trial in Tanzania. 'Food Policy, 98', 101891.

Cochrane, N., & D'Souza, A. (2015). Measuring access to food in Tanzania: A food basket approach. '1476-2016-121041'.

FAO. (2008). 'Nutrition Country Profile United Republic of Tanzania'. Food and Agriculture Organization.

FAO. (2018). 'Small Family Farms Country Factsheet'.

FAO. (2019). 'Reducing post-harvest losses'. Retrieved from Food and Agriculture Organization

FAO. (2020a). 'GIEWS - Global Information and Early Warning System'.

FAO. (2020b). 'Global Forest Resources Assessment 2020: Main report'.

FAO, IFAD, UNICEF, WFP and WHO. (2020). 'The State of Food Security and Nutrition in the World 2020'.

Fungo, E. (2018). Road infrastructure improvement for efficient utilisation of the agricultural potential: a case study of Morogoro, Tanzania. 'Doctoral dissertation, Stellenbosch: Stellenbosch University'.

Goedde, L., Ooko-Ombaka, A., & Pais, G. (2019, 02 15). 'Winning in Africa's agricultural market'. Retrieved from McKinsey&Company

IFAD. (2017). 'Investing in rural people in the United Republic of Tanzania'. Retrieved from International Fund for Agricultural Development

ITA. (2021). 'Tanzania - Country Commercial Guide'. Retrieved from International Trade Administration

Jalango, D., Begasha, E., & Kweka, T. (2019). 'Tanzania Country Climate Risk Profile Series - Kilolo District'. Dar Es Salaam: CARE International Tanzania.

Kiaya, V. (2014). Post-harvest losses and strategies to reduce them. 'Technical Paper on Postharvest Losses, Action Contre la Faim (ACF)'.

Kiprono, P., & Matsumoto, T. (2018). Roads and farming: the effect of infrastructure improvement on agricultural intensification in South-Western Kenya. 'Agrekon, 57(3-4)'.

Lukmanji, Z., Hertzmark, E., Mlingi, N., Assey, V., Ndossi, G., & Fawzi, W. (2008). 'Tanzania Food Composition Tables - First Edition'. Dar es Salaam and Boston: Muhimbili University of Health and Allied Sciences (MUHAS), Tanzania Food and Nutrition Centre (TFNC), and Harvard School of Pubic Health (HSPH).

MoHCDGEC, MoH, TFNC, NBS, OCGS, and UNICEF. (2018). 'Tanzania National Nutrition Survey using SMART Methodology (TNNS) 2018'. Dar es Salaam, Tanzania.

Msogoya, T., & Kimaro, E. (2011). Assessment and management of post harvest losses of fresh mango under small-scale business in Morogoro, Tanzania.

Mutungi, C., & Affognon, H. (2013). Fighting food losses in Tanzania: The way forward for postharvest research and innovations. 'ICIPE policy brief; no. 3/13'.

Netherlands Enterprise Agency. (2015). 'Tanzania Horticulture'.

Neubert, J. (2016). 'Long distances'. Retrieved from D+C

OCED. (2007). 'Scaling Up and Improving Infrastructure for Poverty Reduction'.

Pham, A. (2018). 'Developing an Irrigation Fund in Tanzania'. Retrieved from 2030wrg.org

PwC. (2015). 'Tanzania'.

Region, K. (2017). Market linkages, trade costs, and technology adoption in rural Tanzania.

Reith, J., Ghazaryan, G., Muthoni, F., & Dubovyk, O. (2021). Assessment of Land Degradation in Semiarid Tanzania–Using Multiscale Remote Sensing Datasets to Support Sustainable Development Goal 15.3. 'Remote Sensing, 13(9)', 1754.

Sauer, C., Reardon, T., Tschirley, D., Liverpool-Tasie, S., Awokuse, T., Alphonce, R., . . . Waized, B. (2021). Consumption of processed food & food away from home in big cities, small towns, and rural areas of Tanzania. 'Agricultural Economics'.

TANROADS. (2021). 'Trunk and Regional Roads Network'.

Temu, A., Nyange, D., Mattee, A., & Kashasha, L. (2005). Assessing rural services, infrastructure and their impact on agricultural production, marketing and food security in Tanzania. 'Dar es Salaam: IFPRI Eastern Africa'.

The United Republic of Tanzania. (2018). 'Land Degradation Neutrality Target Setting Programme Report'.

The United Republic of Tanzania, Ministry of Agriculture. (2019). 'National Postharvest Management Strategy'.

Transport & ICT. (2016). 'Measuring Rural Access: Using New Technologies'. World Bank, License: Creative Commons Attribution CC BY 3.0.

Tripathi, H., Smith, H., Sait, S., Sallu, S., Whitfield, S., Jankielsohn, A., . . . Nyhodo, B. (2021). Impacts of COVID-19 on Diverse Farm Systems in Tanzania and South Africa.

USAID. (2019). 'Farm Gate to Market Effeciency Analysis Report'.

USAID. (2020). 'Case Study Growth of Tanzania's Horticulture Sector: Role of Taha in Reducing Food Loss'.

WFP. (2017). 'Fill the Nutrient Gap' Tanzania: Findings. Retrieved from World Food Programme

WFP. (2020). 'Tanzania.'

WFP. (2021a). 'United Republic of Tanzania CONCEPT NOTE FOR THE SECOND GENERATION OF COUNTRY STRATEGIC PLAN (2022-2027)'. World Food Programme.

WFP. (2021b). 'United Republic of Tanzania - Integrated Context Analysis (ICA) Technical Paper'.

World Bank. (2017). 'Climate-Smart Agriculture in Tanzania.'

World Food Programme
Tanzania Country Office
wfp.org