Ceres2030 Deep Dives into the Nexus of Food Systems, Climate Change, and Diets

Achieving Sustainable Food Systems in a Global Crisis:

NIGERIA

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Head Office

111 Lombard Avenue,
Suite 325
Winnipeg, Manitoba
Canada R3B 0T4

Tel: +1 (204) 958-7700
Website: www.iisd.org
Twitter: @IISD_news

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Written by Livia Bizikova, Alan De Brauw, Mali Eber Rose, David Laborde, Kulthoum Motsumi, Mike Murphy, Marie Parent, Francine Picard, and Carin Smaller

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Executive Summary

Nigeria is not on track to achieve the United Nations Sustainable Development Goals by 2030, with poverty and hunger levels projected to be higher in 2030 than they are today. The situation is being made worse by internal conflict, economic recession, the climate crisis, the COVID-19 pandemic, and skyrocketing food and fertilizer prices. The Russian invasion of Ukraine further exacerbates the situation - although it is partly offset by rising energy prices that benefit Nigeria. To get back on track, it is critical to pursue policy pathways that encourage synergies and limit the trade-offs between hunger, poverty, nutrition, and climate change. This report presents an evidence-based and costed country roadmap for effective public interventions to transform agriculture and food systems in Nigeria in a way that ends hunger, makes diets healthier and more affordable, improves the productivity and incomes of small-scale producers and their households, and mitigates and adapts to climate change.

The financing gap in Nigeria is immense. The report shows that while it is possible to achieve sustainable food system transformation in the next decade, it would require an additional public investment of USD 4.9 billion on average per year and targeting this spending on a more effective portfolio of interventions that achieve multiple sustainable development outcomes. Importantly, comparing the financing gap between the long-term investment needed to achieve Sustainable Development Goal 2 and the short-term investment needed for emergency food assistance shows that while emergency assistance to Nigeria has increased in recent years, there is significant underfunding of the longer-term investment needs. The shortfall in longer-term funding increases the vulnerability to shocks and crises, pushing the number of people affected by hunger and poverty higher. This is incredibly pertinent given the devastating impacts of the current conflicts and economic recession, including the considerable rise in the need for emergency food assistance. Donors should therefore complement the increased allocation of emergency food assistance with increased investments in longer-term agricultural development priorities in order to build resilience to help mitigate against future shocks and crises.

The findings are based on research of academic and grey literature, as well as donor-funded projects, micro- and macroeconomic modelling, and engagement and consultations with key stakeholders in Nigeria. The report is part of a project that explores the interactions between reducing hunger and poverty, achieving healthy diets, and addressing climate change within the evolving food systems in three countries—Ethiopia, Malawi, and Nigeria.

The report finds that:

1. **Poverty and hunger have risen sharply in the past years, and without additional public investment, significant levels of hunger, malnutrition, and poverty will persist after 2030.** In recent years, food insecurity and undernourishment have increased. By 2030, progress in reducing extreme poverty is expected to stagnate, and even reverse slightly, without additional public investment (from 40% in 2019 to 46% in 2030). Chronic hunger is also predicted to rise (from 14% in 2019 to 21% in 2030). While stunting fell by as much as 8% from 2008 to 2015, it drastically increased to 44% in 2016, due to factors including Boko

Haram violence and low oil revenues. The country also has a challenge of increasing overweight and obesity that will require the attention of policy-makers and donor agencies. Healthy diets are and will continue to be unattainable for more than 90% of Nigerians by 2030.

2. **Diet diversity is poor in low-income households and in northern households, while higher-income households and southern households have higher dietary diversity.** Cereals and starchy vegetables account for more than half of the calories consumed in both urban and rural households. Regional heterogeneity is a significant factor. Households in southern Nigeria allocate more of their food budgets to fish and seafood, roots and tubers, and fruit than northern households, contributing to greater dietary diversity. Cultural and other non-economic factors influencing diets are important considerations for intervention design. To transition to healthier diets requires a higher calorie intake, increased consumption of fruits and vegetables (400g per day, according to the World Health Organization, and a higher share of calories from animal-source foods, including dairy (for calcium and B12).
3. **With an additional public investment of USD 4.9 billion per year from 2023 to 2030, it is possible to achieve sustainable food systems transformation in Nigeria.** The results from using a computable general equilibrium model and household-level data show that it would cost an additional USD 4.9 billion in public investment per year from 2023 to 2030 to end hunger, double the incomes of 14.6 million small-scale producer households on average, transition to healthier diets for 126 million people, maintain greenhouse gas emissions in agriculture to Nigeria's nationally determined contribution and increase resilience to climate change. Of this total additional spending required per year, USD 2.3 billion needs to be provided by external resources (donors), with the majority—USD 2.6 billion—to be provided through domestic resources. Currently, donors provide an average of USD 114 million per year of agriculture and food security official development assistance.
4. **The financing gap between the long-term investment needs and short-term emergency food assistance needs is large.** While the total amount of ODA to emergency food assistance has increased overall from the period 2012–2014 compared with the period 2017–2019, the total amount of ODA to long-term agricultural and food security has stagnated over the same period (International Food Policy Research Institute [IFPRI] & International Institute for Sustainable Development [IISD], in press). There is insufficient attention to bridging the short-term emergency food assistance programs with longer-term investments in agriculture and food systems and massive underfunding of the longer-term investment needs.
5. **Increasing agricultural productivity for both plant and livestock, especially amongst small-scale producers, is a top policy priority.** Over the past years, Nigeria has experienced low productivity due to limited inputs, including quality seeds and fertilizer and quality irrigation and harvesting systems. Critical policy documents emphasize the need to improve agricultural productivity and address low yields in the sector through farm-level support enabling access to land, extension, inputs, and improved value chains (FRN, 2016, 2021b). Many of the donor-identified projects

addressed such areas, suggesting a high degree of coherence between donor projects and national priorities.

6. **The effects of climate change are undermining the country's ability to become food and nutrition secure.** It is expected that the frequency and severity of droughts and floods will increase with climate change. In particular, it will increase desertification in the northern part of the country, whereas the southern part is expected to experience the impacts of sea level rise, saltwater intrusion, and flooding. While the country is undertaking efforts to address climate change and enhance climate adaptation, more effort is required to support climate-resilient agricultural practices that address the linkages between food systems, food security, nutrition, gender equality, and women's empowerment.
7. **The contribution of the livestock sector to total and per capita GHG emissions will continue to rise by 2030, and is inadequately addressed by government and donors.** Agricultural emissions, mostly from livestock production, are a growing problem. In 2018, livestock accounted for 78% of agricultural emissions in Nigeria, and its share will continue to grow. Total agricultural GHG emissions are predicted to increase by 2.3% per year, or 25% over 10 years. The authors are not aware of any projects implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit, United States Agency for International Development, or the European Union that focus on livestock,[1] which therefore represents a potential area for impactful investment. Integrating mitigation and adaptation measures and promoting resilient agricultural development are critical to making environmentally sustainable improvements in diets, food security, and farmers' incomes. This should be targeted in a way that promotes gender equality and women's empowerment.
8. **Social protection programs target some of the challenges of the most vulnerable.** The country's policies focus on poverty reduction while simultaneously alleviating the impacts of socio-economic shocks and promoting food security and nutrition. Specific measures include efforts to improve income, cash transfers, free access to health care for vulnerable groups, school feeding programs, and free and/or subsidized access to food and fuel (FRN, 2021a).
9. **There is limited support for regional and national institutions to improve their capacity to monitor, analyze, and inform on progress and achievements.** Such capacities are critical to monitoring the food systems outcomes of investments in the portfolio of interventions, including better-disaggregated data to account for subnational and gender differences.

The report recommends that the Government of Nigeria and its development partners:

1. **Urgently and significantly increase public investment by an additional USD 4.9 billion per year from 2023 to 2030 to achieve the transition to sustainable food systems.** Development partners should provide an additional USD 2.3 billion

[1] Analysis of donor-funded or implemented projects is based on a non-exhaustive desk review which looked at current (or recently terminated) projects implemented and/or funded by GIZ, EU, or USAID. Only projects that had a degree of focus on two or more aspects of our nexus were included for review. Overall, 10 projects were reviewed in Nigeria. See Section 4.1 for more information on the methodology.

on average per year for 8 years (2023–2030), from a current baseline of USD 114 million per year. The Government of Nigeria should provide an additional USD 2.6 billion per year. This will reverse the severe underfunding of longer-term agricultural investment needs and will help achieve food security and nutrition.

2. **Increased spending is needed in all areas: on and off the farm and through social protection programs.** An additional USD 2.0 billion per year on average is needed to improve farm productivity and incomes; an additional USD 1.6 billion per year on average is needed for social protection, education, and school feeding programs; and an additional USD 1.3 billion per year is needed to move food to markets. In particular, interventions should focus on enabling access to inputs, including quality seeds and fertilizer and quality irrigation and harvesting systems (FRN, 2014, 2016).
3. **To transition to healthier diets, nutrition education must accompany on and off-farm investments to improve consumer choices.** Attention needs to be given to the design and implementation of nutrition-sensitive interventions in order to achieve multiple and complementary outcomes. Initiatives that provide nutrition education and deliver advice on storing and utilizing diverse, nutritious food products are critical to complement and maximize the impact of social protection programs, nutrition programs, and agricultural productivity programs.
4. **Ensure climate resilience and adaptation are integrated into agricultural and food system policies and programs.** Interventions identified through the modelling in this report are in line with Nigeria's efforts to promote climate-smart agriculture through targeted extension services, improved crop choices, investment in machinery, and increased access to improved animal feed and breeds to protect soils and biodiversity, conserve water, and limit land-cover change. In addition, donor support could be targeted to greenhouse gas emissions-reduction efforts, thus contributing to the more ambitious mitigation target reflected in Nigeria's updated nationally determined contribution, which is conditional on such support (FRN, 2021b). Gender equality and women's empowerment must be considered when the above integrated measures are designed.
5. **Scale up support for environmentally sustainable intensification** to improve both plant and livestock productivity. Given that this is a top priority for Nigeria, the government and development partners should allocate additional resources to implement the goals and actions listed in its relevant strategies supporting growth in productivity, including those focusing on climate-smart agriculture. Policy interventions need to enhance the availability of and access to better fodder, veterinary services, and improved breeds and to address conflicts in grazing area allocations (FRN, 2016, 2021b). New donor-funded projects should focus on the livestock sector which represents a potential area for impactful investment.
6. **Focus interventions and policies to reduce post-harvest losses and improve food safety on better road networks and storage capacities, including cold storage.** Such interventions should be prioritized to enable producers to reduce losses during the production and storage of foods. To support the transition to healthier diets

and improve food safety, such investments could include cold storage and preservation of food items, such as vegetables, fruits, and animal products and fish.

7. **Increase support for regional and national institutions to improve their capacity to monitor, analyze, and inform on progress and achievements.** This will help institutions support the transformation of sustainable food systems, including by collecting disaggregated data to account for subnational and gender differences.

These recommendations overlap significantly with Nigeria's National Pathway for Food Systems Transformation, which was written in light of the United Nations Food Systems Summit in 2021 and to support the 2030 Agenda (FRN, 2021d). Specifically, many of these recommendations can be found as both short- and long-term strategies within Nigeria's country clusters for food systems transformation. In particular, country clusters 1, 3, and 4—which aim to support research, skill, and capacity development of agri-food systems, develop value chains and market systems, and increase the demand and consumption of diverse, nutritious foods, respectively—have clear overlaps with our recommendations (FRN, 2021d). In this way, the results, findings, and recommendations of our study offer an evidence base on which to support the implementation of the key priority action areas identified in Nigeria's National Pathway for Food Systems Transformation.

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Abbreviations and Acronyms

BAU	business as usual
CGE	computable general equilibrium
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FRN	Federal Republic of Nigeria
GHG	greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
IFPRI	International Food Policy Research Institute
IISD	International Institute for Sustainable Development
LSMS	Living Standards Measurement Survey
NDC	nationally determined contribution
OECD	Organisation for Economic Co-operation and Development
PoU	prevalence of undernutrition
SDG	Sustainable Development Goal
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WEF	water–energy–food

1.0 Introduction

Agriculture and food systems in Nigeria face key challenges. They need to simultaneously provide sufficient food for all, improve incomes and productivity for small-scale producers, make diets healthier and more affordable, reduce greenhouse gas (GHG) emissions, and build capacities needed to adapt to climate change. However, in the past few years, as a result of internal conflict, low oil prices, an economic slowdown, COVID-19, and now rising food and fertilizer prices, made worse by the Russian invasion of Ukraine, hunger and poverty have been rising steeply, healthy diets are unattainable for most people, and the impacts of climate change are experienced more frequently and severely.

Hunger and poverty are projected to keep rising until 2030. Even among those who do get enough calories, many will be malnourished due, in part, to the unaffordability of diets that both provide sufficient calories and satisfy the complex nutritional requirements of human bodies. The demographic dynamics in Nigeria will continue to exacerbate these challenges, with the population expected to grow from 206 million people in 2020 to 263 million people in 2030 (United Nations, 2019).

As the population and incomes grow in Nigeria, so too will demand for food and more diversity in food choices, which will exacerbate environmental challenges. At the same time, Nigeria is home to some of the global public goods that are needed to address climate change, preserve biodiversity, and achieve the United Nations Sustainable Development Goals (SDGs). Transforming food systems to deliver on hunger, poverty, healthy diets, and climate change while safeguarding global public goods will require significant efforts and resources and therefore global solidarity—in other words, more external aid.

Box 1. Defining nutrition in this report

We refer to *nutrition* as food consumption patterns and healthy diets from sustainable food systems. At the same time, we acknowledge that healthy diets alone will not ensure good nutrition, but can be an outcome achieved through building livelihoods, empowering women, improving incomes and access to markets, and facilitating access to services, improving food safety, and others.

To support the transformation to sustainable food systems in Nigeria, this report aims to equip country-level decision-makers and the donor community with knowledge regarding the cost of sustainable food system transformation; evidence on which to base decisions regarding where and how to make investments to simultaneously contribute to access to sufficient, safe, and nutritious food (SDG 2.1 and 2.2); smallholder productivity and incomes (SDG 2.3); and environmentally sustainable agriculture production (SDG 2.4).

The report combines a review of country-level policy documents and peer-reviewed literature with microeconomic analysis of changing diets, food consumption habits, and nutrition; three rounds of consultations with in-country stakeholders; and the country-level findings

for Nigeria from the project Ceres2030: Sustainable Solutions to End Hunger.[2] The findings are integrated into a computable general equilibrium (CGE) model that estimates the cost of ending hunger, doubling the income of small-scale producers and transitioning to healthier diets while protecting the climate and investing in climate change adaptation.

Section 2 describes the key food system challenges facing Nigeria today and in 2030, focusing on poverty and hunger, the current composition of diets and their nutritional deficiencies, and the impact and threat of climate change. Section 3 presents the findings as a package of proposed interventions for a pathway to transform the agriculture and food system by 2030 and the implications of this transition, as well as the public investment required by the Government of Nigeria and external resources to facilitate such a transformation. Section 4 provides an overview of the methodology and research approach used to explore potential pathways for food system transformation, including the scenarios, targets, and interventions included in the CGE model and a discussion of the limitations of the research approach. Section 5 provides recommendations and conclusions. A technical appendix provides further details on the research approach and methodology.

[2] See Laborde et al., 2020a and 2020b for more information.

2.0 Nigeria's Food System Challenges

This section provides an overview of the recent trends for key aspects of the food system in Nigeria to 2030. Specifically, it focuses on the prevalence of extreme poverty and hunger, the prevalence of the unaffordability of healthier diets, and dietary composition. It also pays attention to the contributions of agriculture to climate change, mostly due to the GHG emissions intensity of the sector, deforestation, and water withdrawal, as well as efforts to improve resilience and farmers' capacities to adapt to climate change, as described in the country's policy documents.

Critical for agriculture and food systems in the country, Nigeria is the 14th largest country in Africa by land area, with the continent's largest population, estimated at just over 200 million (World Bank Development Research Group, 2021b). Two-fifths of the population (43.7%) is under 15 years old (World Bank Development Research Group, 2021a). The UN predicts that the country's population will grow from 206 million in 2020 to 263 million by 2030 (United Nations, 2019). The country's climate ranges from hot, arid desert in the north to tropical rainforest along part of the coast in the south, but the tropical savanna climate prevails.

Nigeria's economy strongly relies, directly or indirectly, on oil production and exports. The share of agricultural contribution to GDP in 2020 stood at 23.4%—up from 21.9% in 2019, with the highest contributions documented in 2002 (37%) (World Bank Data Portal, 2022a). While employment in agriculture has been steadily decreasing for the last two decades (from 49% in 2000), the agricultural sector remains the largest employer in Nigeria, engaging more than 35% of the workforce in 2019 (World Bank Data Portal, 2022b). In addition, more than 80% of Nigeria's farmers are smallholders delivering most of the country's production (Mgbenka & Mbah, 2016). Agricultural production is predominantly (85%) focused on crops (Federal Republic of Nigeria [FRN], 2016).

Given Nigeria's large population, its agricultural productivity is insufficient to meet increasing food demand (Federal Republic of Nigeria, 2016) in terms of both ensuring food security and transitioning toward healthier diets. The average productivity of major crops in Nigeria is less than 1,000 kg/ha on over 60% of farmland (Mungai et al., 2016). In comparison, the Organisation for Economic Co-operation and Development (OECD) database suggests the global average is 3.5 times higher (Mungai et al., 2016). The picture is the same for other crops and livestock. Critically, there is significant potential and opportunity for agricultural development in Nigeria (see Figure D1).

Agriculture's vulnerability to climate change further impacts productivity gains in Nigeria. For example, irrigation coverage, which can mitigate the effects of erratic rainfall, is very low. While recent statistics are not available, irrigation coverage was estimated to be at just 0.3% of agricultural area in 2004 (Food and Agriculture Organization of the United Nations [FAO], 2021a). In addition, approximately 80% of the population depends on climate-sensitive economic sectors such as rain-fed agriculture and artisanal fishing (FRN, 2020a).

Food system transformation toward healthier diets will not be possible without improving agricultural productivity. This transformation would need to assist small-scale producers in achieving significant improvements in productivity and income, access to markets, and climate resilience, to meet the nutrition and food security needs of a growing population in a way that does not increase vulnerability to climate change and environmental degradation.

2.1 Hunger, Poverty, Small-Scale Producers, and the Unaffordability of Healthy Diets

Extreme poverty (at the USD 1.90 international poverty line) in Nigeria is at a level similar to the average for sub-Saharan Africa (39% versus 40% in 2018) (World Bank Development Research Group, 2021c). The prevalence of undernourishment is lower than the regional average: 13% in 2018 versus 18% on average in sub-Saharan Africa for the same year (FAO, 2021a). A smaller proportion of Nigeria's population experiences severe food insecurity: 9% in 2018 versus 21% on average in sub-Saharan Africa for the same year (FAO, 2021a). However, poverty and food security indicators for Nigeria, as shown in Figure 1, mask in-country variations, including regional differences between the north and the south[3] (see Figure D2 for the geographical distribution of poverty across Nigeria). Finally, like other countries in the region, small-scale producers—the largest segment of Nigeria's farmers—are impacted by low income, limited productivity, and climate change.

In recent years, poverty and hunger in Nigeria have increased due to political instability and conflicts, especially in the north, as well as several economic recessions triggered by declining oil revenue. COVID-19 and the rise in food and fertilizer prices, made worse by the Russian invasion of Ukraine - although this is partly offset by rising energy prices that Nigeria benefits from.

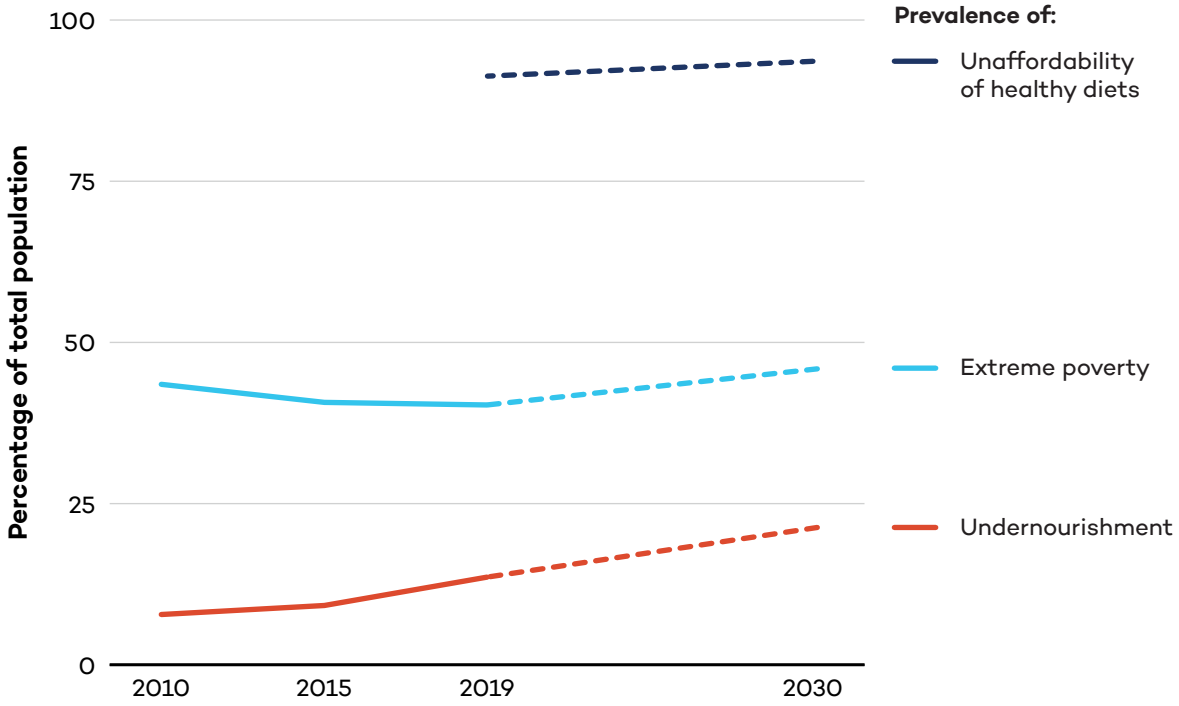
Nigeria remains one of the countries with the strongest demographic pressure in the world, with an annual population growth rate of about 2.5% in the next decade (compared to 1.1% worldwide). Because of the low initial GDP per capita in the country and relatively weak economic growth (projected at 3.2% per year, i.e., near the average for sub-Saharan Africa), per capita GDP income growth will remain relatively low compared to the global average (World Bank, n.d.).

The agricultural sector will continue to develop in response to increases in local food demand, particularly for animal-sourced products. This will lead to an increase in production emissions of 2.3% per year, or 25% in 10 years. Land-use change from forestry to agriculture is projected to plateau, with forested areas expected to decrease by 5% in the next 10 years. The livestock sector will require environmentally sustainable intensification if Nigeria is to achieve its climate targets and environmental objectives. Finally, despite moderate economic growth and progress in reducing extreme poverty, without additional public investment, the prevalence of extreme poverty is expected to stagnate and even slightly reverse. Expansion

[3] For this reason, the project's modelling work accounts for north–south variations as well as diversity at the household level. The modelled population is composed of different types of households, distinguished by the level of income, source of income, and consumption pattern, including dietary diversity. See Section 4 for more information.

of agricultural production will not be able to keep up with demographic growth. As a result, without additional public investment, chronic hunger will rise, and healthy diets will continue to be unaffordable for most people by 2030.

Figure 1. Prevalence of hunger, poverty, and the unaffordability of healthy diets in 2030



Source: In this figure, we use the approach from The State of Food Security and Nutrition in the World 2021 (FAO et al., 2021) to define the (un)affordability of healthy diets.

Box 2. Food security and nutrition challenges and solutions as listed during the consultations

- Addressing malnutrition is a major challenge for the country, and efforts should focus on food security and nutrition issues.
- The country is currently experiencing a triple burden of food insecurity, micronutrient deficiency, and the rising overweight and obesity. This has significant costs, especially over time, as the rising malnutrition rates increase the need for health care for people with non-communicable diseases that result from poor diet.
- In urban areas, nutrition education could have a large positive impact, while in rural areas, the focus should be on improving production and value chains to ensure access to food to maintain sufficient caloric intake, before moving the focus to dietary diversification and "healthier" diets.
- Promoting sustainable food systems and addressing malnutrition challenges need to account for specific differences in the country, for example the northern and southern parts, and rural and urban areas.
- Increasing households' assets and income is critical to increase the affordability of nutritious foods.
- Promoting aquaculture can bring significant opportunities for production and food consumption patterns, with benefits for food security.

Source: Information listed in this box was collected during the project consultations with national stakeholders and donor agencies. For details on the consultations, see Appendix A.

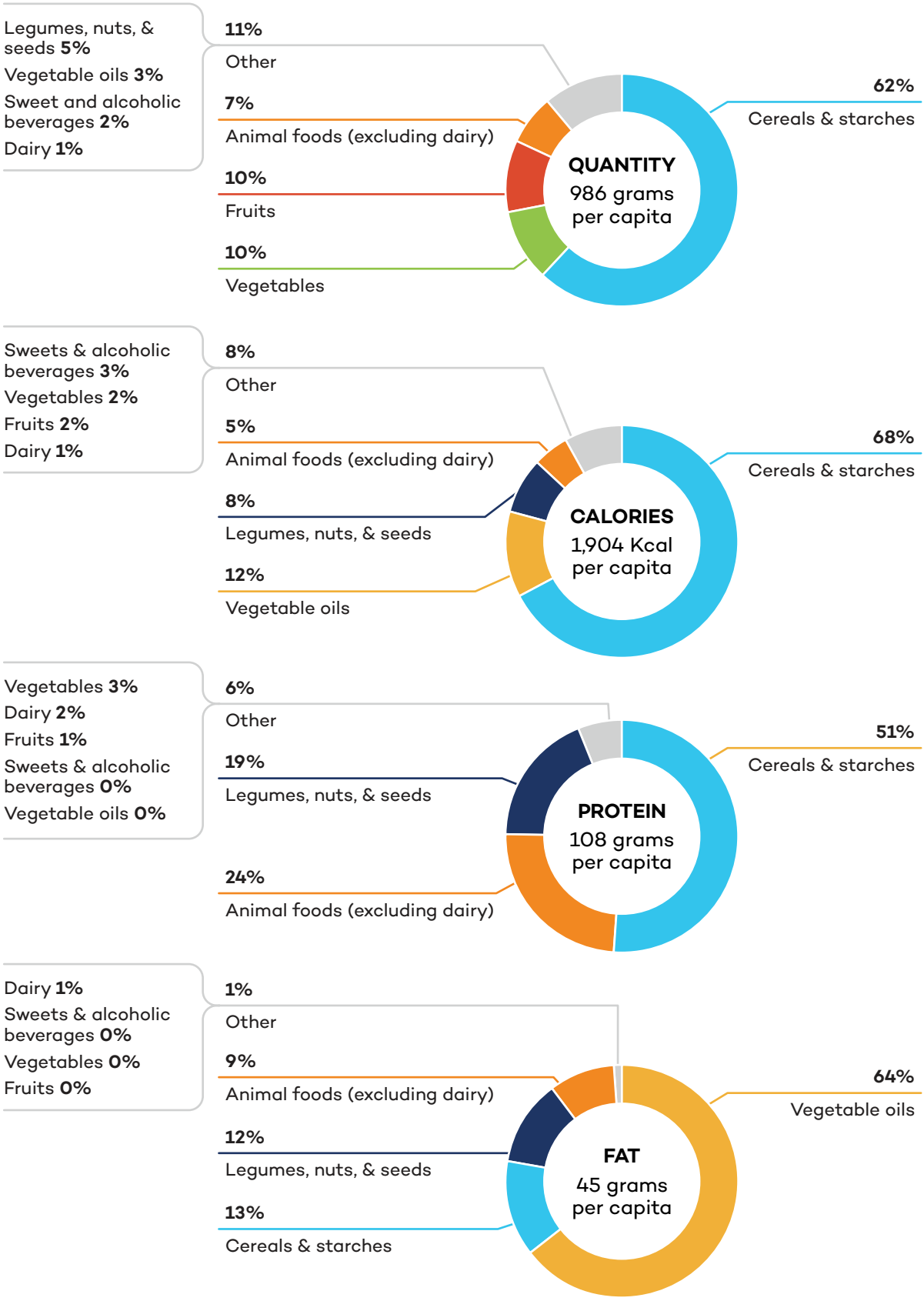
2.2 Diet Composition and Quality

Nigeria devotes 12% of all arable land to cassava production. The five main crops (cassava, maize, yams, paddy rice, and sorghum) represent 51% of harvested area and account for much of the average Nigerian diet (Elbehri et al., 2013). As a result, Nigeria faces the compounded challenge of food insecurity, malnutrition, and growing obesity rates, as listed during the consultations (see Box 2). Given the sheer size of the country and its population, important differences in dietary composition and quality are also observed between low- and high-income groups, urban versus rural populations, and southern versus northern regions.

2.2.1 A Snapshot of Diets Today

Nigeria is experiencing a shift in dietary consumption, with diets becoming more diverse and moving away from meals predominantly made with staple grains and tubers. Simultaneously, the country is experiencing a move toward foods with a higher content of refined carbohydrates and highly processed foods and drinks with higher amounts of added sugars and unhealthy fats. This dietary shift, known as a nutrition transition, is evidenced by rising obesity and stagnating stunting in children. Independent studies have found that in Nigeria, urban obesity increased by 20% between 2002 and 2010 (Morgan & Fanzo, 2020). Despite this trend, malnutrition is currently ranked as the number one risk factor in the country, with suboptimal diets ranked seventh (Morgan & Fanzo, 2020).

Figure 2. Overview of dietary composition, aggregated by food group, per capita, per day



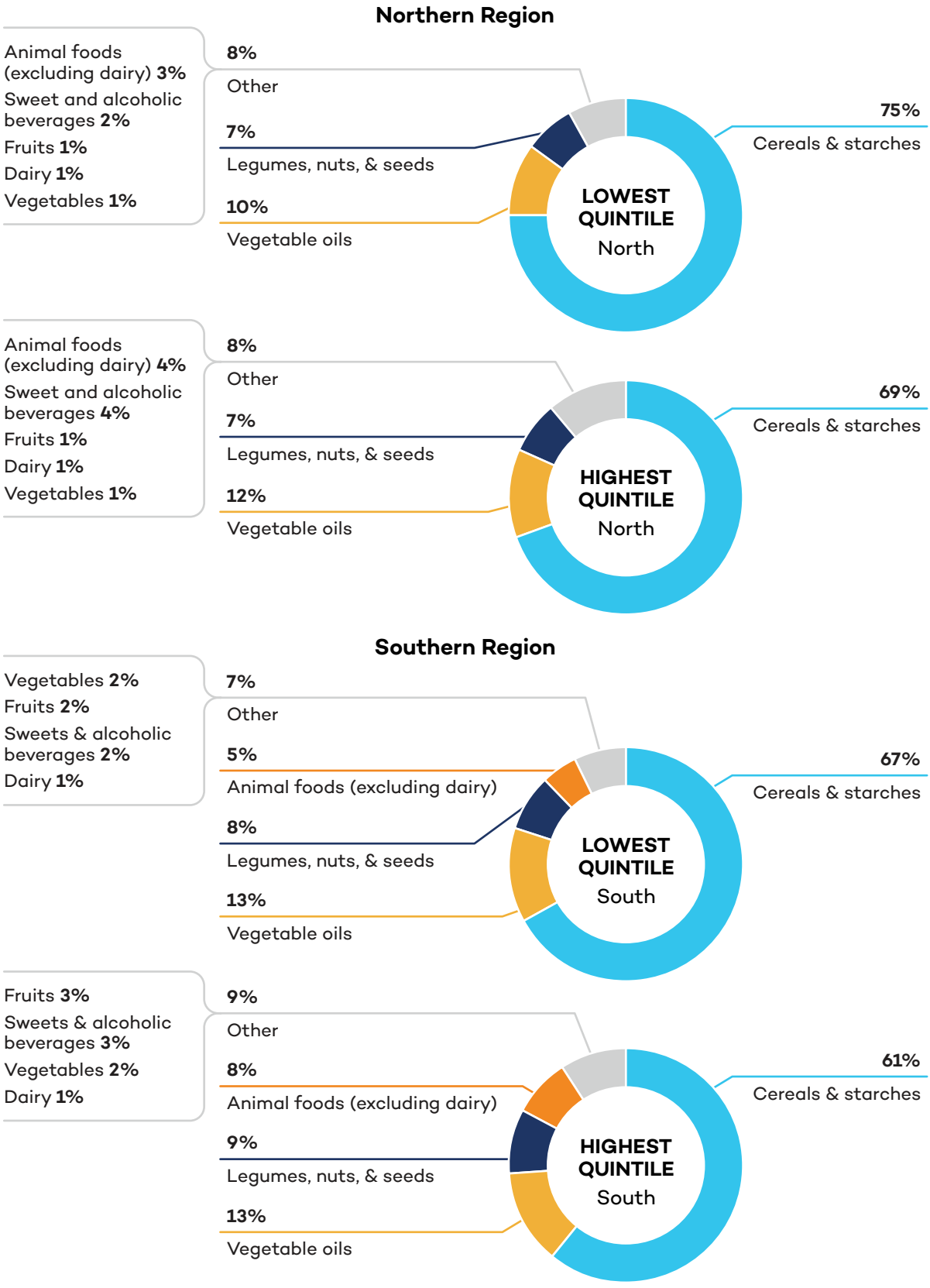
Source: Authors' analysis based on LSMS-GHS Nigeria Harvest Questionnaire Wave 4 2018– 2019 (World Bank, 2019) and nutritient coefficients based on FAOSTAT-SUA (FAO, 2021a).

To study household-level diets on average and by some broad categories, data from the latest round of the Living Standards Measurement Survey-Integrated Surveys for Agriculture (LSMS-ISA) is used. The dataset comprises 4,976 households reporting on 110 distinct food items for a total of 547,360 observations. These are divided into 16 categories: grains and flours; baked and processed products; roots, tubers, and plantains; pulses, nuts, and seeds; oils and fats; fruits; vegetables; poultry and poultry products; meat; fish and seafood; milk and milk by-products; coffee, tea, and related beverages; sugars, sweets, and confectionary; other foods; non-alcoholic drinks; and alcoholic drinks. For some reporting, we reaggregate the consumption data into major food groups to simplify the presentation of findings and also provide a harmonized system with other country analyses included in this study: cereals and starches; legumes, nuts, and seeds; vegetables; fruits; dairy; animal foods (excluding dairy); vegetable oils; sweets; and alcoholic beverages.

Using data from the FAO and the LSMS, Figure 2 illustrates what foods households consume, including overall caloric intake and composition by food group. Reported consumption of grains and other starches, particularly cassava, is high relative to other food groups, accounting for over 60% of all consumption in terms of both overall mass consumed and caloric intake (68%). Vegetables represent 10% of the average daily consumption but less than 2% of total caloric intake. Fruits account for a similar share of dietary calories. There is not much consumption of dairy products. The poor level of diet quality is consistent with the low level of income, high prevalence of poverty, and unaffordability of healthy diets.

These average numbers hide an important regional disparity across and within regions in Nigeria. There are great regional differences, with the north being poorer and the south richer. Considering detailed consumption data, we see that almost all households in both regions report consuming some grains and flours, oils and fats, and vegetables during the previous week, and a large proportion of households also report consuming pulses, nuts, and seeds. More expensive products, like baked or processed products, are more frequently consumed in the south, as are roots and tubers, fruits, and most categories of animal-source foods. For example, among animal-source foods, poultry is consumed by 43% of households in the south compared to 25% in the north, and fish and seafood are consumed by 90% of households in the south versus 53% in the north. This suggests that dietary diversity is better in the south than in the north. Figure 3 shows the components of the diet by both region and wealth level by examining the highest and lowest quintiles in the expenditure distribution. In the north, grains and flours make up the largest share of overall food expenditures, at 38.8% for the poorest households and 28.6% for the wealthiest. By contrast, in the south, grains and flours account for a much smaller share, and the gap between poor and rich households is small in relative terms: 15.2% of total food expenditures in the poorest and 14.1% in the richest households. In the south, roots, tubers, and plantains make up a much larger share, particularly in poorer households (23.4% of total food expenditures), in contrast to the north, where poor households allocate less than 10% to this category. Among poorer households in both regions, meat and poultry account for a relatively small share of total food expenditures relative to wealthy households. Notably, this is not the case for fish and seafood, which account for similar relative shares across wealth groups within regions but different relative shares between regions: 5.1% for the lowest-income group and 6.2% for the highest-income group in the north, compared to 12.1% for the lowest-income group and 11.9% for the highest-income group in the south.

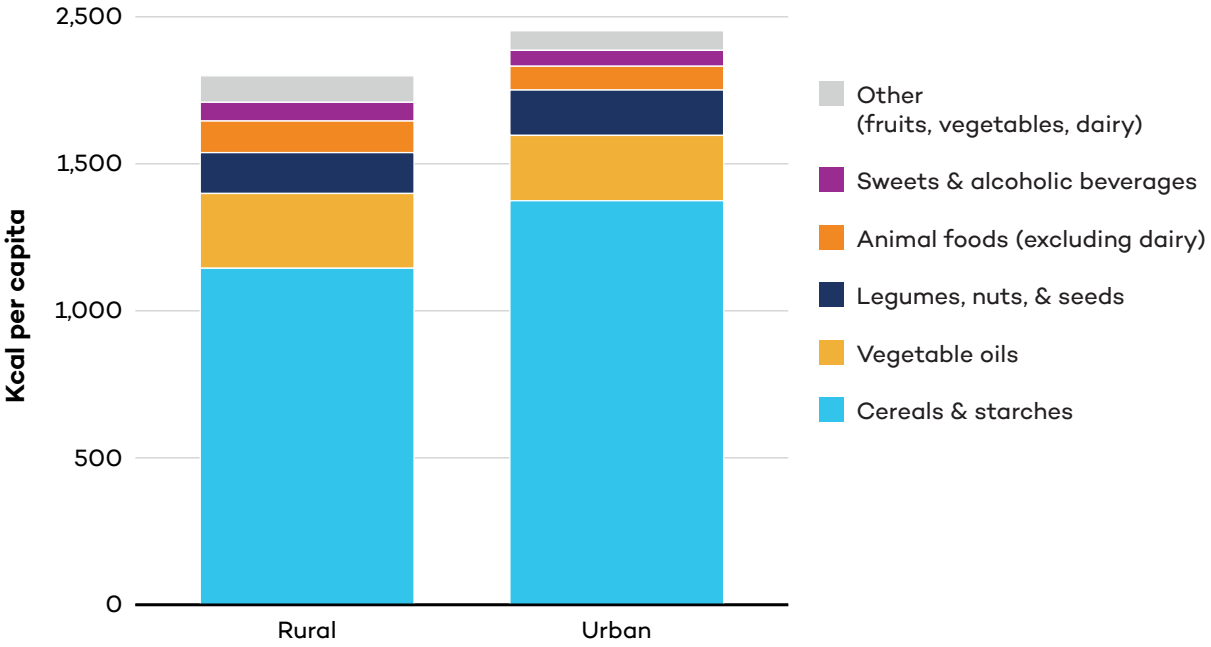
Figure 3. Share of calories consumed by food category, by region, for lowest and highest quintiles of consumption distribution



Source: Authors' analysis based on LSMS-GHS Nigeria Combined Questionnaire, Harvest Questionnaire Wave 4 2018– 2019 (World Bank, 2019) and nutritient coefficients based on FAOSTAT-SUA (FAO, 2021a).

Figure 4 examines dietary patterns by rural–urban location, whether in the north or the south, comparing the share of calories in eight larger food group categories. In both regions, cereals and starches make up the largest share of calories per capita. Consistent with the idea that animal-source foods are favoured as a protein source over vegetable sources like legumes, urban households clearly consume more animal-source foods than rural households, while the reverse is true for legumes, seeds, and nuts. Both groups consume very few calories from fruits and vegetables. The remainder of calories are vegetable oils, consumption of which is comparable in the two locations. Rural households report consuming slightly more calories per capita.

Figure 4. Calories consumed, by food group and location, Kcal per capita per day



Note: Figures represent annualized mean values and do not reflect seasonal variations in dietary consumption.

Source: Authors' analysis based on LSMS-GHS Nigeria Combined Questionnaire, Harvest Questionnaire Wave 4 2018– 2019 (World Bank, 2019) and nutritient coefficients based on FAOSTAT-SUA (FAO, 2021a).

2.2.2 Nutrition Indicators

In terms of specific nutrition indicators, 7% of children under five were affected by wasting and 37% by stunting in 2018. While stunting fell by as much as 8% from 2008 to 2015, it increased drastically to 44% in 2016, due to factors including Boko Haram violence and low oil revenues (Food Security Information Network, 2017). Wasting rates have been even more variable over the last decade. Although the prevalence of anemia has declined since 2000, it still affects one in two women of reproductive age, slightly higher than the average for sub-Saharan Africa. The prevalence of anemia at around 50% has persisted since 2011 (Global Nutrition Report, 2020).

The World Health Organization estimated the prevalence of obesity among adults to be around 9% in 2016 (WHO, 2021), although data from a systematic review in 2013 suggest

this estimate may have been low (Chukwuonye et al., 2013). According to the Global Nutrition Report (2020), the prevalence of obesity and overweight in Nigeria is increasing. Importantly, there is a gender difference in the trends of overweight and obesity, with 36% of women being overweight and 13% obese, compared to 22% and 5% of men, respectively (Global Nutrition Report, 2020). Nigeria is now facing the need to consider policies to promote diets that are both sufficient and healthy (see Box 2).

2.2.3 Current Dietary Policies

Nigeria published food-based dietary guidelines in 2001 and then reprinted them in 2006. According to the FAO database of food-based dietary guidelines, they have not changed since then (FAO, n.d.). While the 2006 guidelines do mention overweight and obesity and associated non-communicable diseases, the problem has grown substantially since that time. Further, the prevalence of eating away from home has increased since the guidelines were published.

The guidelines are general rather than prescriptive in character and put forward the following recommendations for all (FAO, n.d.):

- Eat a wide variety of types of food (grains, legumes, roots and tubers, fruits, vegetables, fish, lean meat, etc.).
- Reduce or limit the consumption of sugary foods and animal-source fats.
- Limit the use of salt or bouillon cubes in cooking.
- Eat in-season fruit.

In addition to the dietary guidelines, Nigeria adopted national guidelines with a micronutrient deficiencies control strategy (FRN, 2013a). It outlined activities to address vitamin A, iron, iodine, and zinc deficiencies, including supporting access to supplements and diversified diets, treatment of certain diseases, food fortification, and awareness raising. Nigeria also has policies that mandate the fortification of wheat and maize flour with several vitamins and minerals, salt iodization, and fortification of cooking oil with vitamin A. It also stresses the importance of biofortification. Finally, the country's Agricultural Promotion Policy, which embraces a food systems approach to address malnutrition, identifies food as a human right and undertakes to protect the population from undernourishment (FRN, 2016).

2.3 Climate Change Impacts, Mitigation, and Adaptation Responses

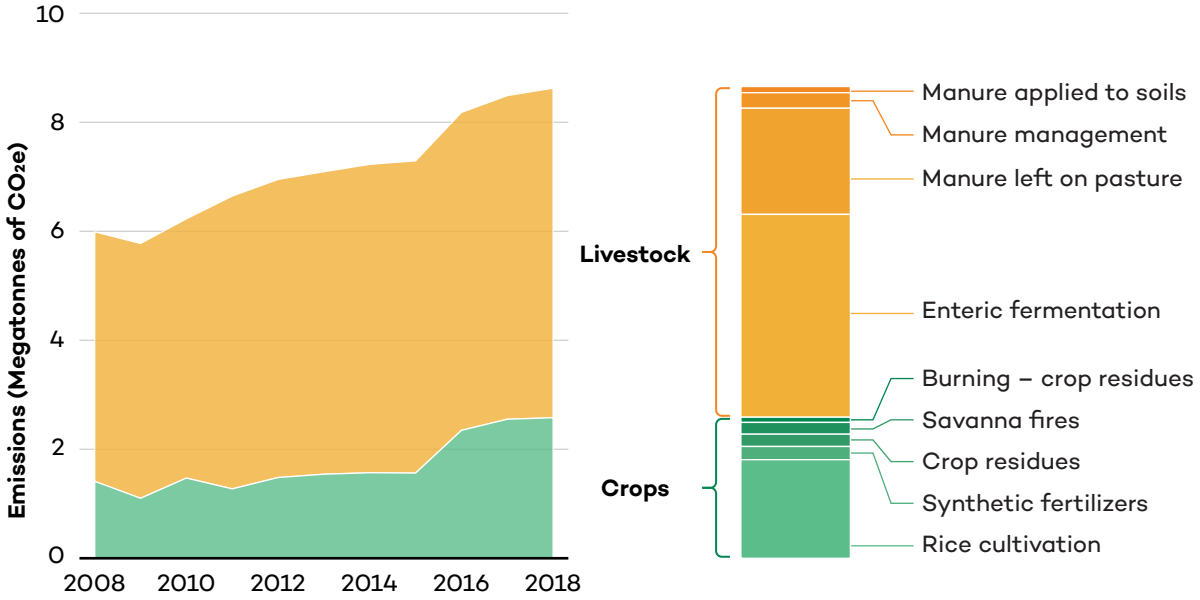
Any effort to address undernutrition, malnutrition, overnutrition, and agricultural productivity gaps needs to account for climate change and climate variability, which are already having significant impacts on livelihoods, the economy, and the agricultural sector (FRN, 2020a, 2020b). Policy pathways geared to food system transformation need to consider responses to climate change, including measures to help small-scale producers adjust their production practices to climate change impacts and variability. It is also critical to focus on more sustainable and resilient approaches to production intensification overall, with a specific focus on integrating environmental and climate perspectives into policies and strategies (see Box 3; FRN, 2020a, 2020b).

2.3.1 Climate Change Mitigation and GHG Emissions

Emissions from agriculture[4] and agriculture-related land use[5] per dollar of agricultural production are higher than the global average but average for West Africa, at 4.9 tonnes per thousand constant 2014–2016 international dollars, versus 3.0 tonnes at the global level and 4.8 tonnes for West African countries, on average (FAO, 2018).

GHG emissions from agriculture are a growing problem in Nigeria and come predominantly from livestock production. From 2008 to 2018, GHG emissions from agricultural production (not including deforestation for agriculture or other uses[6]) increased by 31%, driven in large part by increasing livestock production (see Figure 5 and Figure 6) (FAO, 2021a). In 2018, livestock accounted for 78% of agricultural production emissions. Rice cultivation, which is the largest crop-emission category, accounts for a further 11% of agricultural emissions.

Figure 5. Agricultural GHG emissions in Nigeria



Source: Data from FAO, 2021a.

[4] Agricultural emissions include emissions from crop and livestock production and associated activities: enteric fermentation, manure management, manure left on pasture, manure applied to soils, cultivation of organic soils, rice cultivation, synthetic fertilizers, crop residues, burning of crop residues, burning of savanna, and on-farm energy use. They do not include, and are measured separately from, agriculture-related land-use emissions. See the methodological note available at http://www.fao.org/faostat/en/#data/GT for detail. While on-farm energy use is included in the modelling, it is omitted from some items here due to data gaps.

[5] Agriculture-related land-use emissions include emissions from cropland, grassland, net forest conversion, and fires from burning of organic soils and humid tropical forests. They do not include, and are measured separately from, agriculture emissions. See the methodological note available at http://www.fao.org/faostat/en/#data/GL for detail. While agricultural emissions can largely be conceptualized as flows (emissions that are released each year due to production activities, such that emissions and production occur in the same year), agriculture-related land-use emissions can be better conceptualized as stocks (emissions come from a one-time action such as deforestation or draining of histosols, with emissions occurring over 1 or many years but not linked to the year of production).

[6] FAOSTAT reports land-use emissions, including emissions from deforestation. However, deforestation is not directly attributable to agriculture versus other uses such as timber or fuel.

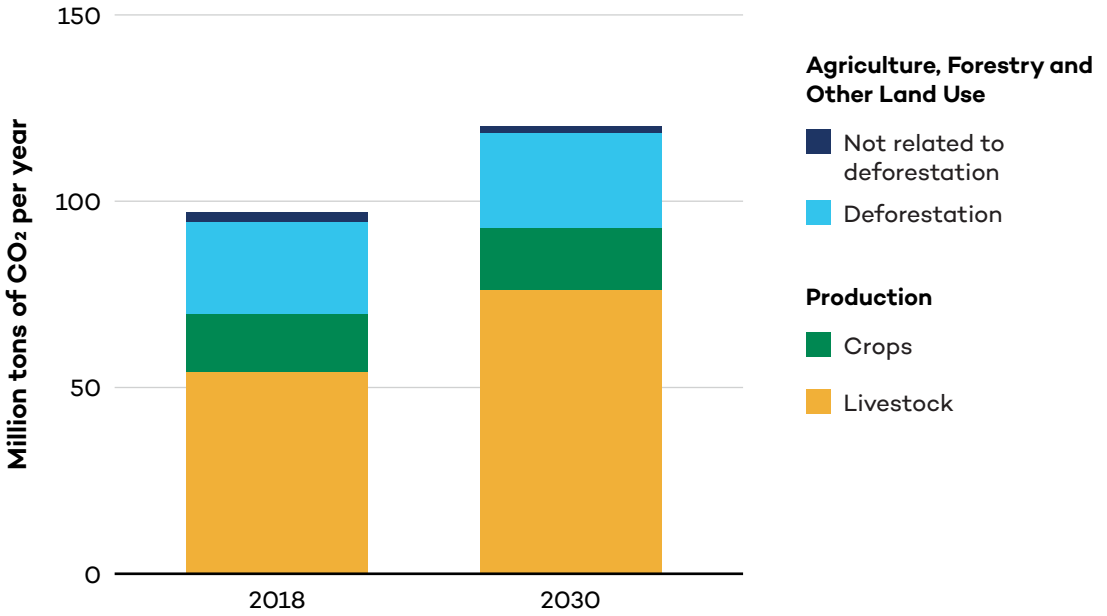
Agriculture-related land-use emissions, which are generally emissions from converting natural land to agricultural land, are about one-half the magnitude of agriculture emissions and have been stable over the last decade (agriculture-related land-use emissions averaged 46 megatonnes of carbon dioxide equivalent (CO_2e) per year from 2008 to 2018, versus 70 megatonnes for agricultural emissions in 2018). Deforestation accounts for almost all of these emissions. In 2018, deforestation accounted for about 20% of emissions from agricultural production and agriculture-related land use combined (FAO, 2021a). However, it should be noted that, while these emissions are counted as agriculture related, they are also driven by mining and logging. With the caveat that the estimation is very approximate, roughly 7% of forest land was converted to agricultural use from 2008 to 2018 (FAO, 2021a).

The agricultural sector will continue to develop as the demand for food increases, particularly for animal products. The estimates indicate that this will lead to a dramatic increase in the production of GHG emissions, by 2.3% annually, or 25% in 10 years. Land-use change from forestry to agriculture is expected to plateau, with forested areas expected to decrease by 5% in the next 10 years. Sustainable intensification of the livestock sector in particular is needed to allow the country to achieve its social, economic, and environmental objectives. However, it is important to stress that increased livestock production is necessary to assist with the transition toward healthier diets and meet Nigeria's nutrition goals. Therefore, improving the emission efficiency of livestock production as the livestock sector grows could play an important role in helping Nigeria keep its emissions within its targets presented in the country's updated nationally determined contribution (NDC) under the Paris Agreement on Climate Change.

In terms of policy priorities for climate action, Nigeria submitted to the United Nations Framework Convention on Climate Change (UNFCCC) its updated climate action plan under the Paris Agreement in May 2021 (FRN, 2021b). In its updated NDC, the country presents its mitigation commitments in the form of GHG emissions-reduction targets, contributing to the Paris Agreement goal of keeping the global average temperature rise "well below" 2°C and pursuing efforts to limit the temperature increase to 1.5°C (UNFCCC, 2015). In its NDC, the country commits to an unconditional emissions reduction of 20% relative to business as usual (BAU) by 2030,[7] based on domestically supported and implemented policies and measures. The NDC also puts forward a more ambitious target of an additional reduction of 45%–47% by 2030 relative to BAU, but this contribution is contingent on the provision of international support and funding. For both targets, the highest contribution is assumed to come from the energy sector, followed by agriculture (FRN, 2021b). There is space for the agricultural sector to make significant contributions to the country's conditional emissions-reduction target, including by promoting climate-smart agriculture and reducing emissions from rice paddies and from crop residues by 2030 and beyond. Donor support is crucial to achieving such outcomes.

[7] This expected reduction is relative to the BAU scenario used in the updated NDC; please note that this scenario is different than the BAU scenario in Ceres2030.

Figure 6. Agricultural and land-use emissions (domestic emissions only): Scenario without the NDC, 2018 and 2030, total



Source: Authors' diagram based on FAOSTAT data for 2018 (FAO, 2021a) and MIRAGRODEP model projections. IPCC Tier 1 approach used.

2.3.2 Climate Change Impacts and Adaptation

Climate change is already affecting Nigeria's economy in several ways. Recent analysis shows that temperatures increased by 1.1oC from 1901 to 2005, while annual average rainfall decreased by 81 mm in the same period (FRN, 2020a). Further, the number of rainy days per year has fallen by 53% in the northern parts of Nigeria and by 14% in the Niger Delta (FRN, 2020a). The southern regions experience strong rainfall events during the rainy season from March to October, with annual rainfall amounts of over 2,000 mm and up to 4,000 mm and more in the Niger Delta (World Bank Group [WBG], 2021).

Observed climate change impacts include desert encroachment (of the Sahara Desert), coastal inundations, the drying up of water bodies such as Lake Chad, and a shift in the types of crops cultivated and the times of cultivation. According to some scenarios, by 2040–2060, extreme climate events such as floods and droughts will increase in frequency and severity. Climate change is projected to increase desertification in the northern part of the country, whereas the southern part is expected to experience sea level rise, saltwater intrusion, and flooding (FRN, 2020a). These projected changes will have far-reaching impacts on already-fragile sectors, such as agriculture, water, energy, and natural ecosystems—all with implications for food security. Table 1 provides a summary of projected changes from climate change by 2060.

Table 1. Impacts of climate change

Impact	By 2060	Reference
Temperature increase	1.48oC to 3.48oC	FRN, 2020b
Rainfall (south)	15 cm increase annually	WBG, 2021
Rainfall (north)	7.5 cm decrease annually	WBG, 2021
Change in yield (north)	Declines by 40%	FRN, 2020a
Annual temperature increases	+3.08°C to +4.63°C	FRN, 2020a

Source: Authors' table based on data from FRN, 2020a, 2020b; WBG, 2021.

Climate projections for agriculture indicate lower yields in the longer term (by 2050). Rice appears to be the most vulnerable crop, with yields predicted to fall 7% in the short term and as much as 25% in the longer term (FRN, 2020a; Morgan & Fanzo, 2020). It is expected that total annual rainfall will increase, potentially having a beneficial effect on the productivity of cassava and ginger, but the productivity of yam, maize, tomato, and melon is threatened by increased precipitation. Conversely, extreme temperatures have a strong negative association with cassava and sweet potato yields, which suggests that temperature change, rather than precipitation, is likely to be the major driver of yield shocks.

Despite improvements in the country's food security achieved by 2018 due to sustained humanitarian assistance, policy actions, and government interventions in the agricultural sector, the situation remains fragile in northeastern Nigeria. Vulnerable households are not able to cultivate enough land nor do they own sufficient livestock to cover their food needs. The ongoing armed conflict in the country also continues to have a direct impact on people's nutrition status, which is further exacerbated by the weak health infrastructure and food insecurity (FAO, 2019).

The Government of Nigeria has responded to the adverse impacts of climate change in many ways. At the international level, Nigeria has submitted its third national communication and its updated NDC to the UNFCCC. More recently, in 2021, Nigeria developed an adaptation communication under the Paris Agreement to provide information to the global community on its national circumstances concerning adaptation, including priorities, needs, plans, and actions (FRN, 2021b). At the national level, the country has developed the National Climate Change Policy Response and Strategy, launched sovereign green bonds, and, more recently, adopted a National Adaptation Plan Framework, which aims to facilitate the management of Nigeria's medium- and long-term adaptation processes in a coherent and coordinated manner.

Climate change is already impacting food production, distribution, utilization, and availability in Nigeria. For example, increased temperatures and rainfall variability in Nigeria have led to reduced rice yields. Additionally, research has shown that increased levels of atmospheric carbon dioxide can be expected to affect the nutrient levels in rice, with up to 17% decline in nutritional value (Kolawole & Aromolaran, 2017). While cassava is somewhat adapted to hot and dry conditions compared to other crops, it is prone to waterlogging (the saturation of soil with water), and reports indicate that high levels of carbon dioxide could increase cyanide concentrations in the cassava root (Kolawole & Aromolaran, 2017).

In turn, the effects of climate change on food systems influence dietary and nutritional outcomes. Studies show that precipitation affects dietary diversity, with rainfall conditions that are favourable to farming and agriculture being associated with higher dietary diversity (Morgan & Fanzo, 2020). Undernutrition has been higher in the northern arid zones of the country, which are predicted to have less rainfall compared to the south (Morgan & Fanzo, 2020). Agricultural production conditions, such as irrigation, crop diversity, and ownership of livestock, also substantially influence household dietary diversity.

The Nigerian government has made some progress at the policy level in addressing agriculture and nutrition in an integrated way that highlights a systemic understanding of the drivers of malnutrition. However, climate change adaptation and mitigation are not integrated sufficiently into nutrition-related policies. Nigeria's nutrition policies have a weak climate change component, while its climate change policy has limited focus on improved nutrition. For example, the agricultural section of the National Climate Policy focuses on the diversification of livestock, increased access to drought-resistant crops, better soil-management practices, national early warning systems, and increased use of irrigation and crop cover. It further subscribes to adopting climate-smart agriculture as a strategy for climate change adaptation and improving agricultural productivity (FRN, 2013b). The National Agricultural Resilience Framework (2014) devotes a chapter to the role of (and need for) mainstreaming adaptation into Nigeria's agricultural sector (FRN, 2014). Most of these policy documents also stress the importance of gender issues and improving the engagement of vulnerable groups in implementing agricultural practices that are climate-smart and resilient.

Nigeria's government has identified key adaptation strategies to increase sectoral productivity as presented in the country's NDC (FRN, 2015b, 2021b), which include:

1. Expanding and optimizing irrigation infrastructure, with national investment schemes and private sector companies taking the lead on procurement opportunities.
2. Introducing drought-tolerant and early maturing crop varieties.
3. Increasing and upgrading storage facilities to reduce loss and increase the country's food security.
4. Providing agricultural insurance and enhancing the country's agricultural extension services and promoting alternatives to livestock production.
5. Diversifying livestock and improving range management.
6. Adopting better soil-management practices.
7. Providing early warning/meteorological forecasts and related information.
8. Providing accurate and timely weather forecasts.
9. Diversifying livelihoods to improve incomes.
10. Planting cover crops such as potatoes and melons to mitigate soil erosion and pests and to enhance soil fertility and quality.

While Nigeria's policy documents highlight some actionable items to create nutrition-sensitive and climate-smart interventions, significant challenges remain with regard to implementation (See Sections 3.2 and 3.3).

3.0 Achieving a Sustainable Food Systems Transformation in Nigeria: What would it cost?

This section identifies pathways—and the associated costs and interventions—for addressing the interlinked challenges of the food system in Nigeria. The focus is on improving hunger, poverty, and nutrition outcomes by increasing incomes, moving toward healthy diets using a more climate-resilient production system with fewer GHG emissions, and improving the adaptive capacities of farmers. This section presents a transformation scenario with a trajectory to drive poverty reduction and support a change in food supply and demand, which leads to a "nutrition transition" in diets. However, such a transition creates environmental and land-use impacts that range from changing production patterns, including soil degradation, overuse of water resources, and increased GHG emissions, as well as health challenges associated with obesity and diet-related diseases such as diabetes or cardiovascular disease. These linkages demonstrate that market-based solutions alone will not produce outcomes that simultaneously address environmental and climate constraints while meeting nutritional targets. Thus, the core focus is to identify policy interventions and related public and donor costs to influence production and consumption patterns that lead to better environmental and nutritional outcomes.

This section presents the additional public costs of transforming agriculture and food systems in Nigeria and the share of external resources needed. The methods and approaches are described in Section 4, including the scenarios, targets, and interventions included in the CGE model and a discussion of the limitations of the research approach.

3.1 Additional Public Cost of Achieving Sustainable Food System Transformation

Based on the policy interventions identified to deliver improvements in diets while mitigating and adapting to climate change, the model estimates the cost of public investment, including domestic and external resources needed to achieve the targets for sustainable food system transformation. Sustainable food system transformation is achieved through SDG 2 sub-targets, including 3% or fewer people affected by hunger (SDG 2.1), healthier diets (SDG 2.2), doubling of the net incomes of small-scale producers on average (SDG 2.3), and GHG emissions in line with NDC commitments (SDG 2.4). While it is not possible to directly incorporate climate change adaptation (SDG 2.4) in the macroeconomic modelling due to the 2030 timeline, it is an important element of achieving resilient agricultural production and needs to be prioritized in the coming decade.

There is currently no universally accepted definition of a healthy diet. However, in order to estimate costs, there is a need to establish a healthier diet target in the model.[8] Therefore,

[8] All targets apply to all households in the population. Full documentation of our dietary targets selection can be found in a technical note for the project, "Dietary Target Choices" (Bizikova et al., in press).

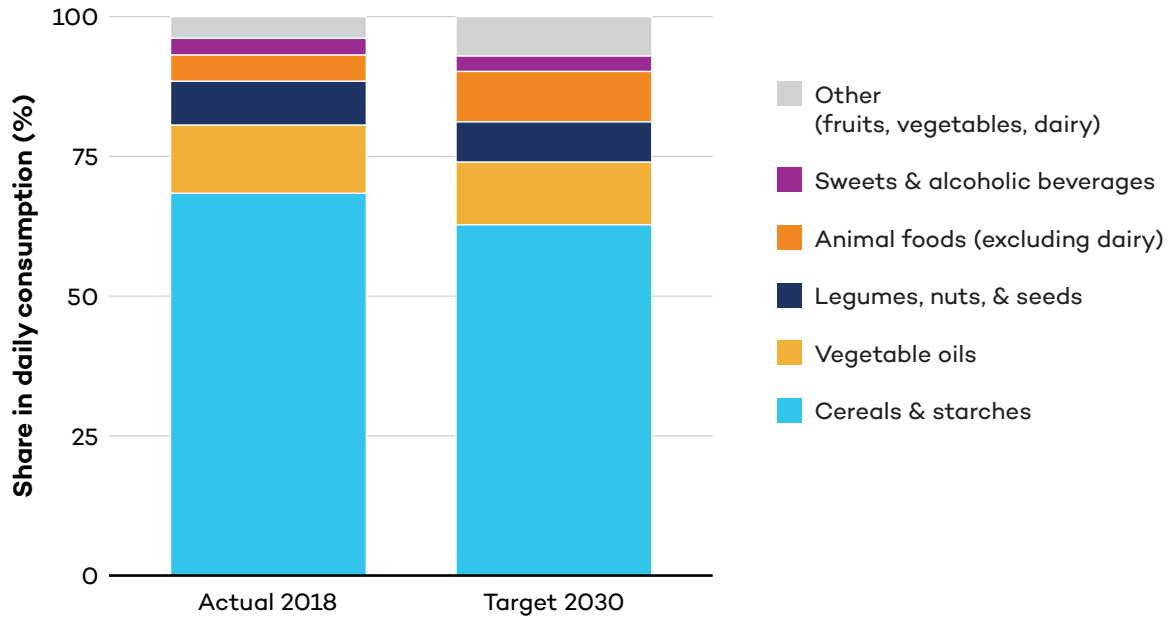
based on national and international guidelines and policy documents, a review of nutrition literature, and expert consultations, we focus on three targets for achieving healthier diets as appropriate for guiding national-level food system investment:

1. **Overall caloric intake** measured using the prevalence of undernourishment (PoU) as a metric, with a target of less than 3% PoU in each country.
2. **Adequate consumption of non-starchy vegetables and fruits**, based on the WHO guidelines of 400 g of fruits and vegetables per day (FAO & WHO, 2003; WHO, 2020).
3. **Adequate consumption of animal-source foods** (including dairy) through a minimum target of at least 10% of households' overall caloric intake to ensure sufficient calcium and B12.

Importantly, the modelling of diets requires that all households achieve caloric sufficiency, but it also demands that households achieve healthier diets. In this way, we model public spending that promotes diversification without compromising on hunger.

Figure 7 compares the existing dietary consumption patterns in Nigeria and the dietary composition targets included in the modelling framework. When comparing the current diet and a healthier future diet, there are considerable differences in terms of consumption of fruit, animal-source food, and legumes and beans. As there is also a need to improve overall daily calorie intake, the consumption of starches also needs to increase.

Figure 7. Comparison of the current (2018) and targeted dietary composition in Nigeria: Consumption per capita, actual and targeted (food grams)



Note: For further details about the model targets, see Section 4.2.2.

Source: Authors' diagram, using data from the Nigeria LSMS-GHS Wave 4 2018–2019 (World Bank, 2019) and MIRAGRODEP model simulations.

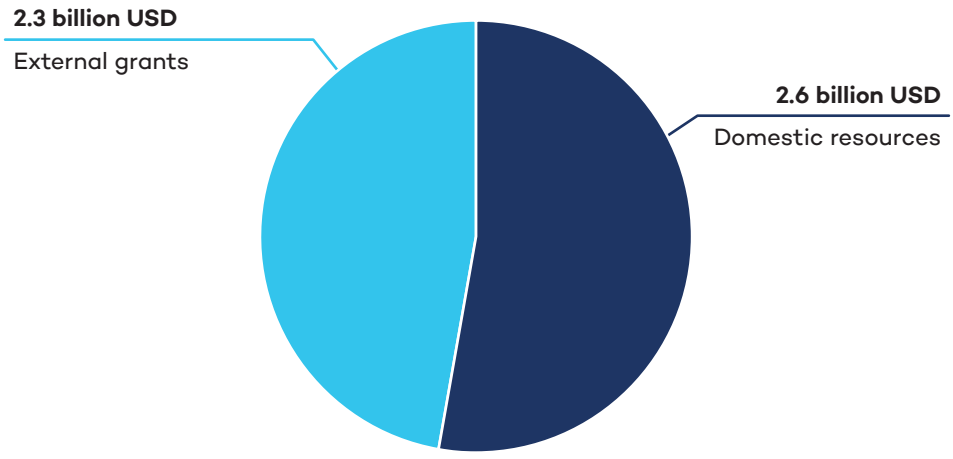
The policy interventions are grouped in three broad areas, following the modelling framework from Ceres2030: Sustainable Solutions to End Hunger:

- **Empowering the excluded**, which includes actions that directly support consumers, such as social protection programs, nutrition education, vocational training, and school feeding programs.
- **On the farm**, which includes actions that directly support producers such as investment and financial services, fertilizer subsidies, production subsidies, as well as research and development (R&D) and extension services. There are also important interventions to support irrigation infrastructure and livestock production through agroforestry.
- **Food on the move**, which includes actions to improve the functioning of markets and value chains, such as roads, electricity, storage, mobile networks, and other infrastructure interventions.

3.2 The Financing Gap

Results from the modelling show that, in Nigeria, it would cost an additional USD 4.9 billion in annual public investment from 2023 until 2030 to end hunger, double the incomes of 14.6 million small-scale producer households on average, transition to healthier diets for 126 million people, and protect the climate.

Figure 8. Summary of total additional public costs required per year, 2023–2030



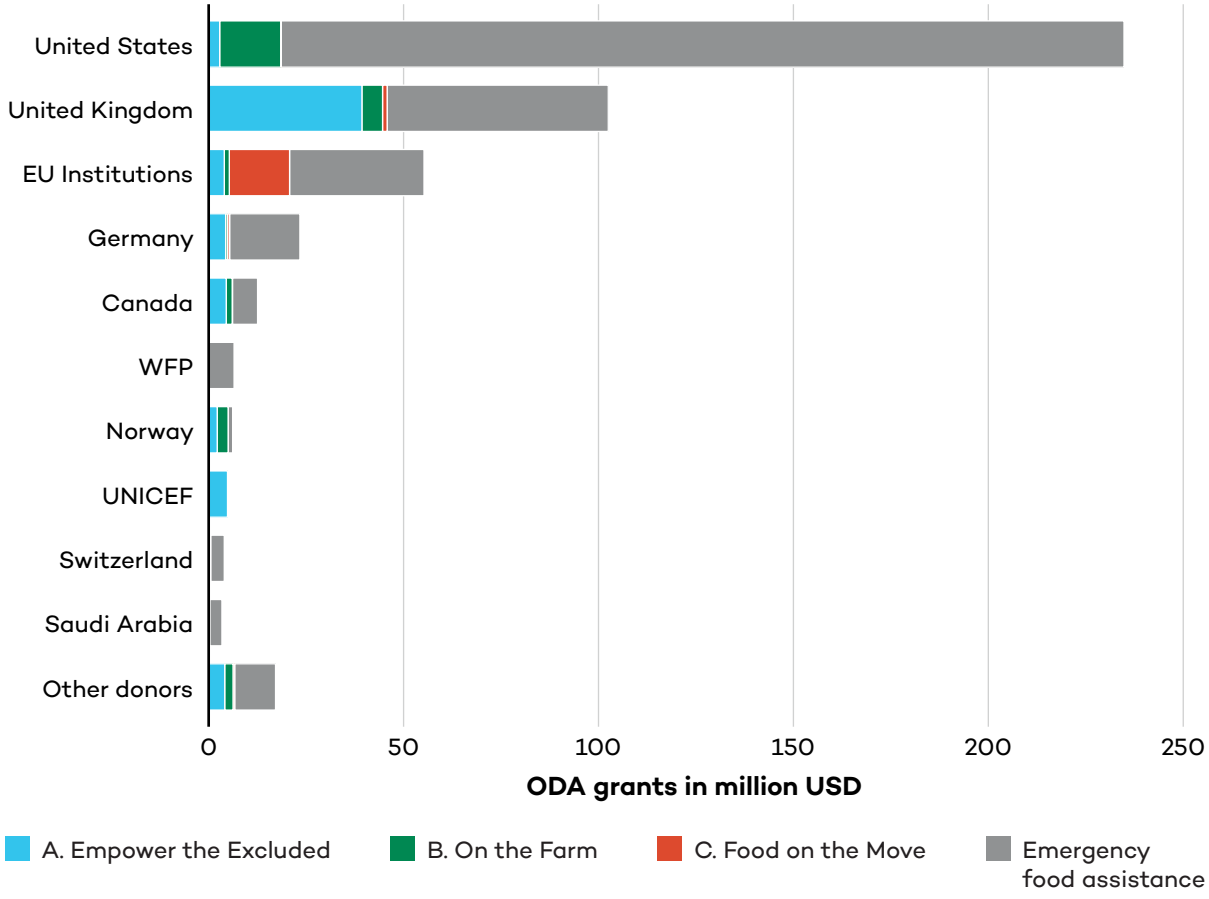
Source: Authors' diagram based on MIRAGRODEP model simulations.

To contextualize this required increase in public costs directed toward the food system, donors currently disburse an average of USD 114 million per year to projects directly affecting agriculture and food security and nutrition in Nigeria (see Figure 9).

The United Kingdom is the top donor to projects in agriculture and food security and nutrition in Nigeria, followed by European Union (EU) Institutions and the United States (Figure 9). A desk review of the projects implemented by the Deutsche Gesellschaft

für Internationale Zusammenarbeit (GIZ), the EU, and the United States Agency for International Development (USAID) found 10 projects closely related to the nexus of food security, nutrition, and climate change. The focus of these projects ranged from the promotion of private sector investment in agriculture and capacity development of governance institutions to production support, agri-development, extension services, and capacity development (see Bizikova et al., 2022). Most of the identified projects focused on two elements of the nexus, for example, increasing the productivity and diversity of the agriculture sector as well as its adaptation to climate change (Delegation of the European Union to Nigeria & Economic Community of West African States [ECOWAS], 2019a) or promoting nutrition-sensitive agriculture (Delegation of the European Union to Nigeria & ECOWAS, 2019b). While the exact objectives of the projects differed, nearly all had a strong focus on increasing agricultural production. None drew strong links between or directly addressed all three aspects of the nexus.

Figure 9. Top 10 donors by average annual disbursement, 2017–2019



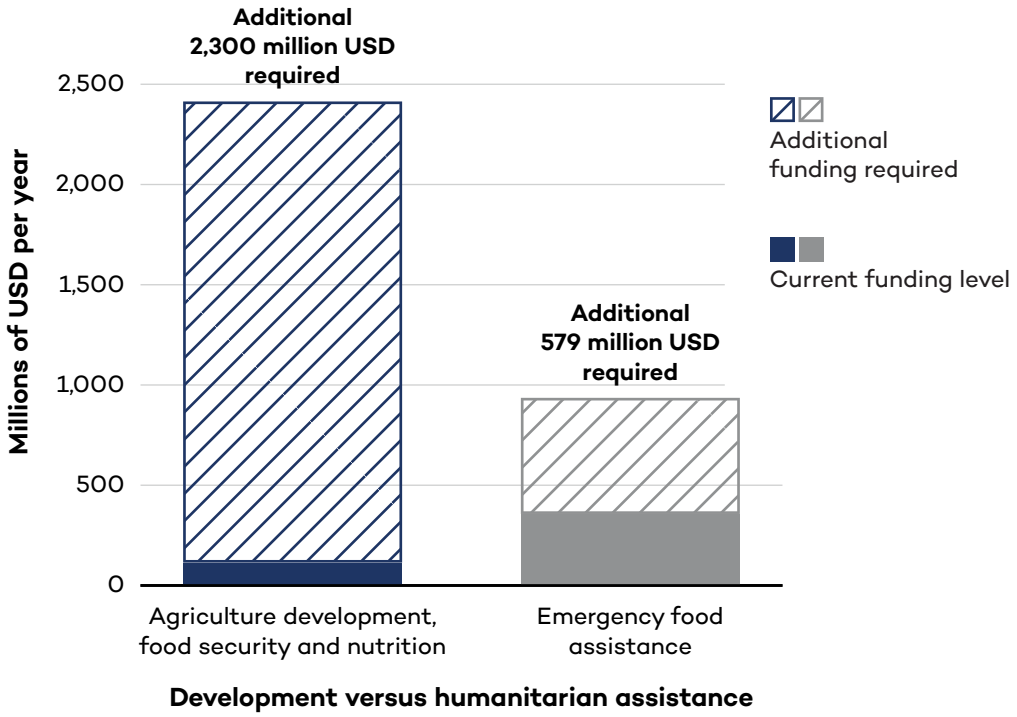
Source: Authors' analysis of OECD's Creditor Reporting System (OECD, 2021).

Results from the modelling show that, in Nigeria, an additional USD 4.9 billion in annual public investment is needed per year from now to 2030 for food systems transformation. Of this USD 4.9 billion, an average of USD 2.3 billion per year needs to be provided by external resources (donors). Compared to the average USD 114 million per year that donors currently provide, it is evident that the funding gap in Nigeria is immense. Donors need to increase their

agriculture and food security official development assistance (ODA) to Nigeria by nearly 20-fold if the SDG 2 sub-targets are to be met by 2030.

Importantly, comparing the gap between the long-term investment needed to achieve the SDG 2 sub-targets and the short-term investment needed for emergency food assistance shows that there is significant underfunding of the longer-term investment needs (Figure 10). Unless corrected, shocks and crises will continue to lead to massive rises in hunger and poverty. This is incredibly pertinent given the devastating impacts of current crises, including the considerable rise in the need for emergency food assistance. Donors should increase their allocations to longer-term development priorities in order to support resilience building, which would help mitigate against future shocks and crises.

Figure 10. Additional donor contribution needed for long-term agriculture and food security investment compared to emergency food assistance



Source: Authors' diagram based on MIRAGRODEP model simulations.

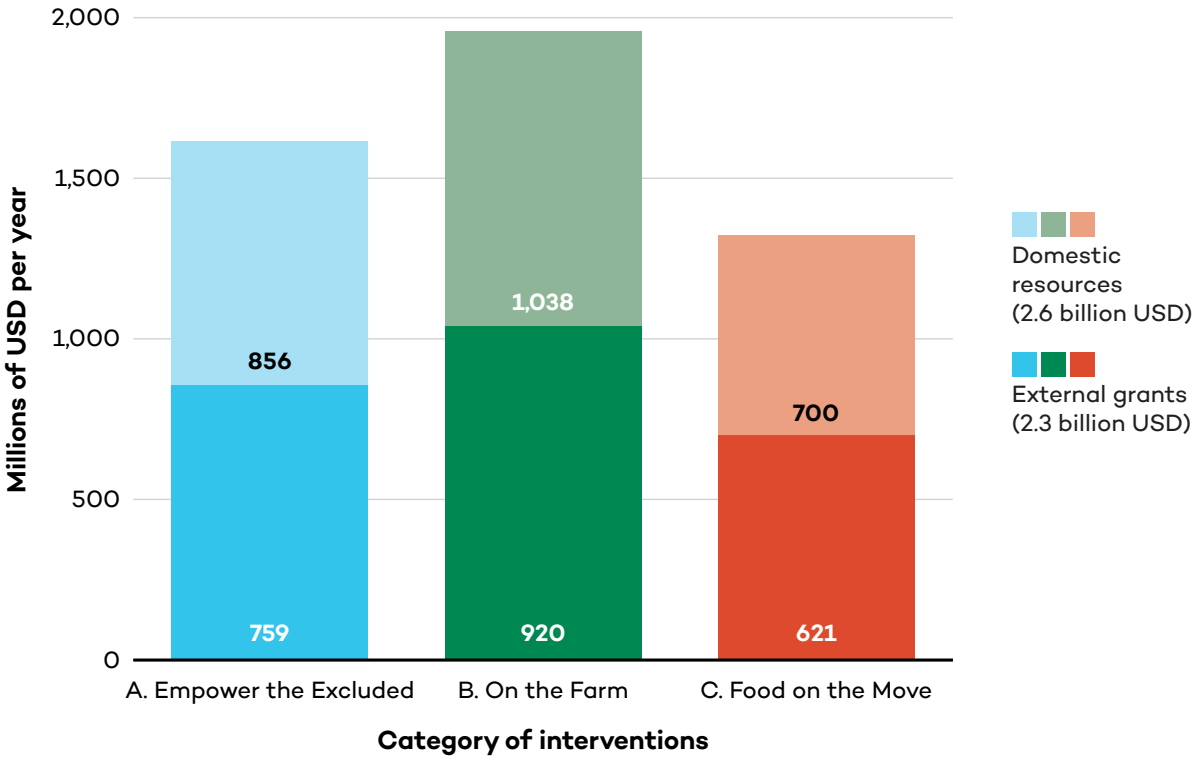
3.3 How Should the Money Be Spent?

To achieve sustainable food systems transformation, what matters are not only the total public costs but also the allocations to specific interventions combined with policy and strategic support to promote the implementation of these interventions. In this context, it is critical to prioritize the actions and programs outlined in existing policies and strategies (see Box 3) and, if necessary, complement these policies with additional actions to account for the outcomes of the cost modelling.

3.3.1 Interventions Supporting Food System Transformation

Figure 11 shows the allocation of the total public costs across the three areas: an additional USD 1,615 million per year is needed to "Empower the Excluded," USD 1,958 million is needed annually "On the Farm," and USD 1,321 million is needed every year for "Food on the Move." Given the scale of the investment gap, there is an urgent need for donors to scale up support in all three areas, particularly on-farm investments, in Nigeria.

Figure 11. Summary of additional public funding required grouped by intervention category



Source: Authors' diagram based on MIRAGRODEP model simulations.

Of the three broad areas, the largest share (USD 1,958 million) is allocated to on-farm interventions that provide direct support to farmers to produce more food, improve production quality, and increase production diversity. This category of interventions provides multiple benefits to the farming community by improving capacities (including knowledge and inputs to increase productivity), income, and food security and nutrition.

On-farm interventions do not lead only to income improvements: they also result in improved access to healthier foods, such as fruits and vegetables and animal-source foods. As suggested during consultations, these complement—and need to be complemented by—other nutrition-focused measures such as nutrition education and school feeding programs in order to have maximum effect on dietary outcomes (see Box 3).

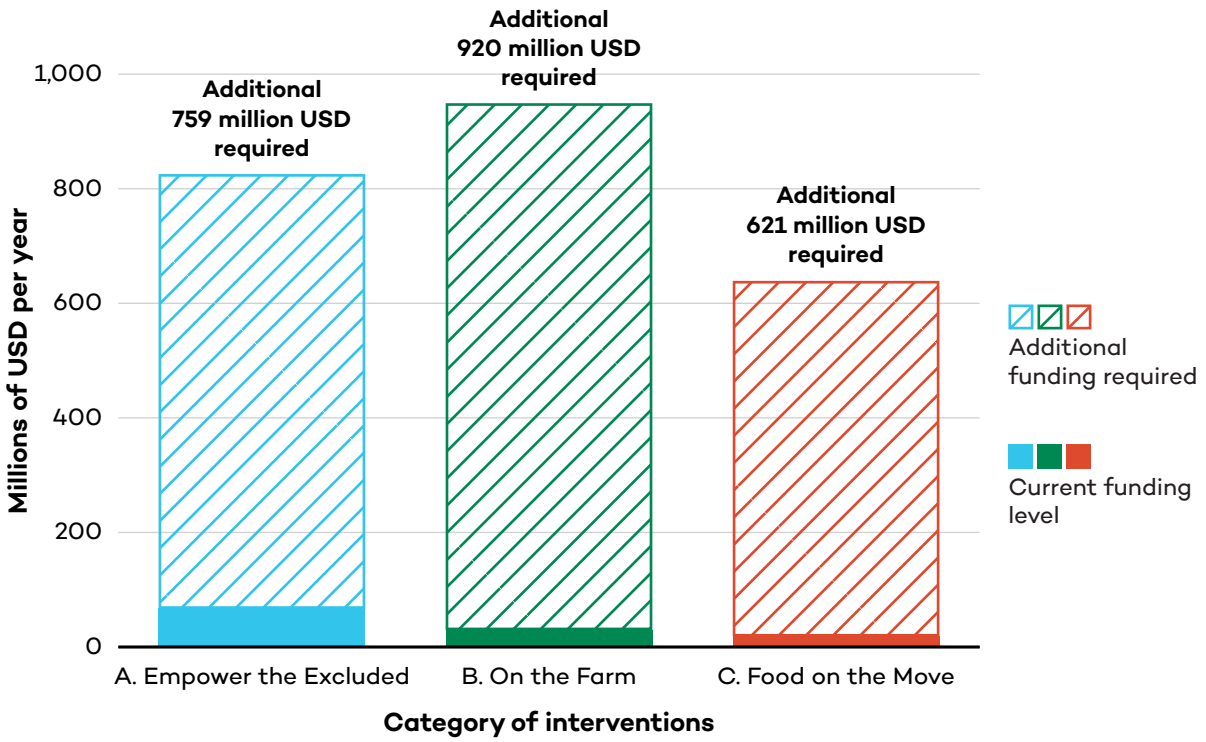
The next biggest share goes to empower the excluded, and it is almost as important as the on-farm interventions, amounting to an additional USD 1,615 million per year on average. This

covers financial allocations to social safety nets, nutrition education, vocational training, and school feeding programs to address the needs of vulnerable groups in terms of food security and transition toward healthier diets (also stressed during the consultations, see Box 3).

Another important area for investment is market and value chain interventions (food on the move), which require USD 1,321 million per year on average. These interventions are closely linked to farm-level measures and link producers to consumers by addressing Nigeria's considerable infrastructure deficit (FRN, 2016). Beyond focusing on roads and other infrastructure to ensure access to markets, improvements in storage and processing are included. Such improvements could contribute to healthier diets by preserving nutritious foods such as vegetables, fruit, and animal-source products and thus help improve the nutrition of households accessing these foods. This is also recognized in the country's policies (see Box 3; see also Section 3.3).

The priority areas for the required increase in donor spending mirror this distribution across the three categories of interventions: an additional USD 920 million is needed on the farm, USD 759 million to empower the excluded, and USD 621 million for food on the move (Figure 12).

Figure 12. Total annual external funding required grouped by intervention category



Source: Authors' diagram, using data from the OECD's Creditor Reporting System (OECD, 2021) and MIRAGRODEP model simulations.

3.3.2 Policies Supporting Sustainable Food System Transformation: Focus on food security, nutrition, and livelihoods

Several policies stress the importance of supporting agricultural productivity while promoting food security and addressing malnutrition challenges. Specifically, the documents stress the need to address the gap in the production of sufficient fresh, high-quality foods for the country and for export (FRN, 2016, 2021b). To improve productivity, the country's policy documents prioritize plant and livestock production such as rice, wheat, maize, meat, milk and milk products, fish (aquaculture), fruits and vegetables, and sugar (FRN, 2016). In line with this, donor projects focus specifically on improving the quality of maize and soybeans (USAID, 2018) and rice (GIZ, n.d.a). However, alongside production increases, it is necessary to improve market access and value chains (FRN, 2014, 2016). Projects such as USAID's Feed the Future Nigeria Agribusiness Investment Activity are therefore crucial as they support the integration of micro, small, and medium-sized agricultural enterprises into domestic and international commercial agriculture, ultimately with the outcome of diversifying and developing agricultural value chains in Nigeria (USAID, 2019).

Over the past years, Nigeria has experienced low productivity due to limited inputs, including quality seeds and fertilizer and quality irrigation and harvesting systems (FRN, 2014, 2016). Critical policy documents emphasize the need to improve agricultural productivity and address low yields in the sector by focusing efforts on three areas: 1) farm-level support through access to land, extension, inputs, and improved value chains; 2) integration of private sector investment with access to finance and agribusiness; and 3) ensuring institutional alignment to address issues such as R&D, food security, and nutrition as well as the needs of specific groups such as women, youth, and children (FRN, 2016, 2021b). Many of the donor-identified projects addressed such areas, especially the first two, suggesting a high degree of policy coherence between donor projects and national priorities. For example, USAID's Partnership for Inclusive Agricultural Transformation project is supporting the development of Nigerian seed systems in addition to the provision of inputs, access to markets, and the availability of extension services (USAID, 2020). The desk review found a further three projects that support the provision of inputs, equipment, and technology, as well as supporting farmer's access to credit, market information and finance (Delegation of the European Union to Nigeria & ECOWAS, 2019b; GIZ, n.d.a, n.d.b.).

The Nigeria Agriculture Resilience Framework focuses on improving productivity using climate-smart agriculture (FRN, 2014). The strategy aims to sustainably increase agricultural productivity and improve farmers' incomes by also integrating climate change, including GHG emissions-reduction and adaptation efforts. However, the policies also identify major constraints to advancing climate-smart agriculture, including the lack of awareness of appropriate responses and management practices to address climate change impacts such as droughts and changes in water availability, as well as soil nutrient deficiency; the lack of infrastructure; and limited coherence between policies and among different levels of government. Some of the efforts under the Nigeria Agriculture Resilience Framework focus on small-scale producers by, for example, setting up the Growth Enhancement Scheme to provide targeted access to inputs, financing, and extension services (FRN, 2014). Similarly, projects such as the RESILAC–Lake Chad Inclusive Economic and Social Recovery

Project, funded by the EU, seek to support the diversification and adaptation of agricultural production systems to climate change at the household and family level (Delegation of the European Union to Nigeria & ECOWAS, 2019a).

Nigeria's policy documents also focus on investing in value chains. They stress the absence of value addition and supply-chain linkages in the country, noting that Nigeria mostly focuses on food production, thus neglecting segments of the value chain (FRN, 2014, 2016). Challenges to effectively promoting value chains are attributed to gaps in financing for small-scale producers and inefficient transport, as well as limited availability of processing and storage systems (FRN, 2014, 2016). The policy documents note that the current post-harvest loss rates in Nigeria can be as high as 60% for perishable crops and recommend improving road infrastructure and storage, including cold storage, to reduce losses from spoilage before crops reach markets (FRN, 2016). All these priority actions require additional financial resources, consistent with the results from the model.

Nigeria has made significant progress in expanding livestock production. The country has a strong poultry sector, which is one of the largest in Africa (FRN, 2016). However, the development of the livestock sector is facing challenges, including the lack of updated census data on the livestock sector; waste management, especially for the growing poultry sector; and an underdeveloped cattle value chain, which also creates tensions between landowners and herders. Thus, Nigeria's policy documents focus on creating ranching systems as well as on access to veterinary services, management choices with reduced GHG emissions, and market and storage issues (FRN, 2016). Currently, none of the projects implemented by GIZ, USAID, or the EU were found to have a focus on livestock, which therefore represents an important area for impactful future investments.

In terms of improving the well-being of the most vulnerable, the country developed a social protection policy in 2015, which was revised in 2020 (FRN, 2015a, 2021a). The policy envisions different programs with a primary focus on poverty reduction and alleviating the impacts of socio-economic shocks. It also stresses the importance of providing social welfare and improving food security and nutrition. Specific measures to address these issues include efforts to improve income through public works and conditional and unconditional cash transfers, free access to health care for vulnerable groups, school feeding programs, and free and/or subsidized access to food and fuel. This policy approach is reflected in the EU's attempts to enhance the resilience and food security and nutrition of conflict-affected communities in Borno State, in particular by providing social protection, enhancing access to basic services, and supporting livelihoods (Delegation of the European Union to Nigeria & ECOWAS, 2019b).

Nigeria's Agricultural Promotion Policy (FRN, 2016) stresses the importance of nutrition-sensitive agriculture in addressing nutrition challenges. This policy follows the country's National Policy on Food and Nutrition (FRN, 2004) and National Plan of Action on Food and Nutrition (FRN, 2005). These policies focus on improving the nutritional status of the population, particularly the most vulnerable groups such as children, women, and the elderly, by ensuring access to adequate food and services, including health care, water, and sanitation. The policies recommend improving the production and availability of (and access to) high-quality foods, including staples and traditional foods. Donor projects such as USAID's

Feed the Future embody this approach, supporting efforts to improve the nutrition status of households, in particular women and children (Feed the Future, n.d.; USAID, 2018). In addition, the literature suggests that policies should integrate consumers instead of only focusing on producers, to increase access to food consumers prefer, which can also contribute to increases in incomes for small-scale producers (Ecker et al., 2021). Nigeria also reports growing levels of obesity and diabetes in urban areas, and related diseases and health issues. Yet, none of the identified donor-funded projects addressed the rising levels of obesity and diabetes in Nigeria. It is critical that the government intensify its efforts to support a transition toward healthier diets to address both undernourishment and overconsumption of certain types of foods, such as carbohydrates.

In Nigeria, national fortification began in 1993 with salt fortified with iodine; the fortification of other products such as flour, sugar, and oil with multiple micronutrients was adopted in 2004 (updated in 2021) (FRN, 2021c). Presently, there is limited information on the actual implementation and whether fortified foods are accessible to the most vulnerable (Food Fortification Initiative et al., 2018). In addition, Nigeria adopted national guidelines for a micronutrient deficiencies control strategy, outlining activities to address vitamin A, iron, iodine, and zinc deficiencies, including by promoting access to supplements, diversified diets, treatment of certain diseases, food fortification, and awareness raising (FRN, 2013a). The annual Nigeria Food Processing and Nutrition Leadership Forum recently highlighted the country's commitment to increasing the production of fortified wheat flour, sugar, cooking oil, and salt; ensuring greater access to these types of foods; improving food safety; and addressing nutrition challenges (Office of the Vice-President of the Federal Republic of Nigeria, 2020). However, despite Nigeria's commitment to fortification and supplementation, none of the identified donor-funded projects support these efforts.

Finally, Nigeria's policy documents emphasize the importance of engaging the private sector, investors, small and medium-sized enterprises, and farmers' groups in food systems transformation. Policy documents emphasize the engagement of such groups in agricultural production, processing, and value chains, as well as in fortification and biofortification, and in ensuring access to nutrition and safe foods. Recommended actions include improving private sector engagement in the distribution system for fresh foods and in reducing post-harvest losses to promote the transition toward healthier diets. Practically, Nigeria has embarked on an Agricultural Transformation Agenda (ATA) that will promote agribusiness in the country, attract private sector investment in agriculture, reduce post-harvest losses, support value addition to local agricultural produce, and enhance farmer access to financial services and markets. Through the ATA, over 3.5 million jobs will be created along the value chains of the priority crops and sectors, which include rice, sorghum, cassava, cotton, cocoa, and oil palm, as well as horticulture, livestock, and fisheries (FRN, 2016). The ATA is supported by the country's efforts to develop a national agricultural resilience program. In addition, several donor-implemented projects support Nigeria's strategy of attracting private sector investment by seeking to diversify and strengthen the agricultural markets and business environment in Nigeria. Specifically, donors have supported the development of relations with processing and marketing companies (GIZ, n.d.a), the growth of agri-enterprises, cooperatives, and institutions (Delegation of the European Union to Nigeria & ECOWAS, 2019b), and the integration of farmers into the commercial agricultural market (Feed the Future, n.d.; USAID, 2019).

3.3.3 Policies Supporting Sustainable Food System Transformation: Focus on climate change mitigation and adaptation

The transformation scenario presented illustrates the types of interventions and policy options needed to end hunger, double incomes and productivity for small-scale producers, and make healthy diets more affordable. At the same time, because of the growing impacts of climate change and the need to reduce GHG emissions, policy-makers need to make sure that implementation of the transformation scenario also improves the capacities of farmers to adapt, promotes the overall resilience of the agricultural sector, and reduces the environmental footprint. Farmers' income gains and diet improvements can be jeopardized if climate resilience is not strengthened.

Climate change impacts, responses, and resilience building need to be an integral part of any future agriculture and food systems strategy. In Nigeria, promoting sustainable intensification is key to building climate-resilient agriculture as presented in the ATA (FRN, 2014), the Agriculture Promotion Policy (FRN, 2016), and the recently updated NDC (FRN, 2021b). This would help the country meet its climate mitigation targets and address poverty, food security, and dietary challenges.

Importantly, while Nigeria's agricultural policies are strongly centred on improving productivity, they also stress the need to account for food security and, to some extent, healthier diets by prioritizing both staples and traditional crops. The policies recommend that this be achieved by ensuring that both plant and livestock production is resilient and able to meet the country's climate change mitigation priorities. This is significant, as dietary improvements achieved as a result of focusing on existing technologies and agricultural production choices alone will likely exacerbate agricultural emissions and make climate change policy measures challenging to implement. Sustainable intensification will require improving agricultural productivity with production techniques that are GHG efficient and promote access to improved fodder and certain breeds (FRN, 2016; 2021b).

In terms of climate change mitigation, the transition scenario assumes considerable increases in livestock production, similar to the country's updated NDC (FRN, 2021b). However, such increases would need to be achieved in a way that would enable Nigeria to meet its GHG emissions-reduction targets listed in its updated NDC. The findings show that the most relevant interventions are those to do with livestock production, as growing livestock production, including for its contribution to healthier diets, is a significant contributor to the country's GHG emissions. Interventions focused on livestock production assume a move toward small ruminants and improved feed choices and manure management—practices that help reduce agricultural emissions. Nigeria is already the country with the largest poultry sector in Africa, and better management, market access, and storage are critical to improving its efficiency and environmental sustainability (FRN, 2016).

Current donor support and priorities are insufficient and inadequate to support the Nigerian government's goals and targets. Despite the importance of the livestock sector to Nigeria's agriculture and food system transition, the desk review found no projects implemented by GIZ, USAID, or the EU that focused on sustainable livestock intensification. Programs and interventions that support the sustainable development of the livestock sector should therefore

be an urgent and critical focus for additional public investment, both for the Government of Nigeria and its development partners.

Box 3. List of policy priorities, measures, and interventions to address food security, nutrition, and agricultural transformation challenges from the consultations

- Increasing research on food systems, including improved data to guide effective interventions' selection and implementation to create a sustainable food system transformation.
- Improving value chains and market access as the lack of roads, particularly in rural areas, prevents farmers from moving food to the market.
- Providing appropriate dietary education tailored to different groups and with a focus on what is culturally appropriate and seasonably available.
- Considering institutional buyers, such as for school feeding programs, to promote production and buying up of certain products, especially those assisting in nutrition.
- Enhancing interaction and coherence between different levels of decision making in the creation and implementation of measures, with a focus on a multi-sector approach to improve nutrition.
- Improving the design and implementation of nutrition policy through coordination between different levels of government to tailor the actions to local needs by promoting nutrition-sensitive agriculture, including the production of cassava and orange-fleshed sweet potatoes.
- Increasing social protection, the consumption of biofortified crops, and the delivery of nutrition education, especially when provided with consideration to cultural and seasonal variations.
- Addressing the siloed nature of thinking about nutrition, which is widely considered to be a health issue as opposed to an issue warranting a multisectoral approach.
- Increasing and repurposing social protection programs both to ensure sufficient access to food and to provide more nutrition knowledge and access to healthier foods.
- Promoting programs to increase consumption of biofortified crops and to encourage households to produce nutrient-dense crops to improve dietary diversification and access to micronutrients.
- Increasing the capacity of institutions to provide nutrition education.

Source: Information listed in this box was collected during the project consultations with national stakeholders and donor agencies. For details on the consultations, see Appendix A.

Interventions in the model support the achievement of Nigeria's climate change adaptation goals through investments in improved planting and crop choices, irrigation and soil management, and access to improved storage and markets. Interventions in the model reduce

post-harvest losses and increase processing and storage capacity through policy actions, such as targeted extension services that improve economic resilience, improve availability of breeds, and provide support services so that farmers can adjust production to account for climate change impacts. The model interventions on farms provide direct support to farmers to produce more food, improve production quality, and increase production diversity, which contributes to climate adaptation and resilience building. Thus, there is a role for extension services and targeted subsidies to promote crop diversification away from grains and cereals toward more legumes, oilseeds, fruits, vegetables, and meat production.

Finally, while the model is not able to integrate institutional reform and capacity building, this is the foundation for the success of any of the policy interventions. Such institutions are also critical to monitor the achievement of the portfolio of interventions, using appropriate indicators for farm-level, individual, household, system-wide, and aggregate outcomes to cover productivity improvements as well as climate change impacts on production and the agricultural sector's resilience, including that of small-scale producers.

3.3.4 Trade-Offs and Synergies in the Context of Sustainable Food System Transformation

Addressing the compound challenge of food system transformation in light of climate change and the need to achieve healthy diets will not happen without trade-offs. For example, achieving healthier diets will require people to consume more diverse foods, including animal-source foods, which will lead to higher GHG emissions. These tensions are real for people in Nigeria. In this context, Nigeria's policies focus on improving agricultural productivity and on sustainable intensification at the farm level as well as on improving value chains to address persistent food quality and availability challenges. The country also has specific policies to address nutrition and food security challenges that are linked to agricultural development by improving access to healthier foods, mostly from the production side (FRN, 2004, 2005, 2014). Further policy efforts that promote nutrition education and access to affordable healthier foods while accounting for consumer preferences can also help reduce these tensions.

Improvements to diets delivered through the use of existing technologies alone will exacerbate GHG emissions in agriculture and make it challenging to achieve climate change mitigation commitments. Solutions need to build on the capacities of small-scale producers to simultaneously improve agricultural productivity while making production techniques that are GHG efficient more commercially viable alternatives. The emphasis on improved practices at the farm level means that specific policies, programs, and interventions need to be designed to also foster climate change adaptation and build resilience, including promoting access to modern irrigation, renewable energy, and adjusting planting practices and crops, as well as supporting post-harvest storage. Many of these interventions are considered in Nigeria's policies, especially those on irrigation, sustainable management practices, and post-harvest loss reduction.

Tensions will be created not only at the level of actual measures but also during policy development, coordination, and review. In the Nigerian context, specific challenges emanate from the lack of coordination between federal-/state-level priorities and local needs and challenges, which leads to inefficiencies and limited access to financial resources (Ecker

et al., 2021). As mentioned during the consultations, integrating a focus on nutrition and healthier diets into agricultural and food security efforts and programs could help increase positive synergies from limited resources (Box 3). Thus, improving the capacities of agencies both vertically and horizontally to promote coherence and adopting a multisector approach could help prioritize interventions with benefits across different sectors and help address implementation issues. While several donor-implemented projects already address the need for capacity development of state and national governments (USAID, 2020), to strengthen policy systems relating to resilience, food and nutrition security, and agriculture (Feed the Future, n.d.), and to design more effective policies relating to agricultural production and investment flows (USAID, 2019), additional efforts are needed to identify additional sources of financing, both domestic and donor.

Nigeria will need to decide what trade-offs it is willing to make based on the best available evidence while maximizing synergies at the same time. To some extent, new policies and interventions can help manage and mitigate some of the tensions. For example, Nigeria's strong focus on improving productivity and addressing GHG emissions from agriculture, together with efforts to improve value chains, including by reducing food loss and waste, can contribute to increasing food availability. In this context, the production of animal protein would need to become more GHG efficient to balance the trade-offs between the required significant increase in animal-source foods for healthier diets and the need to minimize agricultural GHG emissions. These efforts should go hand-in-hand with addressing the immense productivity gap in agriculture, particularly in the livestock sector. This is typically achieved through more and better feed and improved animal health—and most of these measures are included in Nigeria's agricultural development strategies.

Another key factor is how manure is dealt with, as it accounts for a large portion of GHG emissions from animal agriculture. The model includes interventions that collectively offer some proxy for interventions to improve the GHG efficiency of animal agriculture, such as R&D, extension services, and livestock subsidies for agroforestry and improved forage. The GHG limits also bias the model against ruminant meat since ruminants are much more GHG intensive per calorie than eggs, poultry, pork, fish, and other non-ruminant foods. The results point to the importance of public investment in measures that promote emissions-efficient animal-source foods, especially since consumption of these foods will tend to increase as incomes rise, even without public intervention.

Finally, as mentioned earlier, indicators for farm-level, individual, household, system-wide, and aggregate outcomes need to be designed in a way that would account for possible trade-offs so that policy-makers and other stakeholders are able to track progress in managing these trade-offs and adjust policies along the way.

4.0 Methods for Researching and Modelling Food System Transformation

This section presents the methods and approaches used, including a review of academic and grey literature, policy documents, national plans and programs, donor-funded projects, several rounds of stakeholder consultations, and microeconomic modelling to map dietary diversity and macroeconomic modelling to estimate the additional public costs of policy interventions.

4.1 Methodological Approach: Literature review and consultations

The literature review focused on peer-reviewed literature, reports and briefing notes developed by major agencies such as the FAO, the World Bank, major development agencies (GIZ, USAID, UK aid, and others), as well as the country's policy documents. To access peer-reviewed literature, we searched the ScienceDirect database (www.sciencedirect.com) for papers focused on Nigeria and papers outlining regional trends with specific details on Nigeria regarding issues such as climate change adaptation, food security, nutrition, and agriculture. We covered the period from 2017 to 2022 (papers in pre-publishing). A total of 1,656 papers were collected. The research team briefly screened the abstracts of the papers, and those papers that were deemed relevant were included in the study. For reports and briefing notes by international and government agencies, we visited the agencies' websites and reviewed their publications for the 2010–2022 time period. A total of 45 documents were collected. Finally, we reviewed strategies and policy documents published by ministries and government agencies in Nigeria and selected 18 documents for the 2010–2022 time period. The findings from these sources informed our understanding of current trends and policy-making priorities with respect to agriculture, food security, nutrition, and the environmental and climate change impacts of agricultural production; fed into the consultations; and informed the selection of interventions included in the model.

To inform the development of pathways for food system transformation, the research draws on three rounds of consultations with in-country stakeholders and an inventory of ongoing development projects and policies. The consultations, which targeted EU delegations, GIZ clusters, USAID missions, and national partners, included online and in-person events, as well as surveys. To support the consultations, a non-exhaustive desk review was undertaken to review the current (or recently terminated) projects implemented and/or funded by GIZ, the EU, and USAID. Only projects that had a degree of focus on two or more aspects of our nexus were included for review. Overall, 10 projects were reviewed. See Bizikova et al. (2022) for the names, objectives, and strategies of the projects included.

The consultations offered stakeholders the opportunity to feed into and provide feedback on the research process, results, and findings at various stages. The consultations also sought to validate the model targets for healthier diets in each country. In addition, a network of experts that formed as a result of their participation in the consultations engaged in disseminating the results of the research, which helped develop joint ownership of the final recommendations

and increased the probability of utilization of the research. For a detailed overview of the consultations, see Appendix A.

4.2 Methodological Approach: Quantitative modelling

The findings of the literature review and consultations were integrated into a hybrid micro- and macroeconomic modelling approach to the food system of Nigeria, based on the analytical framework developed in the Ceres2030 project (www.ceres2030.org).[9]

As part of the project's modelling approach, and as another important contribution of the project, a microeconomic analysis of changing diets, food habits, and nutrition was undertaken. To do so, micro-level consumption data from the LSMS was aggregated into multiple sets of categories. This "meso-level" data was then linked to disaggregated macro-level statistics. The microdata was used to perform a cluster analysis: a data-driven approach that allows households to be classified based on commonalities in observed diets, complementing top-down analysis based on observed household characteristics (such as urban/rural status). The detailed microdata enabled us to estimate a demand system for the country so that our CGE model estimates of how dietary patterns change in response to changes in income are driven by household survey reports. Full details of the microeconomic approach are described in Appendix B.

4.2.1 Scenarios for Identifying Policy Pathways and Costs

In order to identify potential pathways for food system transformation, the findings from the stakeholder consultations, literature review, and microeconomic analysis have been used to apply a CGE model[10] hybridized with microeconomic household modelling to project two future scenarios until 2030:

- **Baseline scenario:** This scenario is a projection of the focus countries' economies, based on current trends, without additional public spending. We make the assumption that agriculture-related GHGs are kept to the countries' NDCs. When no specific targets for agriculture are defined, the evolution, in percentage, of the nationwide target is applied to agriculture.
- **Food System, Climate Change, and Healthy Diets Transformation scenario:** This scenario addresses the key challenges laid out in Section 2. Specifically, the PoU is reduced (to less than 3%), nutritious food targets to achieve healthier diets are reached (e.g., fruits and vegetables and animal-source proteins), the average net incomes of small-scale producers doubles in 2030 compared to 2015 levels, and agriculture-related GHGs are kept to the countries' NDCs. These four targets are related to SDG targets 2.1, 2.2, 2.3, and 2.4, respectively.

[9] See Laborde et al., 2020a and 2020b for more information.

[10] The model is adapted from the MIRAGRODEP model. See Laborde et al. (2013). MIRAGRODEP 1.0: Documentation (AGRODEP Technical Note). IFPRI.

4.2.2 Establishing Model Targets for Food System Transformation

To model and provide a costing for sustainable food system transformation, quantitative targets are required. The model seeks the achievement of zero hunger (SDG 2.1), a nutritious food target to achieve healthier diets (SDG 2.2.), a doubling of the incomes and productivity of small-scale producers (SDG 2.3), and the constraining of GHG emissions in agriculture (SDG 2.4).

Hunger and Poverty

Corresponding to SDG target 2.1, the model simulates the removal of households from the status of hunger, as defined by the FAO's PoU metric. Specifically, the level of undernourishment in the country is reduced to less than 3%.

Healthier Diets

Nigeria adopted Food-Based Dietary Guidelines in 2001, which were reproduced in 2006. In order to estimate costs for achieving healthier diets, there is a need to establish a quantitative target in the model. Three quantitative targets are used in the model as key indicators of a healthy diet. With a food group-based approach, we model diets that are "healthier" than current diets rather than achieving a "universally healthy" diet. Under current policy scenarios, "universally healthy" diets will not be feasible by 2030 for all Nigerians. Additionally, there is no singular "healthy" diet since multiple healthy diets (diets that differ by the exact food group composition but are each healthy) are possible, and cultural acceptability, preferences, and other aspects of appropriateness can vary within Nigeria. The targets therefore represent progress toward healthier diets, balanced with an assessment of what could feasibly be achieved in the next decade.

Based on national and international guidelines and policy documents, a review of nutrition literature, and expert consultations, we have focused on three targets for achieving healthier diets in Nigeria:

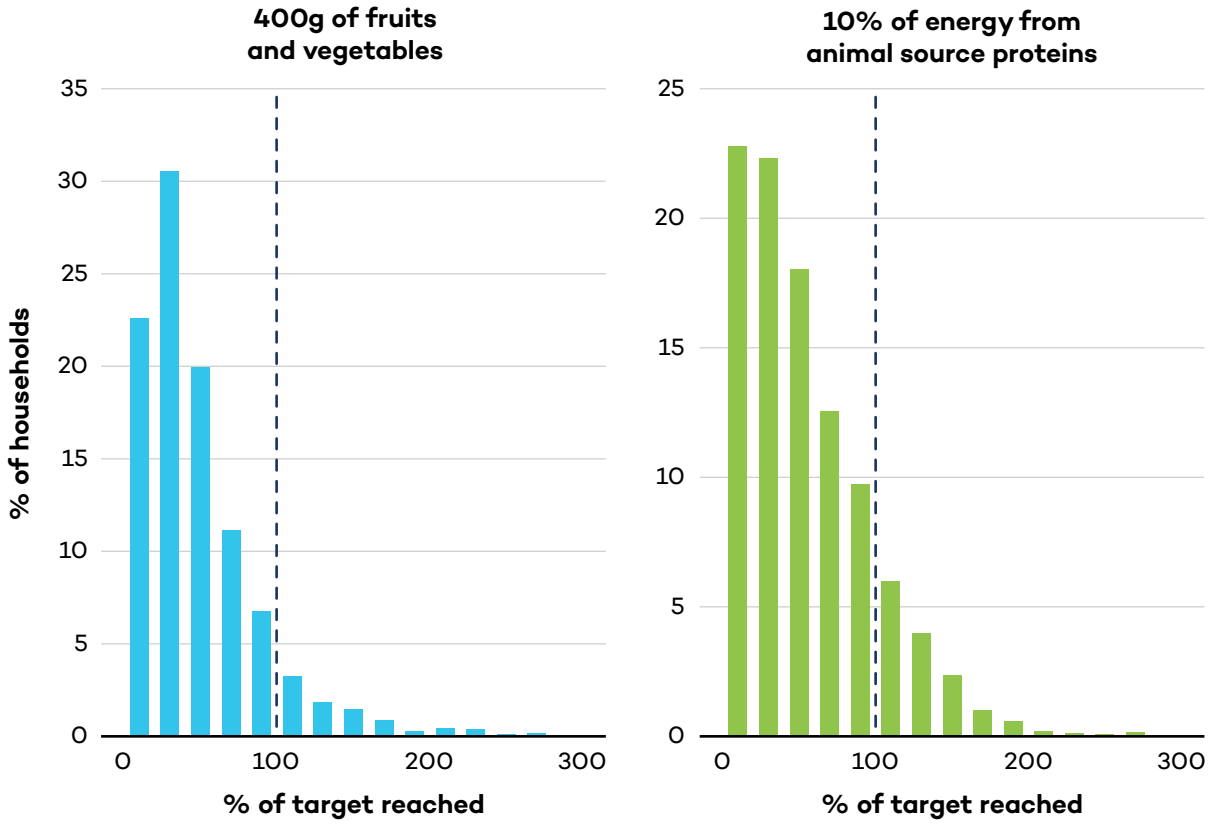
1. **Overall caloric intake**, measured using the PoU, with a target of less than 3% PoU in each country.
2. **Adequate consumption of non-starchy vegetables and fruits**, based on WHO guidelines of 400 g of fruits and vegetables per day (FAO & WHO, 2003; WHO, 2020).
3. **Adequate consumption of animal-source foods** (including dairy) through a minimum target of at least 10% of households' overall caloric intake to ensure calcium and vitamin B12.

A set of targets for sufficient caloric intake at the household level is based on the modelling of household consumption in comparison to calorie requirements (FAO, 2001), adjusted for the age and sex of household members. For fruits and vegetables, a minimum target of 400 g per person per day is set based on WHO guidelines, adjusting for household demographic characteristics (FAO & WHO, 2003; WHO, 2020). As with caloric intake, the target is adjusted for each household in the sample based on the age and sex of its respective members. Vegetables and fruits are important for meeting a wide variety of micronutrient

needs, including vitamin A and iron, which are commonly insufficient in diets. An overall minimum target for animal-source foods, including dairy, is set to at least 10% of households' overall caloric intake. The inclusion of animal-source food in the diet is a key means for at-risk populations, especially children, to get sufficient amounts of nutrients, such as zinc, iron, vitamin A, vitamin B12, calcium, and selenium. All targets apply to all households in the population. Full documentation of our dietary targets' selection can be found in Bizikova et al., in press.

While the dietary targets are relatively general, their achievement would indicate large nutritional progress for Nigeria. Figure 13 shows the distribution of households in Nigeria for two of these indicators by the share of the overall target achieved.[11]

Figure 13. Current distribution of households, by share of healthy diets target



Source: Authors' analysis based on LSMS-GHS Nigeria Combined Questionnaire, Harvest Questionnaire Wave 4 2018– 2019 (World Bank, 2019) and nutritient coefficients based on FAOSTAT-SUA (FAO, 2021a).

[11] For visualization, a small number of households whose share exceeds 300% are excluded from the figure.

Smallholder Income

SDG target 2.3 envisions the net incomes of small-scale producers doubling on average between 2015 and 2030.

Climate Change Mitigation and Adaptation

While it is not possible to integrate climate change adaptation (SDG 2.4) directly into the cost modelling, it is important to achieve resilient agricultural production, and consideration of the impact of—and impacts on—climate change is central to our nexus approach. To reflect this, we follow the approaches of the water–energy–food (WEF) nexus that highlight the critical importance of including climate change impacts and responses.[12] Climate change is integrated into the model by accounting for the gradual impacts of climate change on crop production using FAO crop projections under climate change. This approach suggests that by 2030, climate change will lead to less than a 10% drop in production for major crops in sub-Saharan Africa, especially if drought-resistant crops are planted (Malhi et al., 2021). In the model, GHG emissions for agriculture conform to the commitments made in the countries' intended NDCs or NDCs. For Nigeria, the country's NDC targets reduction efforts by 2030 (FRN, 2015b, 2021b). In the model, the country has a carbon budget (permitted GHG emissions) for agriculture, and land-use emissions and emissions from energy and fertilizer use are included in this budget. The model maintains the budget through a domestically determined carbon tax.

4.3 Portfolio of Interventions

The complex interrelationships among the key food system challenges require a balanced mix of interventions. For example, the necessary changes in consumption patterns to progress toward healthier diet targets will require—and trigger—changes in production patterns. Those changes will have to be compatible with the shift toward a more resilient agriculture and food system, in particular in the context of climate change mitigation (reduction of GHG emissions) and adaptation (resilience to weather variability and the changing climate). While climate-smart agriculture addresses production-side issues, diets must also adapt to allow for more environmentally sustainable food systems. Food system interventions should therefore not be considered as isolated fixes but rather as an integrated portfolio designed to meet complex objectives.

The set of interventions included in the model represents such a portfolio of interventions, designed to leverage synergies and balance trade-offs within food system transformation. In total, there are 15 interventions integrated into the model. These represent a combination of all 13 interventions used in Ceres2030 and an additional two interventions that specifically target nutrition:[13] nutrition education[14] and school feeding programs. In consultations,

[12] Recent WEF nexus studies often call for a climate change, water, energy, and food nexus (Hoff, 2011).

[13] The quantitative inclusion of interventions in our research is limited by the availability of detailed, relevant costing information, which is required to integrate an intervention into the modelling framework.

[14] Participants in the consultations in Malawi noted that nutrition education should also qualitatively include social and behavioural changes.

national stakeholders in Malawi, Ethiopia, and Nigeria emphasized the importance of opportunities to increase nutritional outcomes through changes to school curricula, the introduction of dietary guidelines in school feeding programs, or in improvements to the provision of food in boarding schools. It was noted that these interventions would work toward addressing the nutritional challenges and stereotypes that emerge in children at an early age. Stakeholders in all three countries emphasized that the production of diversified crops would not be effective unless accompanied by education on their utilization, storage, and the end products that can be created. Nutrition education and school feeding programs are therefore crucial complementary measures to maximize the effectiveness of supply-side interventions.

The 15 interventions are categorized into three broad action areas based on the Ceres2030 framework—"Empower the Excluded," "On the Farm," and "Food on the Move." The interventions are broken down into categories and summarized in Table 2.

Table 2. Policy interventions included in the model

Category	Interventions in the model
Empower the excluded	1. Social protection (food subsidy)
	2. Vocational training
	3. Nutrition education
	4. School feeding programs
On the Farm	5. Investment subsidy
	6. Fertilizer subsidy
	7. Production subsidy
	8. Capital endowment
	9. R&D
	10. Extension services
	11. Rural infrastructure (irrigation)
	12. Livestock subsidy (agroforestry)
	13. Livestock subsidy (improved forage)
Food on the Move	14. Storage (post-harvest losses)
	15. Rural infrastructure (roads)

Shaded interventions linked to adaptation.

Note: Nutrition education and school feeding programs are included based on feedback from stakeholder consultations to ensure stronger targeting of nutrition in the model.

The interventions were selected based on their relevance for addressing the multi-dimensional challenges of the food system and their potential to deliver on hunger, diet, small-scale food producer income, and climate change mitigation and adaptation targets. At the systemic level—and through the model interactions—all the interventions contribute to improved diets and could lead to stronger resilience to climate change of the food system and its actors. Nonetheless, how each intervention affects each of the four modelled targets can be complex, particularly because the model accounts for both direct and indirect effects on the economic system. However, there are some rules of thumb for how the modelled interventions affect each target.

- **SDG 2.1 (hunger):** Generally, any intervention that increases household incomes can contribute to reducing hunger. For example, a social protection program, like a food subsidy or direct cash transfer, increases the income of a household and their ability to buy more food.
- **SDG 2.2 (nutrition):** Similarly, anything that increases income allows people to improve their diets. As incomes increase, households tend to increase their consumption of animal-source foods, while increases in the consumption of fruits, vegetables, legumes, nuts, and seeds tend to be relatively small compared to increases in income. Actions that decrease the price of important under-consumed food groups relative to other foods can also play a role in improving diets.
- **SDG 2.3 (small-scale producers):** Poverty reduction is critical in the countries studied. Thus, anything that increases the incomes of small-scale producers, including income from non-farm sources, or allows those unable to make good livelihoods in agriculture the option to do something else, contributes toward the target of doubling the income of small-scale producers. Examples of this include investment subsidies to help small-scale producer households increase their agricultural income, vocational training to enable employment that is more lucrative than agriculture, or social protection programs that provide non-farm income.
- **SDG 2.4 (sustainable agriculture):** Anything that improves the GHG efficiency of agricultural production or other components of the food system helps limit overall GHG emissions from agriculture and land use. While interventions such as agroforestry subsidies have obvious benefits for GHG mitigation, interventions like fertilizer subsidies can also increase the overall GHG efficiency of a crop's production. When used in a context where fertilizer use and yields are very low (as is the case in Nigeria), fertilizer subsidies can lead to land savings outcomes, delivering higher yields on existing cropland, which could reduce deforestation and slash-and-burn practices.

The impacts of climate change on average temperatures and rainfall are included in the model, but due to the 2030 time horizon, they play a minor role in the assessment. However, given the increased frequency and intensity of extreme weather events in all three countries, there is a need to scale up public investment to increase the climate resilience of food systems. Of the 15 interventions included in the model, nine contribute to building resilience and promote adaptation to climate change (see Table 2). While all the interventions should be designed and implemented in a diet- and climate-sensitive way, these nine interventions are in line with climate change adaptation priorities as stated in national policy documents,

peer-reviewed literature, and stakeholder feedback in the three countries. In addition to contributing to climate change adaptation, these interventions promote the economic resilience of small-scale producers and their households by improving food production and access to diverse agricultural inputs, increasing incomes, and providing access to financial services and social transfers for small-scale food producers with limited capacities. This type of synergistic approach, with interventions simultaneously progressing toward multiple, complex targets, is at the core of the food systems notion and is critical if the targets of SDG 2 are to be met by 2030.

4.4 Limitations and Challenges of the Methodological Approach

As with any nexus study, we face a number of challenges due to the complexity of the nexus's elements and its translation to a quantitative model. Limitations include our inability to incorporate gender issues, extreme weather/climate events, regional differences, and institutional challenges. The constraints we are most concerned about include modelling within-year variation in hunger and diets and modelling at the individual level, especially with respect to gender. This section provides an overview of critical aspects impacting the food system, including climate change, nutrition, and other challenges, that we were unable to integrate into the model.

4.4.1 Data Limitations

The microdata used in the analysis were intended to give the best possible representation of diets in Nigeria. The primary data source is the World Bank LSMS, which provides interview data drawn nationally and sub-nationally from representative samples of households in each of the target countries. As part of each interview, data on food consumption is recorded over a 7-day recall period. This forms the basis of our estimation of current and projected dietary trends.

Gender and Other Individual Characteristics

The unit of observation for the LSMS surveys is the household, and hence food consumption is reported at the household level. This is logical both from an economic perspective, since food resources are typically pooled (i.e., food is purchased for and consumed by the household), and from a practical perspective, since it would be extremely difficult and costly to obtain individual-level food consumption data at a nationally representative level. A key consequence for the analysis is that it is now possible to observe the intra-household allocation of consumption items: while it is possible for a given household to observe what the average household member consumes, it is not possible to attribute individual consumption levels. For a household with male and female members, it is not possible to attribute the amount of a given food item consumed by males versus females, and hence it is not possible to make gender-disaggregated comparisons. This is an important limitation to the analysis that we hope can be addressed in the future through improved resources and methods for gender-disaggregated data collection.

Seasonality and Its Impact on Diets

Many of the households in Nigeria experience variation in the availability and price of different food items at different points in the year. This is particularly true of certain categories of perishable items such as fruits, which may only be available in some areas for limited periods. Similarly, where market integration is limited, the price of locally produced staple crops may be low around harvest season and high during planting season. These and other factors contribute to seasonal variation in diets, resulting in differences in the quantity of macro- and micronutrients individuals receive at different points in the year. There is variation in the timing of surveys that allows us to partially observe seasonal variation across households (see Bizikova et al., in press). However, since each household was not interviewed at all points in the year, we do not observe seasonal variations within households. Our estimates therefore reflect average consumption in a given year. Within-year variation in diets is an important concern that should be considered in the design and implementation of nutritional and other interventions relating to food consumption.

Use of Non-Standard Measurement Units

Food items are frequently purchased, exchanged, and consumed in quantities that respondents may not be able to easily estimate in terms of standard units of weight or volume. For example, a respondent will typically report consuming a bowl of porridge rather than a number in grams or millilitres. Efforts were made during the survey process to get the best possible estimates of these measures through discussion with respondents and the use of standardized visual aids, with auxiliary data also collected from local markets to enable the conversion of non-standard units to metric units. While these procedures reduce measurement error in quantities, some noise in estimates remains, and, for a small group of rarely consumed food items, it is not always possible to convert the reported amount into metric units. We discuss these conversion issues in greater detail in Bizikova et al., in press.

4.4.2 Impacts of Extreme Events

While our research approach considers gradual responses to climate change, impacts of extreme events such as droughts, floods, and heavy rainfall pose a serious challenge for our analyzed countries. For example, in Nigeria, natural disasters including droughts, floods, diseases, and pests (specific to some regions) have affected the livelihoods of significant numbers of people (FRN, 2015b). Interventions included in our model indirectly contribute to increasing the resilience of farming households through improved food production, access to healthier food, and access to diverse agricultural inputs. However, analysis of the frequency and intensity of extreme weather events and their impacts that might affect these outcomes was beyond the scope of this project.

4.4.3 Institutional Challenges

In practice, agricultural, food security, and nutrition policy interventions can be delivered in a variety of ways that rely on different delivery mechanisms and supporting systems. This study includes information on income, seasonality in rates of undernourishment, gender and family status, and model factors such as access assets and caloric intake (Bizikova et al., 2022). Other

factors that are also important in shaping effective interventions in this context include the use of formal and informal institutions, access to knowledge and physical infrastructure, as well as consideration of social, historical, and cultural conditions when promoting the interventions. In our study, for instance, we consider the impact of food subsidies (e.g., food stamps) that can be delivered through universal unconditional cash transfer, depending on the country context. Our model does not currently integrate an appraisal of institutions and delivery mechanisms that would likely speed up implementation or increase effectiveness. Yet, such delivery mechanisms are critical and often include agencies of central or regional governments (or other public or non-governmental entities) to ensure that, for example, a fertilizer subsidy reaches its intended beneficiaries. For more accurate estimates, institutional preparedness and the effectiveness of delivery of interventions should be considered in future work.

5.0 Recommendations and Conclusions

Nigeria is way off track to achieving the SDGs by 2030. Without more and better public investment, hunger and poverty will rise, healthy diets will remain unattainable for most of the population, GHG emissions will continue to grow, and the impacts of climate change will become more extreme and frequent. This is not how the UN 2030 Agenda was meant to unfold.

All of this could be reversed. This report shows that Nigeria needs an additional USD 4.9 billion between now and 2030 to end hunger, double the incomes of 14.6 million small-scale producer households on average, transition to healthier diets for 126 million people, maintain GHG emissions in agriculture to Nigeria's NDC, and increase resilience to climate change.

This report recommends that the Government of Nigeria and its development partners:

1. **Urgently and significantly increase public investment by an additional USD 4.9 billion per year from 2023–2030 to achieve the transition to sustainable food systems.** Development partners should provide an additional USD 2.3 billion on average per year for 8 years (2023–2030), from a current baseline of USD 114 million per year. The Government of Nigeria should provide an additional USD 2.6 billion per year. This will reverse the severe underfunding of the longer-term investment needs for agriculture and to achieve food security and nutrition.
2. **Increased spending is needed in all areas: on and off the farm and through social protection programs.** An additional USD 2 billion per year on average is needed to improve farm productivity and incomes; an additional USD 1.6 billion per year on average is needed for social protection, education, and school feeding programs; and an additional USD 1.3 billion per year is needed to move food to markets. Interventions should focus on enabling access to inputs, including quality seeds and fertilizer and quality irrigation and harvesting systems (FRN, 2014, 2016).
3. **To transition to healthier diets, nutrition education must accompany on- and off-farm investments to improve consumer choices.** Attention needs to be given to the design and implementation of nutrition-sensitive interventions in order to achieve multiple and complementary outcomes. Initiatives that provide nutrition education and deliver advice on storing and utilizing diverse, nutritious food products are critical to complement and maximize the impact of social protection programs, nutrition programs, and agricultural productivity programs.
4. **Ensure climate resilience and adaptation are integrated into agriculture and food system policies and programs.** Interventions identified through the modelling in this report are in line with Nigeria's efforts to promote climate-smart agriculture by targeted extension services, improved crop choices, investment in machinery, and access to improved animal feed and breeds to protect soils and biodiversity, conserve water, and limit land-cover change. In addition, donor support could be targeted to GHG emissions-reduction efforts, thus contributing to the more ambitious mitigation target reflected in Nigeria's updated NDC (FRN, 2021b), which is conditional on such support. Gender equality and women's empowerment must be considered when the above integrated measures are designed.

5. **Scale up support for environmentally sustainable intensification** to improve both plant and livestock productivity. Given that this is a top priority for Nigeria, the government and development partners should allocate additional resources to implement the goals and actions listed in its relevant strategies supporting growth in productivity, including those focusing on climate-smart agriculture. Policy interventions need to enhance the availability of and access to improved fodder, veterinary services, and improved breeds and to address conflicts in grazing area allocations (FRN, 2016, 2021b). New donor-funded projects should focus on the livestock sector, which therefore represents a potential area for impactful future investment.
6. **Focus interventions and policies to reduce post-harvest losses and improve food safety on better road networks and storage capacities, including cold storage.** Such interventions should be prioritized to enable producers to reduce losses during production and storage of foods. To support the transition to healthier diets, such investments could include cold storage and preservation of food items, such as vegetables, fruits, and animal products and fish, to improve food safety.
7. **Increase support for regional and national institutions to improve capacity to monitor, analyze, and inform on progress and achievements.** This will enable institutions to better support the transformation of sustainable food systems, including by collecting disaggregated data to account for subnational and gender differences.

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Appendix A. Research Questions

The project will answer seven research questions by applying them to the three countries, Ethiopia, Malawi, and Nigeria, and is aimed at studying the food system transitions and supporting decisions to trigger transformative changes:

1. What are the expected trends in terms of diets for the three countries?
2. What is the definition of a healthy diet for a country, considering cultural and economic specificities and the nutritional value of different food items?
3. Based on micro-econometric evidence, how well do we understand consumer decisions regarding food, in particular in transitioning food systems (for example, with rising income, urbanization, food processing, and food consumed away from home)?
4. What are the policy instruments and the food system innovations required to achieve healthier diets?
5. What are the costs and benefits, both in economic and environmental terms (GHG focus), of these diets, and what is their mitigation value?
6. Considering the answers from questions 2–4, what is the most efficient set of actions to achieve this transformation? (Criteria to assess efficiency include these factors: feasibility, potential costs/benefits, gender-transformative or -sensitive aspects, if applicable).
7. How do the different sets of actions in question 6 translate in terms of weather or climate risk exposure to the future food systems?

Appendix B. Country Consultation

The project encompassed three rounds of country-level consultations that focused on linking the research conducted in the two other components—the large-scale modelling exercise based on the Ceres2030 modelling framework and the research into food demand behaviour at the household level—with the country policy and institutional environment and ongoing projects.

More specifically, the objectives of the consultations were threefold:

1. To produce an accurate inventory of ongoing projects and policies impacting our main research question in order to identify potential strategy gaps by development actors and integrate country actions as much as possible into the modelling exercise.
2. To validate our operational definition of healthier diets in each country and guarantee that various stakeholders feel confident in using our criteria.
3. To disseminate the results of the research and develop joint ownership on the final recommendations, and increase the probability of utilization of the research in the short term (food system discussions) and long term (country-level strategies).

The three objectives listed above directly translated into three different rounds of consultations for each country.

First Consultation

The first set of consultations consisted of a round of online surveys, supported by bilateral phone/zoom interviews. The consultations aimed to assess how the nexus between food security, environmental sustainability and healthy diets are integrated in various agencies' strategies and national policy framework. In particular, it identified existing initiatives and projects aimed at incentivizing healthy diets (consumption lens) as well as projects aimed at fostering the climate-smart production of nutrient-dense food. This stage informed the scope of policy instruments to be considered but also the cost information, and potential benefits, from monitoring and evaluation reports to improve the costing information included in the Ceres2030 model. For more details on the process and findings from the first round of consultations, including a list of donor-funded projects relevant to the nexus of food systems, climate change, and healthier diets, see the Nigeria Country Diagnostic Report (Bizikova et al., 2022).

Second Consultation

The second consultation was organized as an Independent Dialogue of the United Nations Food Systems Summit, and was held on June 24, 2021. The Dialogue was organized in collaboration with the Senior Special Assistant to the President on Agriculture, Office of the Vice President of Nigeria. The consultation included a group of 20 stakeholders and national actors. See https://summitdialogues.org/dialogue/29345/ for more details.

The specific purpose of the Dialogue was to receive inputs on reasonable steps toward a food system transition pathway to healthier diets in Nigeria. Specifically, the focus of the Dialogue was to receive input and feedback from stakeholders on proposed context-sensitive healthy diets, what they view to be the criteria and considerations for healthier diets and food system transformation, and the possible interventions and policies to achieve this based on their prior experience and opinion on potential opportunities.

One of the main areas of discussion in the Dialogue was the conception of a "healthier" diet, the current policy frameworks regarding nutrition in Nigeria and the challenges that exist with regard to their implementation. Here, the main finding was a need to enhance interaction and coherence between state and federal policy creation and implementation for a concerted effort to embrace a multisector approach to nutrition. A second main finding was an agreement that, while addressing malnutrition as a major issue facing Nigerians, the international community's tendency to move past caloric intake toward healthier diets represents a worrying trend that ignores massive issues regarding food availability.

The second main area of discussion focused on the interventions that could address the challenge of increasing the availability of food (production-side interventions) and for the consumption of "healthier" diets. One of the main findings here was a need to increase agricultural research on the food system. Only with improved data on the food system can effective interventions be implemented to create a sustainable food system transformation in Nigeria. Other findings included an identification of the possibility of increasing social protection, the consumption of biofortified crops, and the delivery of nutrition education, especially when provided with consideration to cultural and seasonal variation.

For a more detailed report on the second consultation, see https://summitdialogues.org/dialogue/29345/official-feedback-29345-en.pdf?t=1627397593 .

Third Consultation

A final e-consultation was held in which the final draft of the country report was presented to a wide group of national and international stakeholders for feedback. These comments were taken into consideration before the final versions of the reports were published and disseminated.

All the feedback, questions, and comments received during the rounds of consultations fed into this final country report.

Appendix C. Microeconomic Approach

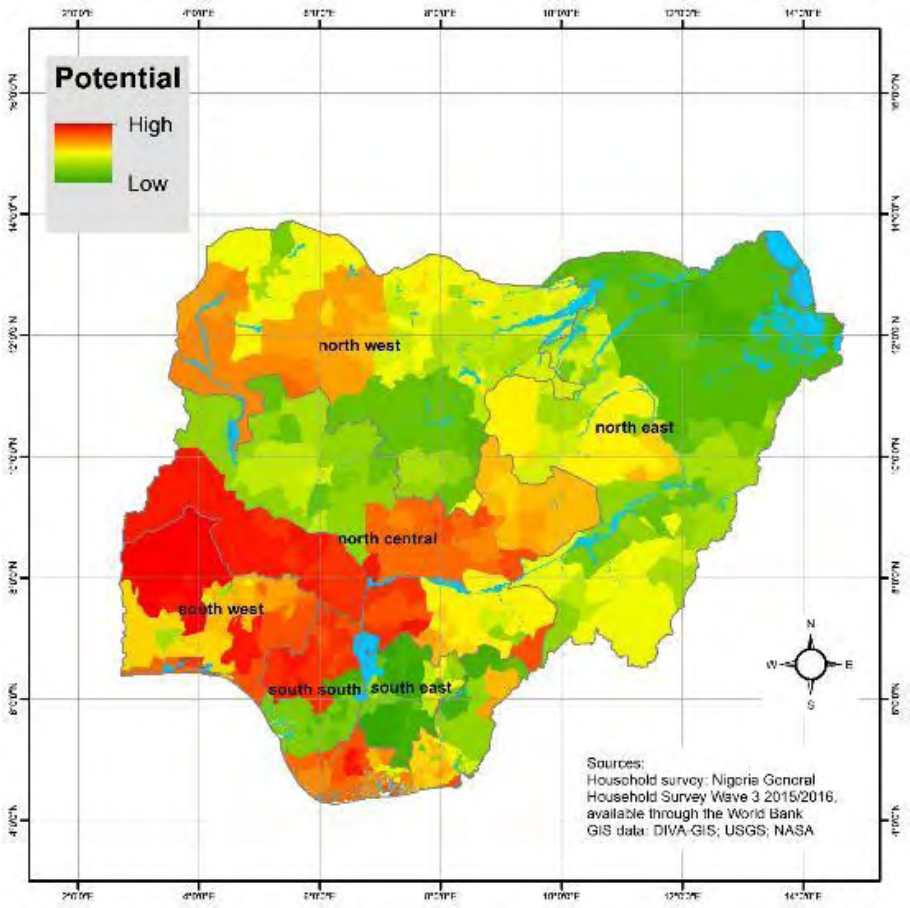
Table A1. Summary statistics of key nutritional indicators

		SD	Min	Max.	N
Calories (Kcal)	**1,896.67**	**920.18**	**0.00**	**10,173.76**	**4973**
Cereals and starches	1,297.51	679.18	0.00	6,366.79	4973
Legumes, nuts, and seeds	154.58	127.44	0.00	1,958.85	4973
Vegetables	28.22	23.15	0.00	338.57	4973
Fruits	30.75	42.39	0.00	403.10	4973
Dairy	13.81	28.42	0.00	539.29	4973
Animal foods (excl. dairy)	88.76	87.43	0.00	1,420.48	4973
Vegetable oils	228.92	177.20	0.00	1,865.37	4973
Sweets and alcoholic beverages	54.11	71.09	0.00	1,007.16	4973
Protein (grams)	**107.88**	**63.31**	**0.00**	**639.88**	**4973**
Cereals and starches	23.78	14.32	0.00	122.18	4973
Legumes, nuts, and seeds	8.78	6.87	0.00	90.68	4973
Vegetables	1.37	1.06	0.00	12.35	4973
Fruits	0.41	0.51	0.00	4.54	4973
Dairy	0.91	1.94	0.00	42.53	4973
Animal foods (excl. dairy)	11.39	11.59	0.00	198.67	4973
Vegetable oils	61.21	47.96	0.00	490.41	4973
Sweets and alcoholic beverages	0.04	0.09	0.00	1.60	4973
Fat (grams)	**45.07**	**29.34**	**0.00**	**328.73**	**4973**
Cereals and starches	5.61	4.20	0.00	44.80	4973
Legumes, nuts, and seeds	5.61	7.79	0.00	112.00	4973
Vegetables	0.46	0.87	0.00	18.58	4973
Fruits	0.12	0.16	0.00	1.52	4973
Dairy	0.51	1.43	0.00	50.19	4973
Animal foods (excl. dairy)	4.16	4.16	0.00	57.04	4973
Vegetable oils	28.60	21.75	0.00	232.65	4973
Sweets and alcoholic beverages	0.00	0.00	0.00	0.09	4973

Source: Authors' calculations using LSMS Nigeria, Harvest Questionnaire Wave 4.

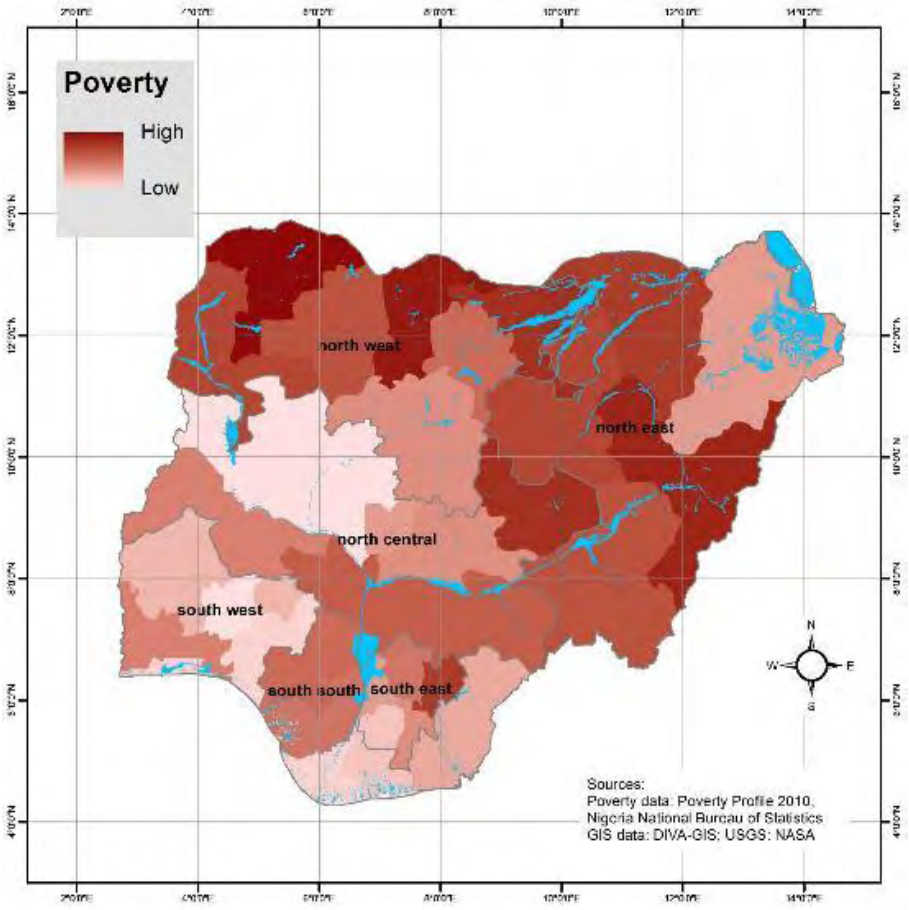
Appendix D. Maps

Figure D1. Agricultural potential in Nigeria



Source: Maruyama et al., 2018.

Figure D2. Poverty in Nigeria



Source: Maruyama et al., 2018.

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Ceres2030 is a partnership between academia, civil society, and economists, led by three institutions—Cornell University, the International Food Policy Research Institute, and the International Institute for Sustainable Development—who share a common vision: a world without hunger, where small-scale producers enjoy greater agricultural incomes and productivity, in a way that supports sustainable food systems.

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