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Food Systems in Conflict-Prone and Climate-Affected Areas of Northern Nigeria

Humanitarian and Development Challenges

Bedru Balana
Steven Were Omamo
Mulubrhan Amare
Olufemi Popoola
Chibuzo Nwagboso
Augustine Iraoya
Serigne Loum
Khusro Jawed
Kwaw S. Andam

Natural Resources and Resilience Unit
Development Strategies and Governance Unit

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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AUTHORS

Bedru Balana (B.balana@cgiar.org) is a Research Fellow in the Natural Resources and Resilience (NRR) Unit of the International Food Policy Research Institute (IFPRI), Washington, DC.

Steven Were Omamo (S.W.Omamo@cgiar.org) is Director of IFPRI's Development Strategies and Governance (DSG) Unit and Director for Africa, Nairobi, Kenya.

Mulubrhan Amare (m.amare@cgiar.org) is a Senior Research Fellow in IFPRI's DSG Unit, Washington, DC.

Olufemi Popoola (O.popoola@cgiar.org) is a Research Analyst in IFPRI's DSG Unit, Abuja, Nigeria.

Chibuzo Nwagboso (C.Nwagboso@cgiar.org) is a Research Analyst in IFPRI's DSG Unit, Abuja, Nigeria.

Augustine Iraoya (a.iraoya@cgiar.org) is a Research Analyst in IFPRI's DSG Unit, Abuja, Nigeria.

Serigne Loum (serigne.loum@wfp.org) is a Senior Programme Policy Officer, WFP, Abuja, Nigeria.

Khusro Jawed (khusro.jawed@wfp.org) is a Senior Supply Chain Officer, World Food Programme (WFP), Abuja Nigeria.

Kwaw S. Andam (k.andam@cgiar.org) is a Senior Research Fellow in IFPRI's DSG Unit, based in Abuja, Nigeria at the time of this study.

Abstract

Protracted conflict and climate shocks have profoundly disrupted food systems in northern Nigeria, yet little empirical evidence exists on how these shocks shape the functioning of the region's food system (production, transportation, value addition, and trade). This study addresses this evidence gap by combining GIS-based mapping, cost structure analysis, and investment opportunities in food production, transportation, processing, and trade in key staple commodities across conflict-prone and climate-affected areas of northern Nigeria and connected market hubs. The analysis quantifies cost structures for key food supply chain actors, identifies systemic food system inefficiencies driven by conflict and climate factors, and examines how these factors undermine both commercial and humanitarian food flows. By integrating commodity-specific diagnostics with stakeholder perspectives, the study offers an evidence-based rationale for prioritizing interventions in conflict contexts. Two investment cases—on-farm storage and localized wheat milling—illustrate how targeted actions can reduce losses, enhance resilience, and create co-benefits for humanitarian operations and market recovery. By combining food-flow maps and cost structures for multiple actors along the food supply chain in a high-risk environment, and by demonstrating simplified approaches to linking empirical diagnostics with practical investment strategies, the study's findings contribute to the literature on the functioning of food systems in conflict-prone and climate-affected contexts. In addition, the findings provide evidence to support policy changes, interventions, and investment decisions aimed at transforming food systems and addressing structural failures, while enhancing the efficacy of short-term humanitarian interventions. They also address the underlying causes of chronic food insecurity and support economic recovery in the region.

Keywords: Conflict, climate, cost structure, food system, food supply mapping, northern Nigeria

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1. Introduction

While a growing body of literature examines agricultural value chains and food systems in stable contexts, empirical evidence on conflict-affected regions remains sparse—particularly studies that quantify costs across multiple commodities and actors and links these to broader food system functioning. Most existing studies on conflict-affected settings focus either on the logistics of humanitarian food assistance or localized production systems, with little integration of the two. This paper addresses this gap by combining GIS-based mapping of food supply chains; quantitative cost structure analysis for producers, traders, transporters, and processors; and qualitative ground-truthing (field validation) from stakeholders in conflict-prone and climate-affected areas of northern Nigeria. This mixed-methods approach provides a data-driven view of how conflicts, climate shocks, and infrastructure deficits shape the performance and resilience of agrifood supply chains. In doing so, it not only documents current inefficiencies but also offers methodological insights on policy interventions or investments that can improve food systems in conflict-prone areas.

The growing prevalence of violent conflicts and changing climate present serious obstacles to achieving food security goals in many low- and middle-income countries (LMICs) such as Nigeria. As a result, improving livelihoods and welfare in conflict-prone, climate-affected settings remains a formidable development challenge. Rising global hunger is largely a result of these conditions, and projections indicate that by 2030, most people living in poverty will be concentrated in conflict-affected areas (Corral et al. 2020).

In Nigeria, conflict has severely disrupted food systems, driving recurring food crises and emergencies, particularly in the north and northeast regions. Once the country's breadbasket, these areas now face widespread vulnerability and food insecurity as violent conflicts and climate shocks undermine food production, processing, transportation, and marketing. This disruption occurs through multiple channels, including the impacts of conflicts on farmers' investment decisions, crop choices, and use of yield-enhancing modern inputs (Amare et al. 2024), as well as interruptions to food transport networks and infrastructure. The northeast region, in particular, exemplifies these challenges, with protracted violent conflicts disrupting the smooth functioning of food supply chains, restricting market access, and diminishing livelihood opportunities (OCHA 2024).

For more than a decade or so, humanitarian organizations, including the World Food Programme (WFP), have been responding to food insecurity challenges by delivering food assistance to communities grappling with conflict, displacement, and climate shocks. However, a critical knowledge gap remains in understanding how food systems function in the region—essential knowledge to supporting evidence-based policy decisions, interventions, and investments needed to address structural challenges and transform food systems. Research evidence based on empirical data and

analytics is needed to support the design of interventions, policies, and strategies for food system transformation. Such evidence is essential not only to ensure the efficacy of interventions in meeting immediate humanitarian needs but also to address the root causes of severe food insecurity and economic recovery.

This study focuses on key staple food commodities in WFP's food assistance package, known as the "food basket'[1] (sorghum, millet, maize and cowpeas), as well as on an important cereal outside the WFP food basket (wheat). This combination provides a broader food system perspective in the context of northern Nigeria. Wheat is the third most consumed grain in Nigeria after maize and rice, yet domestic production accounts for only 1 percent of the 6 million metric tons of the country's annual wheat consumption (Balana et al. 2022). Thus, wheat has significant implications for food security.

This paper examines food production hubs, trade flows, and transport routes along the supply chains of these selected commodities. It focuses specifically on costs and insecurity challenges among the key supply chain actors (producers, transporters, processors, and traders) in the conflict-prone states of Borno, Adamawa, and Yobe (BAY) in northeast Nigeria, as well as on the major food market centers and transport corridors in northern and northeast regions, including Kano, Potiskum, Kaduna, Zaria, Maiduguri, and Yola. The study's main aim is to generate research evidence for supporting decisions and investments that increase local food production and improve the operational efficacy of short-term humanitarian assistance. It also seeks to inform investments for long-term recovery through strengthening food system transformation.

This study makes a significant contribution to strengthening the knowledge base for food system transformation in Nigeria. Using a mixed-methods approach and empirical data, it identifies how production costs, logistics, market barriers, and policy gaps constrain food supply chain efficiency in the region. Findings from GIS-based supply chain mapping and cost structure analysis offer data-driven insights into the key financial, logistical, and structural challenges hindering food system functioning. A cost–benefits analysis further highlights areas of potential investment opportunities for food system transformation and resilience. Focus group discussions (FGDs) and key informant interviews (KIIs) offer insights from key supply chain actors, including farmers, traders, transporters, and processors. Qualitative insights supplement the quantitative findings and serve to ground-truth the operational and structural challenges affecting the functioning of the region's food system. By combining quantitative analysis with qualitative narratives, the paper presents a well-rounded, actionable approach for policymakers, food supply chain actors, and development partners seeking targeted interventions to enhance food systems in northern Nigeria.

[1] Detailed information on WFP's food basket is available at www.wfp.org/stories/wfp-food-basket.

The remaining sections of the paper are structured as follows. Section 2 provides a brief overview of the effects of conflict and changing climate conditions on food systems in northern Nigeria. Section 3 describes the study's methodologies, including data collection and analysis. Sections 4 and 5 present results from food supply mapping and cost structure analysis. Section 6 summarizes key insights from the qualitative findings. Section 7 presents findings from the cost–benefit analysis. The last section concludes with key policy recommendations.

2. Conflict, climate, and food systems in northern Nigeria

The contemporary agricultural system in northern Nigeria is rooted in centuries-old cultivation and land management practices. Shaped by the region's distinctive agroecological, climatic, and sociocultural characteristics (Barau et al. 2015), northern Nigeria plays a vital role in national food security. Unfortunately, this same region—once regarded as the nation's food basket—now faces acute food insecurity, driven primarily by more than two decades of violent conflict and increasingly changing climatic conditions (Ayanlade et al. 2022).

Violent conflicts, including the Boko Haram insurgency, the farmer–herder conflict, and armed banditry attacks, pose major security threats in northern Nigeria that affect lives, livelihoods, agricultural production, and food security (Adelaja and George 2019). The nature of these conflicts has evolved, marked by growing numbers of perpetrators, greater intensity, wider geographic spread, and deeper socioeconomic impacts. Though they vary over time and space, key drivers include competition over resources, ideological or political motives, and ethnic and religious factors. Boko Haram has been a major source of insecurity and conflict, mainly in northern and northeastern Nigeria. While the northeast experiences conflicts primarily because of the Boko Haram terrorist attacks, the farmer–herder conflict has also become a significant and persistent challenge in the country (Adelaja and George 2019).

These conflicts have caused widespread displacement, lost lives, and destruction of farmland and livestock, creating a cycle of violence and food insecurity known as the "conflict–food insecurity nexus" (Adelaja and George 2019). The resulting instability has disrupted agricultural production, undermined food supply chains, and heightened food insecurity in a region already grappling with economic and environmental vulnerabilities. The food system continues to experience multiple cascading effects from these conflicts. Farmers face reduced access to arable land and agricultural inputs, while herders struggle with restricted grazing routes and water sources. These disruptions limit productivity, destabilize rural economies, and weaken linkages among producers, processors, and markets. The protracted conflicts have also discouraged investments in agriculture, further constraining the sector's potential for recovery and growth.

Climate change and extreme weather events add another layer of challenge to those already posed by protracted conflicts affecting food systems (Oladunni et al. 2022). More than 90 percent of Nigeria's agricultural production is rainfed, making farmers highly vulnerable to erratic rainfall and extreme weather events (AfDB 2016). Shifting rainfall patterns and more frequent droughts are already placing future crop and livestock production at heightened risk (Tofa et al. 2021; Nigerian Meteorological Agency 2023). This climate-risk perspective underscores the need for targeted interventions to protect yields and rural livelihoods in the face of a changing climate (FMARD 2022).

Furthermore, smallholder farmers in the region face institutional inefficiencies (e.g., inadequate policies and market imperfections), infrastructural deficits (e.g., inadequate storage and postharvest technologies), and liquidity barriers (e.g., lack of access to agricultural credit) (Ikhuoso et al. 2020; de Brauw and Bulte 2021; Balana and Oyeyemi 2022). Gender inequalities further exacerbate these challenges, as women farmers encounter disproportionate obstacles in accessing resources and markets. These disruptions have hit hard, particularly for perishable goods, with postharvest losses exceeding 50 percent in some areas (Affognon et al. 2015; Adelaja and George 2019; Balana et al. 2022). According to the National Bureau of Statistics, a sharp rise in food inflation occurred in June 2024, with the food price index reaching 40.87, up from 25.9 percent in June 2023 (NBS 2024). The cumulative impacts of conflict, climate change, and socioeconomic barriers have severely weakened the region's food systems (Fadare et al. 2024), highlighting the need for transformative actions to strengthen them. Addressing the challenges requires a multifaceted approach that considers economic, social, and environmental factors. As conflict and climate shocks continue to disrupt food production and distribution, stabilizing the functioning of food systems becomes essential for national welfare and resilience. Investment in transforming agrifood systems and implementing climate-adaptative actions should be considered a priority policy for promoting inclusive economic opportunities and addressing the risks of food insecurity in the region.

3. Methodological approaches

The study comprised three key approaches. First, we mapped the supply chains of selected commodities, encompassing major production areas, transport corridors, processing, and market centers. Mapping was based on secondary data and validated by stakeholders. Second, we analyzed the cost structures of key actors along the value chains—food production, transporting, processing, and trade—by disaggregating costs into various components through a cost buildup approach. Third, we conducted a cost–benefit analysis to explore promising investment opportunities to help transform food systems in northern Nigeria. Through these efforts, our primary objectives were to (1) understand the structure and functioning of food systems, focusing on conflict-affected northeast Nigeria, and (2) identify key policy actions, institutional innovations, and investments needed to strengthen food systems and support agriculture-based recovery in the region.

3.1 Data collection

Quantitative primary data for cost buildup and cost–benefit analyses were gathered from farmers, food processors, transporters, and traders in selected communities and markets. Customized survey tools were used for cost and operations data from producers, processors, transporters, and traders. Farmers interviewed for production and cost data were selected from "farmer clusters"[2] producing each of the selected commodities. Transporters and traders were identified from the list of these operators working with WFP in the region, and face-to-face interviews were conducted. A total of 78 respondents participated in the quantitative study, including 61 farmers, 10 food traders, 3 processors, and 4 transporters. Additional secondary quantitative data were obtained from WFP's Research Analysis and Monitoring (RAM) team, the National Bureau of Statistics (NBS), the National Agricultural Extension and Research Liaison Services (NAERLS), agricultural research institutions, IFPRI's Dataverse, farmer associations, and market surveys.

For the qualitative data, FGDs and KIIs were facilitated by two trained local moderators (accompanied by an IFPRI research team) in the local Hausa language, then recorded, translated into English, and transcribed. A total of 65 respondents participated: 50 farmers across seven FGDs and 15 key informants, including food traders, processors, and transporters.

Data collection targeted three northern states—Borno, Adamawa, and Yobe (BAY)—due to WFP's significant interventions, and two more states—Kano and Kaduna/Zari—for their importance in regional food supply chains and logistics. The geographic scope of the study was therefore northern Nigeria, with a particular focus on the BAY states.

3.2 Analytical approaches

A mixed-methods approach was used in the study, consisting of (1) GIS-based food supply mapping, (2) cost buildup analysis, and (3) qualitative analysis. The GIS-based food supply chain maps were generated from secondary state-level data on production, processing, marketing, and major trade routes of the selected commodities. These data were validated by a series of workshops with relevant stakeholders.

The cost buildup analysis focused on the cost structure of selected commodities. An input-based cost approach was used for producers by organizing costs into the following categories: land rental, inorganic fertilizer, organic fertilizer, seeds, agrochemicals, and machinery. Key items for food traders included grain purchase, transportation, cleaning and packaging, interest in borrowed capital, and warehousing. For food transporters, vehicle rental and labor were the main costs, while for processors, raw material, labor, and utilities were the primary costs. Cost buildups are presented using bar graphs and descriptive tables. In the cost–benefit analysis, we calculate net present values (NPV) using cash

[2] In northern Nigeria, farmers often operate in clusters of rice farmers, maize farmers, and so on.

flows of benefits and costs. Transcripts of qualitative data were uploaded into MaxQDA for thematic coding and analysis.

4. Food supply chain mapping

This section presents key results from supply chain mapping and analysis of five commodities: sorghum, millet, maize, wheat, and cowpea. These maps were based on state-level production and trade flow data validated by stakeholders and experts. The maps are self-explanatory, showing production hubs, key market centers (indicating minor, major, and mega markets), trade flows and routes, and food processing locations. Key summary information contained in the mapping—production, demand, marketing, and processing for each commodity is presented in this section. We encourage readers to refer to the maps in Figures A1–A5 in the Annex while reading this section.

4.1 Sorghum value chain

Sorghum is a key crop in Nigeria's agriculture, with the country ranking among the top five global producers along with the United States, India, Mexico, and China (Yahaya et al. 2022). As shown in Figure 1, sorghum is predominantly cultivated in the northern regions, particularly in Kano, Kaduna, Katsina, Bauchi, and Zamfara states, benefiting from the semi-arid climate. The crop's drought resilience and ability to thrive in poor soil conditions make it ideal for these regions. However, production faces challenges, including erratic rainfall, pest infestations, and limited access to modern farming techniques. Traditional farming methods, still widely used, often limit yields. Recently, the government and development partners have provided training and other support to sorghum farmers.

Sorghum is in high demand across Nigeria for its diverse applications in food, feed, and industrial processes. A staple food in northern regions, it is used in traditional dishes such as *tuwo* (a thick porridge) and *kunu* (a flour paste made by wet milling after fermentation and cooked as a thin porridge) and is a key ingredient in poultry feed because of its nutritional content. The food processing industry is increasingly incorporating sorghum into various products, driven by the need for affordable, nutritious options for low-income households. The industrial demand for sorghum is also rising, especially in the production of flour, malt, and beer, supporting the growth of Nigeria's food and beverage industry.

In addition, sorghum is a primary trading commodity in northern Nigeria. Large wholesalers purchase sorghum in bulk and supply it to processing companies. However, recent fuel cost increases have driven up transportation expenses, affecting prices. The major trade corridors are the Kano–Kaduna–Zaria corridor, specifically the Dawanau grain market (Kano) and the Bauchi–Yobe–Borno axis (Figure A1). Sorghum also moves across export corridors toward neighboring countries, including Niger, Chad, and Cameroon, especially from border states such as Sokoto and Borno.

Sorghum processing occurs at both homestead and industrial levels. At the household level, sorghum is processed into flour for traditional dishes and beverages. Industrial processing is more mechanized, transforming sorghum into products such as malt, flour, and beer. Major companies, such as Nigerian Breweries, Sona Malting and Derivatives, and others, rely on sorghum as a key ingredient. The crop's versatility as a food and industrial raw material underscores its value in Nigeria's agricultural landscape, with growing demand.

4.2 Millet value chain

Nigeria contributes about 6.5 percent of global millet and ranks highest in West Africa's millet production.[3] Over the past few decades, most millet-producing LMICs have experienced a decline in cultivation. This decline is attributed to a shift toward other staple crops, evolving dietary preferences, and assured returns from major commercial crops (Meena et al. 2021). Only a handful of countries, notably China, have increased their millet production levels. As shown in Figure A2, the main supply areas of millet in Nigeria are the northern states of Yobe, Borno, Bauchi, Jigawa, Sokoto, Zamfara, Katsina, and Kano.

In terms of local demand, millet is used in various traditional dishes such as *kunu* (thin gruel), *masa* (fried cakes), *fura* (pounded whole grain balls eaten with milk), *ogi* or *akamu*/*kamu* (thick porridge), and *burukutu* (alcoholic and nonalcoholic beverages, including beer). Millet flour is also used to make *tuwo* (a thick paste). The plant's stem is used in construction, while its green parts and outer seed layer serve as animal feed. Approximately 80 percent of millet produced is used for human food, with the remainder used for animal feed and brewing.

The main market centers for millet in northern Nigeria are Dawanau, an assembly and wholesale market in the city of Kano, as well as Maiduguri, Jos, Gombe, Potiskum, Funtua, Jibia, Illela, Maigatari, and Ngalda markets (Figure A2). The most prominent trade corridor for millet is the north–south corridor, which comprises several routes, including the Kano–Lagos corridor, whose major flow originates from Kano and moves southward through cities like Zaria and Kaduna before eventually reaching Lagos. The Maiduguri–Port Harcourt route is another significant flow that connects the northeastern production areas with southeastern markets. Another corridor connects Maiduguri to markets in the northwest, such as Kano and Katsina. This suggests intra-regional trade within the northern production zones, possibly balancing supply and demand across different areas. There are also cross-border trade movements, particularly with the Niger Republic, which potentially export surplus millet.

Millet is processed into various products, ranging from human food to animal feed. However, apart from feed millers and a few food processors, there is little recorded industrial processing. Products

[3] https://ipad.fas.usda.gov/cropexplorer/cropview/commodityView.aspx?cropid=0459100 and https://www.indexmundi.com/agriculture/?commodity=millet&graph=production

from processed millet in Nigeria include *burabusko* (a form of millet grits), *kunu*, and *fura*. Most millet processing takes place either in households in rural areas or in cottage milling firms in urban centers.

4.3 Maize value chain

Maize is a major staple cereal in Nigeria. The country ranks as the second-largest maize producer on the continent, after South Africa, with production reaching approximately 12.8 million metric tons in 2020. Key maize-producing states include Kano, Niger, Adamawa, Taraba, Plateau, Kaduna, Bauchi, Nasarawa, Kebbi, Kwara, FCT, and parts of Borno, Benue, Katsina, Jigawa, Zamfara, and Kogi (Figure A3). The national average yield is approximately 2.2 tons per hectare, which is significantly lower than the potential 10 tons per hectare achievable with improved farming practices and better varieties. Nigeria's maize production follows two main cropping seasons: the wet season (April–June planting, August–October harvest) and the dry season (October–February planting, February–April harvest), with the majority of production occurring during the wet season.

Maize demand in Nigeria is substantial, driven by its role in human consumption, animal feed, and industrial uses. Annual consumption is around 15 million metric tons, with significant portions used for food, feed, and industrial purposes, such as in flour, corn syrup, and starch production. The poultry industry is a major consumer, and maize is a staple in most Nigerian households.

The maize marketing chain typically involves farmgate buyers (middlemen), village market aggregators, urban buyers, transporters, company buyers, and processors. Price volatility is a major issue, causing financial instability for farmers. As shown in Figure A3, the main market corridors are the Kano–Kaduna–Abuja, Sokoto–Kebbi–Niger, and Maiduguri–Yobe–Bauchi axes. Key demand centers include cities such as Kano, Kaduna, Zaria, Bauchi, and Maiduguri, among others. There is also significant, though unofficial, maize export to the neighboring countries, the Niger Republic and Cameroon.

Maize processing occurs at both homestead and industrial levels. At home, maize is milled into flour for traditional dishes such as *tuwo* and for snacks like *pap* or *akamu*. This process is often manual and labor-intensive but is essential for household food security. Industrial processing is mechanized, converting maize into products such as flour, beer, malt drinks, cornflakes, starch, syrup, dextrose, and animal feeds. Significant players in this sector include Nigerian Eagle Flour Mill and Nagari Seeds Nigeria Limited.

4.4 Wheat value chain

Wheat is a crucial staple in Nigeria, but domestic production falls far short of meeting demand, resulting in significant imports. Wheat is the country's third most consumed grain after maize and rice. However, local production meets only 1 percent of annual consumption (Balana et al. 2022). Wheat is cultivated exclusively under irrigation from November to March, primarily in the northern states of Jigawa, Kebbi, Kano, Bauchi, Yobe, Gombe, Borno, Adamawa, Plateau, Sokoto, Katsina, and Kaduna,

where the semi-arid climate supports growth (Figure A4). Production in the northeast has declined sharply due to the Boko Harem insurgency and inadequate irrigation infrastructure. To address this gap, Nigeria's federal government has launched the 2023/2024 dry season wheat farming program under the National Agricultural Growth Scheme and Agro-Pocket (NAGS-AP) initiative, aimed at increasing domestic wheat production.

The demand for wheat and wheat-based products has grown significantly in recent years, driven by changing dietary preferences, urbanization, and population growth. The primary demand for wheat flour comes from bakeries, while additional significant demand arises from households, restaurants, and food processing companies that produce noodles, pasta, and other wheat-based foods. According to World Bank data, an average Nigerian consumes about 28 kg of wheat products per year.[4]

Nigeria faces significant dependency on wheat imports due to its domestic production deficit. In 2020, the country's wheat imports were valued at over $2.15 billion, marking a 40 percent increase from the previous year. This positioned Nigeria as the fourth-largest wheat importer globally, following Egypt, China, and Turkey (Balana et al. 2022). Wheat is the most imported food item in Nigeria (NBS 2021). Major wheat suppliers to Nigeria include Lithuania, Latvia, the United States, Russia, and Ukraine. While this reliance on imports ensures adequate wheat supply for domestic consumption, it also makes the country vulnerable to global price fluctuations and international trade policies.

In terms of wheat processing, Nigeria has a growing milling industry, with several large-scale flour mills operating primarily in urban centers. These mills process both domestically produced and imported wheat into flour for various end uses, including bread, pasta, and confectionery products (Balana et al. 2022).

4.5 Cowpea value chain

Figure A5 shows that cowpea production is predominantly concentrated in northern Nigeria, with varying production capacities. According to NEARLS, in 2024, Nigeria's annual cowpea production was approximately 4.8 million metric tons, making Nigeria one of the largest cowpea producers. Notable production areas include Borno; Yobe; Jigawa; parts of Kano, Sokoto, Zamfara, Katsina; parts of Bauchi, Adamawa, and Taraba; and some areas of northcentral Nigeria. This production pattern aligns with the suitable agroecological conditions of the northern region, particularly the Sudan and Sahel savanna zones.

Cowpea demand in Nigeria is predominantly for household consumption, with minimal demand from the industrial sector. For example, popular cowpea-based dishes such as *moimoi* and *akara* are widely enjoyed throughout the country. Nigeria's per capita consumption of cowpeas is estimated to be around 23 kg per year—substantially higher than in other African nations and the global average. For

[4] https://data.worldbank.org/indicator/AG.CON.WHEAT.PC

instance, per capita consumption in the neighboring countries of Niger Republic and Burkina Faso is about 9 kg and 7 kg, respectively, and only about 1 kg to 2 kg globally.[5]

Nigeria's cowpea market is largely dominated by informal smallholder traders. As shown in Figure A5, the main market center is the Dawanau market in Kano, which serves as the primary hub for cowpea trade in northern Nigeria. Other major markets are strategically located across the region, including Maigatari in Jigawa, Potiskum in Yobe, Maiduguri in Borno, and Illela in Sokoto. These markets are characterized by substantial storage facilities and high trade volumes. Numerous secondary markets serve as collection points for farming communities and facilitate the distribution of cowpeas to larger markets (Figure A5). The major trade corridors follow the north–south routes connecting northern production zones to southern consumption centers, passing through key cities like Zaria, Kaduna, and Abuja. In addition, inter-state routes link major markets within the northern region, facilitating regional trade flows. A significant quantity of cowpeas is also exported to the neighboring countries of Niger, Chad, and Cameroon.

Cowpea processing in Nigeria is done primarily at home or in small cottage milling facilities, mainly for domestic consumption. Recently, some processors have begun producing cowpea flour for retail sales in stores and supermarkets, although this practice has not yet gained widespread popularity. These emerging processors aim to offer consumers a more convenient option and potentially tap into the growing demand for ready-to-use products in urban markets. However, traditional home processing methods continue to dominate because of their deep-rooted cultural acceptance and accessibility.

5. Findings from the cost structure analysis

This section presents the results of the cost buildup analysis for the selected commodities. It begins with the cost buildups for producers, where production costs are disaggregated into land rental,[6] labor, seeds, inorganic fertilizer, organic fertilizer, agrochemicals (pesticides and herbicides), agricultural machinery (rental value), and irrigation (where applicable). This is followed by the cost buildups for traders, transporters, processors, and grain storage. All values are reported in Nigerian Naira (₦)[7] per hectare (/ha).

5.1 Cost structures for producers

Sorghum and Millet

Sorghum is the most widely cultivated crop in northern Nigeria, known for its climate resilience and an average yield of 2.55 tons/ha. Figure 1 presents the cost breakdown for sorghum production. Land

[5] https://www.aatf-africa.org/wp-content/uploads/2021/02/Cowpeabrief.pdf
[6] For owned land, the opportunity cost of land was used.
[7] The exchange rate of Naira (₦) to the US dollar at the time of data collection for this study (June 2024) was US$1 = ₦1,535. This rate applies to all monetary values reported in his paper.

rental (₦89,000/ha) poses a significant cost. While seed and agrochemical (pesticides and herbicides) costs are relatively low, expenditures on inorganic fertilizer (₦196,000/ha) and labor (₦278,000/ha) are substantial. Machinery rental costs, averaging over ₦110,000/ha, underscore both the labor-intensive nature of farming and the shift toward mechanization, albeit at a high cost. The high fertilizer and labor costs suggest that targeted policies or interventions to reduce these two inputs could substantially boost farm profitability.

Figure 2 shows the cost structure of millet production, which is characterized by high labor costs and minimal mechanization. The average yield of millet is about 1.86 tons/ha. Labor (₦200,000/ha) and inorganic fertilizer (₦198,000/ha) account for the largest cost shares in millet production. Machinery rental costs are low, suggesting limited mechanization in millet farming. Agrochemical expenses are also low at ₦16,125/ha, reflecting the limited use of such applications. As with sorghum production, targeted policies or interventions to reduce labor and fertilizer costs could boost profitability.

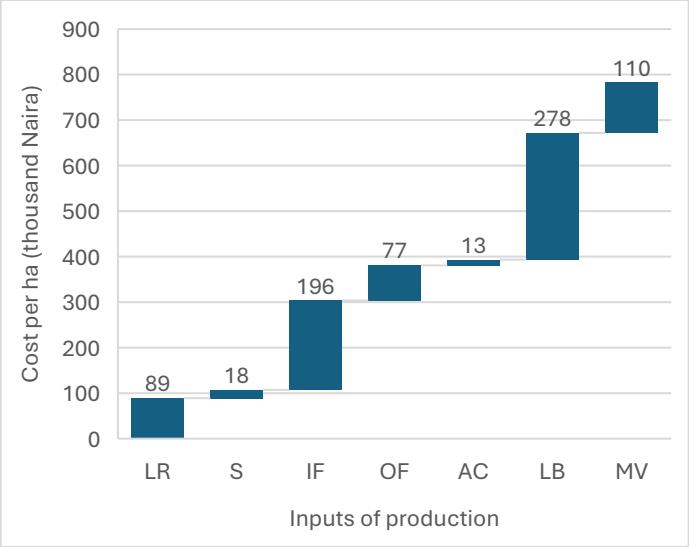

Figure 1. Cost structure for sorghum production in northern Nigeria

Source: Authors' computation from the 2024 field survey data (IFPRI).
Note: LR = land rent; S = seeds; IF = inorganic fertilizer; OF = organic fertilizer; AC = agrochemicals; LB = labor; MV = machinery rental value.

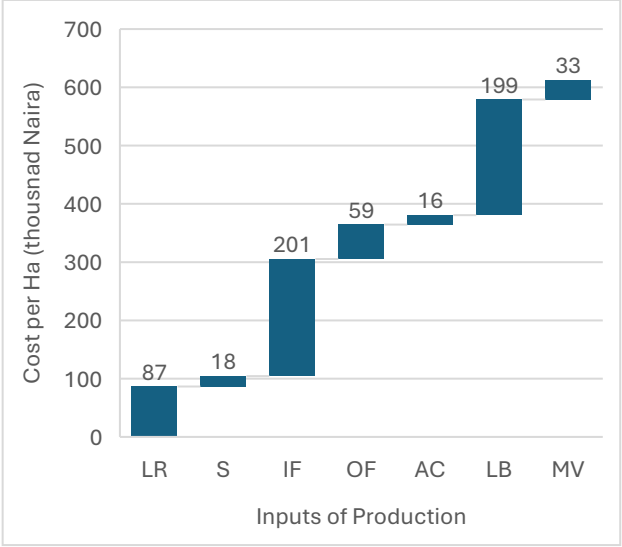

Figure 2. Cost structure for millet production in northern Nigeria

Source: Authors' computation from the 2024 field survey data (IFPRI).
Note: LR = land rent; S = seeds; IF = inorganic fertilizer; OF = organic fertilizer; AC = agrochemicals; LB = labor, MV = machinery rental value.

Maize and Wheat

As shown in Figure 3, with an estimated average cost of over ₦382,000/ha, inorganic fertilizers represent the largest cost in maize production, followed by labor (₦244,000/ha). The high fertilizer cost reflects maize's high nutrient requirements. Seed costs are also notable at over ₦31,000/ha, higher than those for sorghum and millet. With an average yield of about 2.7 tons/ha, maize production remains relatively low in Nigeria compared with other countries south of the Sahara—for instance, about 4 tons/ha in Ethiopia (van Dijk et al. 2020) and 6 tons/ha in South Africa (Anderson 2024).

Farmers could benefit immensely from technologies and policies that improve productivity and cost efficiency in maize production.

As with other cereals, wheat production in Nigeria is characterized by low yields, averaging about 2.4 tons/ha. Figure 4 shows the cost structure for wheat production among smallholders in northern Nigeria. The pattern is similar to that of the other crops discussed above: Inorganic fertilizer and labor account for the largest share of total costs, followed by seeds and agrochemicals. The high labor cost may reflect the labor-intensive nature of production and imperfections in the labor market, possibly exacerbated by movement restrictions due to conflicts. Likewise, the high cost of fertilizer may cause many smallholders to forgo its use or apply suboptimal quantities, resulting in lower productivity.

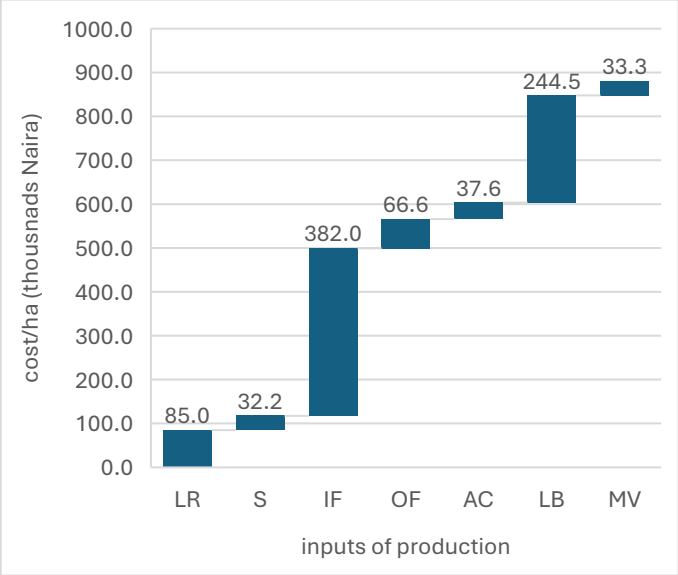

Figure 3. Cost structure for maize production

Source: Authors' computation from the 2024 field survey data (IFPRI).
Note: LR = land rent; S = seeds; IF = inorganic fertilizer; OF = organic fertilizer; AC = agrochemicals; LB = labor; MV = machinery rental value.

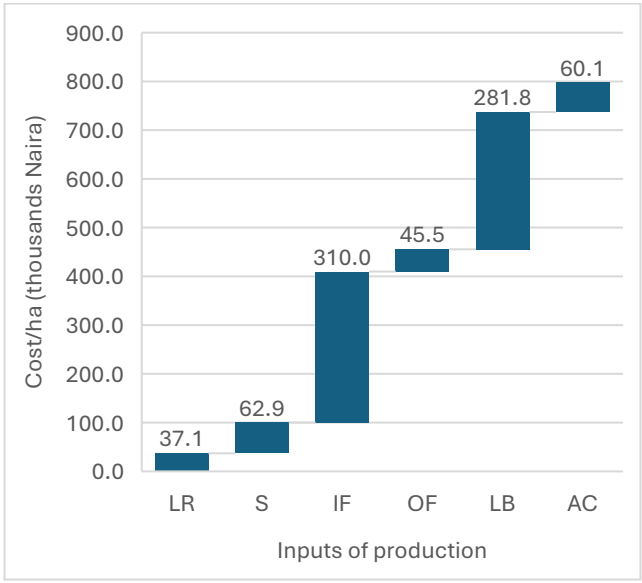

Figure 4. Cost structure for wheat production

Source: Authors' computation from the 2024 field survey data (IFPRI).
Note: LR = land rent; S = seeds; IF = inorganic fertilizer; OF = organic fertilizer; AC = agrochemicals; LB = labor, MV = machinery rental value.

Cowpea

Figure 5 shows the cost structure of cowpea production. Labor dominates production costs, highlighting its labor-intensive nature (land preparation, planning, intensive pest control, and harvesting operations for maintaining crop quality). Compared with other crops, fertilizer cost is relatively low (₦55,800/ha), consistent with cowpea's nitrogen-fixing ability and low dependence on nitrogen-based inputs. Seed costs are significant at ₦34,400/ha, likely due to the use of improved varieties designed for pest resistance and higher yield potential. Land rent, machinery, and agrochemical costs are relatively moderate in cowpea production. Overall, the dominance of labor cost may indicate labor market imperfections driven by insecurity in the region.

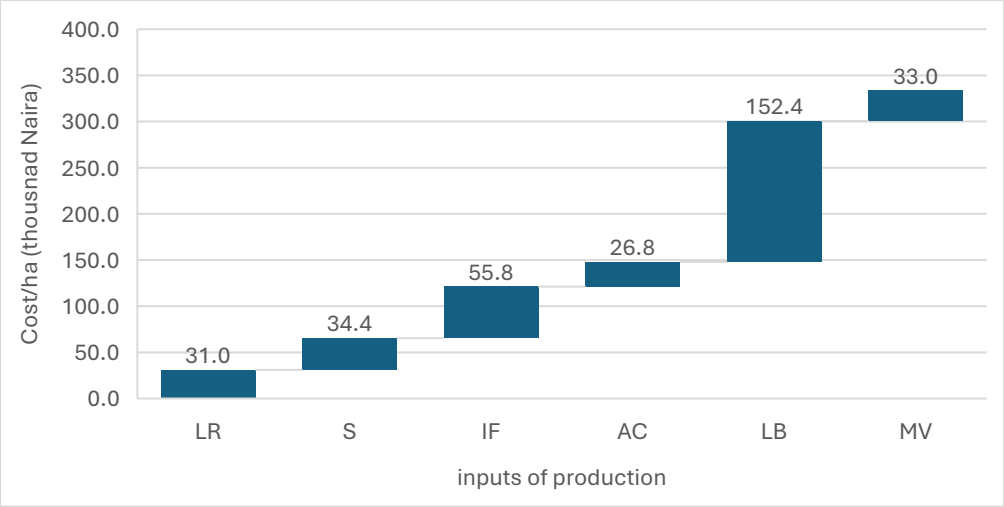

Figure 1. Cost structure for cowpea production

Source: Authors' computation from the 2024 field survey data (IFPRI).
Note: LR = land rent; S = seeds; IF = inorganic fertilizer; OF = organic fertilizer; AC = agrochemicals; LB = labor; MV = machinery rental value.

5.2 Consolidated cost structure of food production

In addition to the production cost analysis in Section 5.1, we further examined the cost structures of soybean, groundnut, and tomatoes. Soya oil is included in WFP's food basket, creating opportunities to explore processing-based solutions. Groundnuts and tomatoes are widely consumed food items with high nutritional and economic importance in Nigeria. Understanding the production cost structures of these commodities is therefore crucial for designing interventions to enhance productivity and cost efficiency. This section provides a consolidated cost structure for eight selected commodities. As shown in Figure 6, the costs of various inputs—land rent, seeds, fertilizers (both inorganic and organic), agrochemicals, labor, machinery, and irrigation—represent different shares of the overall production cost for each crop.

Land rent reflects the cost of acquiring farmland, with its share ranging from 4.5 percent for wheat to 14.1 percent for millet. Millet and sorghum incur relatively high land rent costs (14.1 percent and 11.4 percent, respectively), possibly due to the extensive land requirements of these low-input crops. Seed costs also vary widely. Cowpea has the highest seed cost share (10.3 percent), likely reflecting its reliance on high-quality or certified seeds. Millet, soybean, and sorghum show minimal seed costs (2.9 percent, 2.5 percent, and 2.3 percent, respectively), suggesting farmers may be using farm-saved seeds or less expensive local varieties.

Inorganic fertilizer is essential for maintaining soil fertility, particularly for nutrient-demanding crops. Its share of total production costs is highest for maize (43.3 percent), soybean (38.6 percent), and wheat (37.7 percent), indicating that inorganic fertilizer represents the largest single cost component for these crops. Groundnut and millet follow at 32.8 percent each, a significant share of their

production costs. Tomatoes exhibit moderate inorganic fertilizer costs, while cowpea has the lowest share (16.7 percent), benefiting from its nitrogen-fixing capacity. Organic fertilizer supports long-term soil health, with wet-season tomato production showing the highest organic fertilizer cost share (15.7 percent), underscoring its role in soil conditioning. Groundnut (13.2 percent) and sorghum (9.9 percent) reflect moderate cost on organic fertilizer, while wheat shows a low share (5.5 percent), showing that it relies more heavily on inorganic fertilizer.

Agrochemical costs reflect the need for pest and disease control. Cowpea (8 percent), wheat (7.3 percent), and wet-season tomatoes (7 percent) have higher agrochemical cost shares due to their susceptibility to pests and diseases, while sorghum (1.6 percent) and millet (2.6 percent) show the lowest shares. Labor costs are substantial for all crops and often represent the largest cost component. Cowpea (45.7 percent) and sorghum (35.6 percent) have the highest labor cost shares, indicating either their relative labor-intensive practices or labor market imperfections in the region. In contrast, dry-season tomato production has a lower labor cost share (19 percent), likely due to greater mechanization or efficient labor practices.

Machinery costs indicate the level of mechanization in crop production. Groundnut (15.6 percent) and wet-season tomato (14.3 percent) have the highest machinery cost shares, while millet (5.4 percent) and maize (3.8 percent) reflect limited mechanization. Irrigation costs are essential for crops grown in dry conditions. Dry-season tomato production incurs the highest irrigation cost share (19 percent), while wheat has minimal irrigation costs (3.1 percent), suggesting a reliance on rainfed methods or less water-intensive practices.

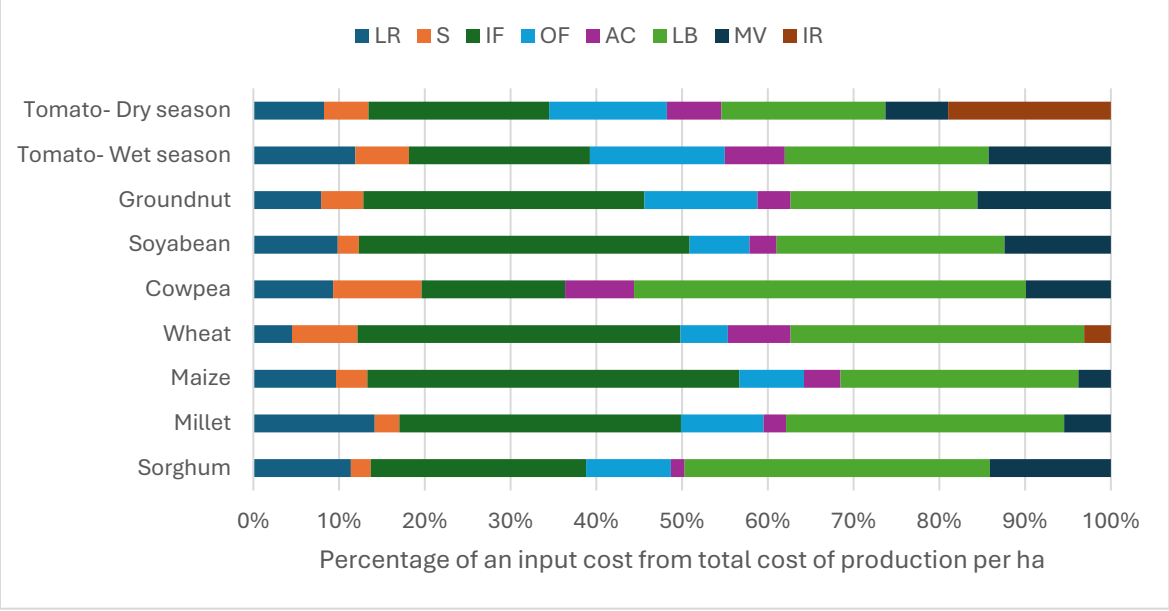

Figure 6. Cost structure of eight selected commodities in northern Nigeria

Source: Authors' computation from the 2024 field survey data (IFPRI).
Note: LR = land rent; S = seeds; IF = inorganic fertilizer; OF = organic fertilizer; AC = agrochemicals; LB = labor; MV = machinery rental value; IR = irrigation cost.

Across the eight commodities analyzed (Figure 6), several systemic constraints emerge. High inorganic fertilizer and labor costs are recurring challenges, reflecting input market imperfections, global fertilizer price trends, and structural inefficiencies in Nigeria's input delivery systems. Storage limitations, while not a direct cost category in the production cost buildups, consistently exacerbate postharvest losses and reduce farmers' bargaining power. Commodities with nitrogen-fixing capacity, such as cowpea, show relatively lower fertilizer cost shares but higher labor costs due to labor-intensive agronomic practices, such as regular pest management. Mechanization levels remain low across most crops, with machinery costs accounting for less than 10 percent of total production costs for the majority of them. These patterns suggest that interventions aimed at improving input supply, labor productivity, and storage infrastructure could yield cross-cutting benefits, while crop-specific strategies will be needed to address unique constraints, such as pest control in cowpea or irrigation requirements for dry-season tomato production.

5.3 Cost buildups for food transporters

This subsection presents the cost structure for food transporters. Transportation costs are assessed based on the volume (in metric tons) transported, the distance traveled, and the specific routes followed. For consistency and clarity, all costs are standardized to metric tons, allowing for a comparison across different routes. The primary costs faced by food transporters include labor for loading, off-loading, and truck rental. Because transporters often move mixed food groups, the costs are calculated based on the total volume of goods transported rather than on the specific types of commodities transported.

To build the cost structure for food transport, we considered major food markets, key transport routes, and destinations for food assistance provided by WFP. The cost buildup analysis focuses on three key transport routes: Kano–Maiduguri–Michika. The Dawanau grain market in Kano is Nigeria's largest grain market, where humanitarian organizations, including WFP, source most of their food assistance. Maiduguri, in northeast Nigeria, is the capital city of Borno state in northeast Nigeria (the most conflict-affected state in the region). WFP operates a significant warehouse facility in Maiduguri that serves as a central hub for emergency food assistance in the region. This warehouse plays a crucial role in delivering food and other aid to vulnerable populations, including internally displaced people (IDPs) affected by conflict and other crises in the northeast. Michika, a town in Adamawa state that is another northeastern state significantly affected by conflict, hosts a large number of IDPs. To illustrate the cost structure of food transportation, we present two cases of cost buildups in two routes in the northeast: the Kano–Maiduguri route (from Kano to Maiduguri's WFP warehouse in Maiduguri) and the Maiduguri–Michika route (from Maiduguri's WFP warehouse to food aid recipients in Michika's IDP communities).

Case 1: Kano–Maiduguri route

Figure 7 provides insights into the cost breakdown for the transport route between Kano and Maiduguri. This route accommodates most of WFP's humanitarian food assistance movements from Kano to the Maiduguri warehouse. Food transport operators along this route charge a fixed cost of ₦2,000 per metric ton for loading and off-loading labor at the points of origin and destination. However, the most substantial cost component is truck hire, at ₦23,750/metric ton of goods transported. This cost includes fuel, driver wages, and essential vehicle maintenance, which are significant expenses given the long distances and sometimes challenging road conditions.

The haulage rate for the Kano–Maiduguri route is ₦29,600/metric ton. Transporters' profit margins on this route are about ₦5,850/metric ton, representing a margin of almost 20 percent. Although these profit margins may appear modest, they help to accommodate various additional costs that may arise, such as vehicle repairs caused by poor road conditions, delays, and other unforeseen expenses. Moreover, the operational landscape along this route poses unique challenges, with seasonal variations and infrastructure limitations impacting transportation efficiency and reliability.

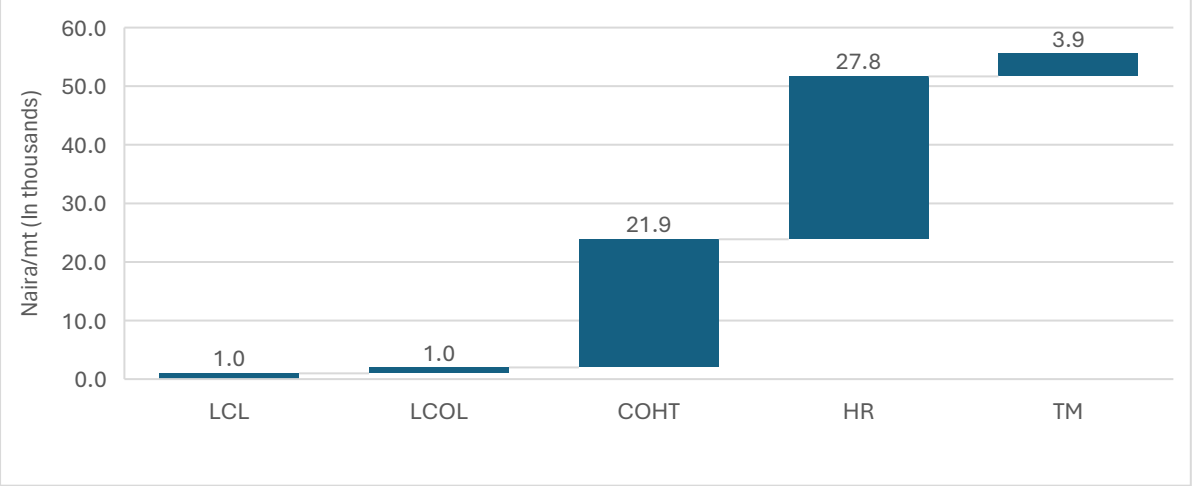

Figure 7. Food transport costs and returns for the Kano–Maiduguri route

Source: Authors' computation from the 2024 field survey data (IFPRI).
Note: LCL = labor cost loading; LCOL = labor cost off-loading; COHT = cost of hiring truck; HR = haulage revenue; TM = transport margin.

Case 2: Maiduguri–Michika route

Figures 8 and 9 present the costs, revenues, and profit margins for transporting goods from the Maiduguri warehouse to the Michika distribution center—comparing the regular route with no road insecurity and an alternative route when heightened road insecurity necessitates a detour. The labor cost for loading and offloading remains constant at ₦2,000/metric ton, covering labor at both ends of the journey. However, truck hire costs differ between routes: ₦13,750/metric ton on the regular route versus ₦15,000/metric ton on the alternative route. Haulage revenue is ₦16,500/metric ton for

the regular route, yielding a low margin of ₦750/metric ton, whereas in the alternative route, haulage revenue significantly increases to ₦26,000/metric ton, resulting in a much higher transport margin of ₦9,000/metric ton. This increased margin serves as a risk premium, compensating for additional costs associated with taking the longer and less secure route.

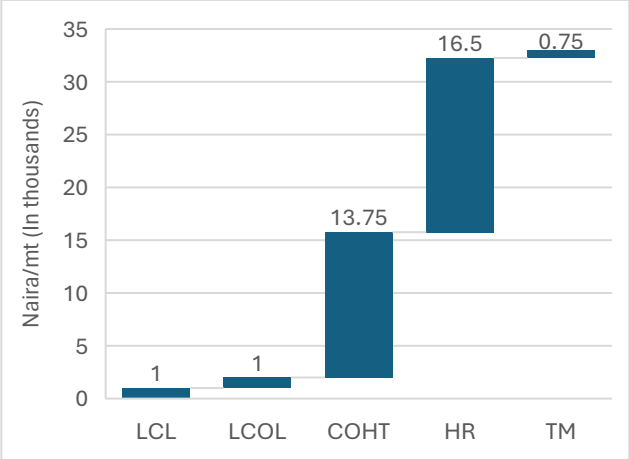

Figure 8. Maiduguri–Michika route (no road insecurity)

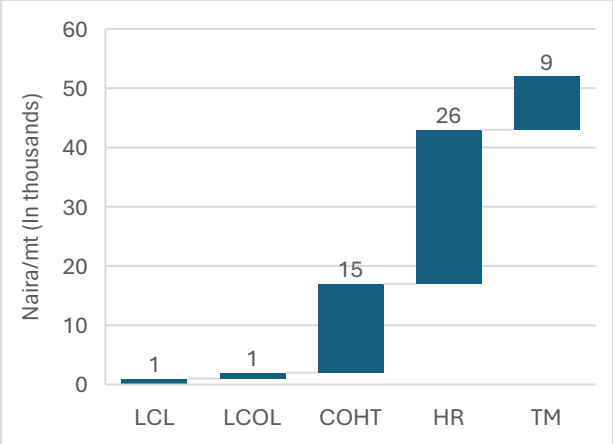

Figure 9. Maiduguri–Michika route (heightened road insecurity)

Source: Authors' computation from the 2024 field survey data (IFPRI).
Note: LCL = labor cost loading; LCOL = labor cost off-loading; COHT = cost of hiring truck; HR = haulage revenue; TM= transport margin.

5.4 Cost structures for food traders

This section analyzes the cost structure for food traders and suppliers, focusing on two major staple cereals traded in the region: sorghum and maize.

Sorghum

Figure 10 shows the cost structure for a typical sorghum trader operating in northern Nigeria. At the time of the survey, the purchase price of raw materials (impure sorghum grain sourced from local markets or suppliers) was ₦980,000/metric ton. During cleaning, an estimated loss of 2.5 percent (equivalent to ₦24,500/metric ton) occurs, resulting from wastage or the removal of impure grains during cleaning and handling. Handling charges, including loading and off-loading costs of ₦3,000/metric ton, appear modest but are essential for moving goods between locations, especially in regions with limited mechanization. Cleaning costs, at ₦8,000/metric ton, indicate efforts to uphold quality standards and ensure that the grain is well-packaged for market distribution. Additional costs include quarantine and documentation at ₦700/metric ton, a regulatory expense that highlights the importance of food safety compliance in the market.

Significant logistical expenses, such as bagging (₦10,000/metric ton) and transportation (₦15,000/metric ton), add to the final cost, while the high financing cost on borrowed capital (₦78,624/metric ton) reflects the challenges traders face in accessing affordable credit. The total cost

per metric ton is ₦1,127,934, with a revenue of ₦1,240,728, resulting in a profit margin of ₦112,794 (9.1 percent). This modest margin indicates the high-cost pressures within the sorghum supply chain, suggesting room for optimizing financing and logistics to improve profitability.

The high share of labor and fertilizer costs in sorghum production is reflected in farmers' accounts of input access challenges. As one producer noted, "Price of fertilizer is very expensive… where you need four bags of fertilizer in a plot, you can only buy one." This aligns with our finding that inorganic fertilizer accounts for over 30 percent of total production costs, while late delivery and adulteration further undermine productivity. These qualitative insights reinforce the cost data by highlighting how market failures in input supply directly reduce efficiency and profitability.

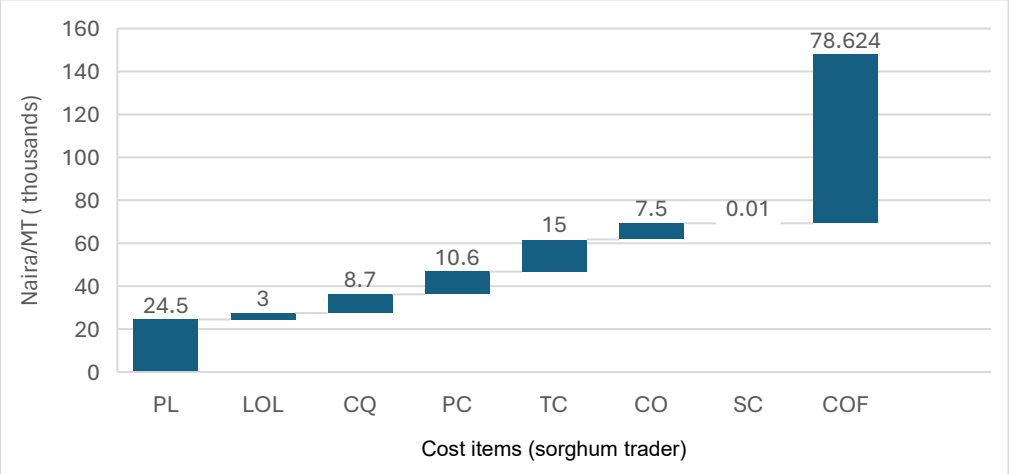

Figure 10. Cost component for sorghum trader

Source: Authors' computation from the 2024 field survey data (IFPRI).
Note: PL = processing loss; LOL = loading and off-loading; CQ = cleaning and quarantine; PC = packaging cost; TC = transport cost; CO = contingency; SC = scaling; COF = cost of finance.

Maize

As shown in Figure 11, maize trading involves transporting the grain from the farmgate to the warehouse (₦14,000/metric ton) and incurring significant losses during cleaning, estimated at ₦100,800/metric ton due to grain impurities. Cleaning costs are ₦8,000/metric ton—including labor, utilities, fumigation, administrative costs, warehouse rental, and packing. The financing cost of ₦23,360/metric ton highlights the significant capital requirements of maize trading, while a 3 percent miscellaneous margin covers unforeseen costs. The maize cost structure underscores the need for efficient cleaning and handling operations to reduce losses and maintain profitability, particularly in a high-demand market where small operational improvements can yield considerable returns for traders.

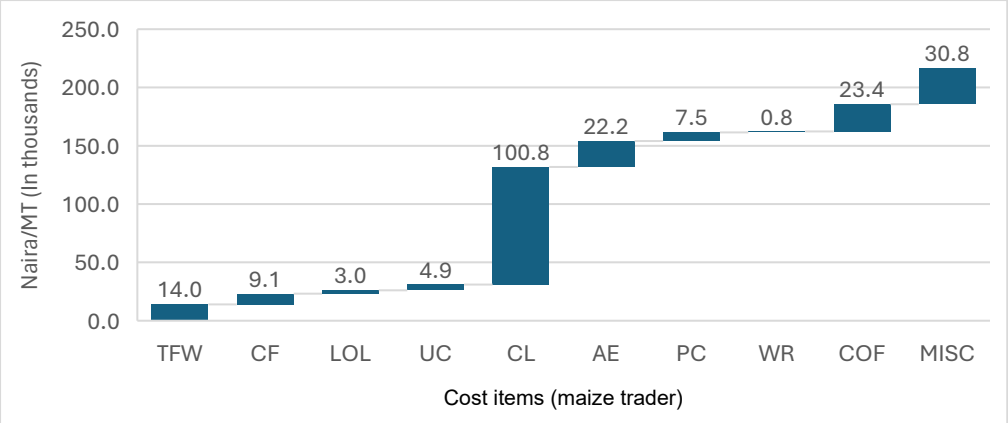

Figure 11. Cost component for maize trader

Source: Authors' computation from the 2024 field survey data (IFPRI).
Note: TFW = transport from farmgate to warehouse; CF = cleaning and fumigation; LOL = loading and off-loading; UC = utility cost; CL = cleaning loss; AE = administrative expenses; PC = packing cost; WR = warehouse rental cost; COF = cost of finance; MISC = miscellaneous costs.

6. Key insights from qualitative findings

6.1 Farmers

Findings from the KIIs and FGDs reveal that smallholder farmers face several interconnected challenges that significantly affect crop production. The first is the high cost of agricultural inputs. Farmers struggle to afford productivity-enhancing agricultural inputs, mainly high-yield seed varieties and fertilizer. The following interview excerpt supports this finding:

> *"Price of fertilizer is very expensive, which affect[s] our production because where you need four bags of fertilizer in a plot, you can only buy one due to the price. A price of fertilizer is now 40–42 thousand Naira depending on the brand, compared to 8–10 thousand Naira a year or so ago." —FGD farmers, Kano and Adamawa*

Farmers also face challenges related to the quality of agricultural inputs due to frequent adulteration. The quality of available inputs, particularly fertilizers, poses a serious concern. The prevalence of adulterated fertilizers in the market not only wastes farmers' limited resources but also significantly reduces crop yields. The following interview excerpt supports this finding:

> *"Adulterated fertilizer is one of our major problems because it affects our yield. We need government inspections on all the seeds and fertilizers sold to us." —FGD farmer, Kano*

Second, government policies and interventions on agricultural inputs have been potentially beneficial; however, their impact has been undermined by implementation challenges. Farmers frequently experience unfulfilled promises and poorly timed program deliveries. Inputs often arrive late in the growing season, rendering them unusable for the intended planting period.

Storage infrastructure and market access also emerge as critical challenges. Farmers express the need for warehouse receipt financing systems that would enable them to store their harvests until market

prices become more favorable. The absence of such facilities forces farmers to sell their produce immediately after harvest, often at lower prices. The following interview excerpt supports this finding:

> *"Due to lack of storage facility, we are not able to keep our produce until better market prices. The middlemen are the ones who determine the price, as farmers have no option rather than sell, which sometimes discourages us. They also break the price lower so that they can get something when they resell it. Cowpeas spoil if not stored properly. Many farmers sell early because they do not have options to store safely or preserve them until good market prices come." —FGD farmer, Adamawa*

Financial constraints compound these challenges. Although credit facilities exist, farmers struggle with long-term credit arrangements, often resulting in high default rates. The agriculture sector needs better mechanisms to connect farmers with reliable supply chains and financial support systems that align with their capabilities and needs, as expressed in this interview excerpt:

> *"Farmers need support to access agricultural finance, particularly either through subsidies or connecting farmers with inputs supplies or affordable credit. Because formal credit is not accessible for farmers." —KII farmer, Kano*

6.2 Food transporters

Transportation of food items in northern Nigeria faces multiple complex challenges that affect costs and the timely delivery of goods. Security concerns, particularly the Boko Haram insurgency, have significantly affected transport routes, with drivers facing risks of attacks and cargo seizures. This insecurity situation has led to as much as a 50 percent increase in transportation costs, as drivers demand higher fees to offset these risks. Infrastructure deterioration compounds these challenges, with collapsed bridges forcing transporters to take longer alternative routes. The cost structure of transportation is further burdened by multiple taxes and fees collected at multiple checkpoints. Rising fuel costs have also led to significant increases in local transportation expenses, threatening the viability of many businesses. Despite these challenges, Kano remains a crucial hub in the region's food distribution network. The following interview excerpts support this finding:

> "*Boko Haram frequently targets trucks carrying food items, attacking and seizing the cargo. As a result, many drivers are reluctant to travel these routes. Those willing to make the journey charge 1.5 million Naira for a trip that would normally cost 1 million Naira, due to their awareness of the risks involved in transporting food items in the region.*"—KII transporter #1
>
> *"We pay a lot of taxes, even for loading our trucks in Dawanau market (Kano), we pay 2,000 Naira per truck. And there is Kano state road transport agency we pay 2500 naira daily. That is 4,500 naira per truck every day. There are also multiple checkpoints and informal (illegal) taxes through the journey."* —KII transporter #2
>
> *"Local transportation cost has drastically increased because of the cost of diesel. If this government continues like this, a lot of businesses will continue to shut down."* —KII transporter #3

6.3 Food traders

The region's grain production has experienced notable disruptions, particularly in Borno state, leading to reduced food production volumes, supply shortages, and subsequent price increases. Price volatility has become a major concern, with traders facing unpredictable market conditions that sometimes force them to sell at a loss. The economic environment has been further complicated by monetary policy changes—particularly exchange rate adjustments by the Central Bank of Nigeria—and the depreciation of Naira. Inflation has had a particularly severe impact on trading volumes. Transaction methods remain predominantly traditional, with farmers and local aggregators strongly preferring cash payments over electronic transfers. This preference for cash transactions persists even when traders work through intermediary aggregators to source from smallholders. The following interview excerpts support this position:

> "*There is a drastic drop in the quantity of food produced from Borno state, and this has contributed to the increase in food prices*." —KII trader #1

> *"Price volatility affects our business relationship with our trade partners. For instance, we enter a binding contract with the WFP to supply 300 tons of sorghum at a price of 800,000 per ton within 4 weeks. But due to inflation the price may increase up to 20. So, we incur a loss in this contract."* —KII trader #2

7. Opportunities for food system transformation

The cost buildup analysis highlights several leverage points where targeted investment could significantly improve efficiency and resilience in northern Nigeria's food systems. High postharvest losses, input price volatility, and long-distance transport costs driven by the regional concentration of processing capacity emerge as critical bottlenecks. Two illustrative cases presented in this section highlight the potential for targeted investments to generate substantial improvements in farmer incomes, food availability, and resilience. Postharvest food losses are one of the main challenges smallholders faces in northern Nigeria. Investment in on-farm storage technologies targeting dispersed smallholder farmers could offer a promising and economically viable solution to this problem.

Case 1: Investment to reduce postharvest losses

Given the high cost of reaching these widely dispersed farmers and the relatively low returns per individual farmer, the private sector alone is unlikely to invest in this area. Therefore, Case 1 illustrates the need for public resources or public–private partnerships to bridge the gap. Such investment would have far-reaching social benefits by enhancing food security, reducing waste, and increasing incomes for small-scale farmers who are integral to the region's agricultural base.

We conducted a cost–benefit analysis of investing in the establishment of an airtight grain silo facility in Yobe state in northeast Nigeria. A field survey confirmed that postharvest losses can reach up to 30 percent of total production for key cereals. These losses are primarily due to inadequate on-farm

storage, leading to distress sales during harvest and missed opportunities for farmers to benefit from seasonal price increases. Investing in airtight grain silos offers a proven solution to reduce postharvest losses to as low as 2 percent.

Tables 1–3 present the key assumptions underlying the cost–benefit analysis of this investment, the numerical values used, and the results.

Table 1. Key assumptions of the cost–benefit analysis

Factors considered	Values or costs
Annual sorghum production in Yobe state	220,000 MT
Volume held on-farm (subject to losses)	110,000 MT
Current loss rate without silos	30% (33,000 MT)
Loss rate with silos	2% (2,200 MT)
Market price of sorghum	$400/MT
Silo sizes	
1,000 L	$75
3, 000 L	$190
10,000 L	$700
Adoption rates by silo size (assumption)	80%
1,000 L	80%
3,000 L	15%
10,000 L	5%
Discount rate	6%

Source: Authors' calculations.
Note: L = liter (measurement unit of silo size); MT = metric tons. Costs are in US dollars.

Table 2. Key numerical values used in the cost–benefit analysis

Silo size (L)	Share of farmers (%)	Volume held by farmer group (MT)	Number of silos needed	Total cost of silos (US$)	Grain loss without silos (MT/year)	Grain loss with silos (MT/year)	Volume of grain saved (MT/year)	Value of grain saved per year (US$/year)
1,000	80	88,000	266,667	20,000,000	26,400	1,760	24,640	9,856,000
3,000	15	16,500	16,500	3,135,000	4,950	330	4,620	1,848,000
10,000	5	5,500	1,667	1,166,667	1,650	110	1,540	616,000
Total	**100**	**110,000**	**284,833**	**24,301,667**	**33,000**	**2,200**	**30,800**	**12,320,000**

Source: Authors' calculations.
Note: L = liter (measurement unit of silo size); MT = metric tons.

Table 3. Results of the cost–benefit analysis (financial returns with 6% discount rate and 5-year lifetime)

Year	Net returns (US$)	Discount rate (6%)	Present value of returns (US$)
1	(11,981,667)	0.9434	(11,303,418)
2	12,320,000	0.8900	10,969,600
3	12,320,000	0.8396	10,342,272
4	12,320,000	0.7921	9,761,032
5	12,320,000	0.7473	9,206,976
Net present value			**28,976,462**

Source: Authors' calculations. Note: Numbers in the parenthesis (-) indicate negative net present value.

As the results show, with an initial cost of $24.3 million, the investment enables significant reductions in postharvest losses—from 30 percent to 2 percent, preserving an additional 30,800 metric tons of grain each year. This translates to an annual value of $12.32 million in saved grain, providing smallholder farmers with larger harvest volumes to consume at home or sell at higher prices, thereby increasing their farm income.

The NPV of the investment over five years is $28,976,462, indicating a return on investment of 19.24 percent. By the second year, the cumulative net returns turn positive, and the investment continues to generate increasing returns. Beyond the financial returns, this investment enhances food security in a vulnerable region, reduces the need for distress sales, and contributes to poverty reduction among smallholder farmers.

Case 2: Investment to improve value addition

Case 2 examines the cost competitiveness of milling locally produced wheat in Maiduguri (Borno state) compared with transporting wheat flour milled in southern Nigeria. The northeastern region, particularly Lake Chad Basim, has a rich history of wheat production because of its favorable climatic conditions and fertile soils. In recent years, however, local wheat production has declined due to factors such as insecurity and limited access to inputs. This decline has forced millers such as Maiduguri Flour Mills Ltd. (MFM) to rely increasingly on imported wheat, thereby reducing local economic opportunities and driving up costs.

MFM, established in 1983 with a designed capacity of 400 metric tons of wheat per day, experienced a major scale-down in operations between 2012 and 2015 as a result of insurgency-related disruptions. When the plant resumed operations in 2015, it shifted its focus to maize processing due to a shortage of locally produced wheat. Currently, half of the milling plant is dedicated to maize processing, while the wheat processing section remains idle—and even maize milling is operating at a reduced pace. Despite these challenges, the facility presents a strong potential for revitalization if local wheat production can be sufficiently scaled up.

Revitalizing wheat production in northeastern Nigeria presents a unique opportunity to restore the region's historical role as a breadbasket, reduce reliance on imported wheat, and revitalize local economies. Investing in local wheat milling capacity, combined with initiatives to boost wheat production, can reinvigorate this important segment of the region's food system. Such efforts would also enhance food security and provide employment and income for smallholders and other food system actors.

Table 4 presents key comparative figures for wheat milling in Lagos (south) versus local milling in Maiduguri (north) and the effects of improving milling efficiency on wheat flour prices. As shown in this illustrative analysis, revitalizing and investing in the exiting milling plant will improve efficiency and reduce the cost of wheat flour from US$ 401.36/metric ton to 360.24/metric ton—a reduction of more than 10 percent.

Table 4. Economics of investing in local wheat milling

Cost element	Milling in the south (per MT)	Milling in Maiduguri (current)	Milling in Maiduguri (with investment)
CIF landed price (import)	$265	N/A	N/A
Farmgate price (local)	N/A	$319	$319
Port fee	$7.95	N/A	N/A
Milling cost	$53	$53	$30
Handling fee	$3.06	$4.76	$4.76
Transport to Maiduguri	$72.35	$5.35	$5.35
Storage and handling in Maiduguri	N/A	$4.76	$4.76
Price of flour in Maiduguri	$401.36	$383.24	$360.24

Source: Authors' calculations.
Note: MT = metric ton; CIF = cost, insurance, and freight (this refers to the price of a good delivered to the frontier of the importing country before the payment of any import duties or other taxes).

8. Conclusions and recommendations

This paper provides a broad overview and analysis of the food system challenges, opportunities, and transformation potential in northern Nigeria. Amid a backdrop of conflict, climate change, and economic instability, the region remains fragile yet serves as a cornerstone of Nigeria's agriculture sector. The findings highlight significant constraints—ranging from low productivity and high input costs to postharvest losses, inadequate infrastructure, and transport inefficiencies driven by protracted conflicts and recurrent climatic shocks—while also underscoring the immense potential of northern Nigeria to reclaim its historical role as the nation's breadbasket.

While our analysis is specific to northern Nigeria, the patterns we observe align with evidence from contexts in other regions south of the Sahara, including South Sudan and parts of the Sahel, where high input costs, insecurity-driven transport disruptions, and limited processing capacity combine to undermine food system performance. The mixed-methods diagnostic approach demonstrated here—

integrating spatial mapping, cost quantification, and qualitative validation—could be applied in these settings to generate context-specific investment priorities. This adaptability strengthens the case for viewing the approach not only as a study of Nigeria, but also as a replicable approach for conflict-affected agrifood systems more broadly.

This study makes three main contributions. First, it fills a critical gap in the literature by providing detailed, multi-commodity cost structure analysis for a conflict-affected region, linking production, trade, transport, and processing in an integrated framework. Second, it demonstrates the value of a mixed-methods diagnostic approach—combining GIS-based supply chain mapping, data-based cost structure analysis, and qualitative ground-truthing—that can be replicated in other conflict-prone settings to generate actionable insights. Third, it translates these diagnostics into targeted investment cases, showing how empirical evidence can inform both immediate humanitarian response and longer-term food system recovery strategies. Together, these contributions advance both the empirical understanding and the operational toolkit for transforming food system in contexts of protracted crisis.

The study's detailed mapping of supply chains and cost structure analysis demonstrates how inefficiencies manifest at each stage of the value chain, with producers facing high input costs, traders experiencing high financing costs, and transporters contending with increased logistical costs due to insecurity-related risks. Results from the cost–benefit analysis provide strong economic justification for allocating public resources to storage infrastructure and improving food processing.

The investment case for air-tight grain silos demonstrates clear opportunities for transforming the region's food systems. With a potential return on investment of 19.24 percent over five years, such targeted interventions can address multiple challenges simultaneously reducing postharvest losses from 30 to 2 percent, improving food security, and enhancing farmer incomes.

The study's findings and recommendations suggest a roadmap for strengthening northern Nigeria's food supply chain and improving food security across the region. Accordingly, the study proposes several key policy recommendations.

First, improving access to yield-enhancing modern agricultural inputs, such as inorganic fertilizer and improved seeds, is essential to boost productivity. Second, investing in physical infrastructure, particularly roads and storage facilities, is crucial to addressing the foundational challenges identified in the cost structure analysis, where poor infrastructure significantly increases transportation costs and postharvest losses. Public–private partnerships could be particularly effective in developing decentralized storage facilities near production areas.

Third, improving market information systems, particularly using digital solutions, can help address market inefficiencies. Fourth, strengthening postharvest handling through training and technology adoption is critical. The study shows that reducing postharvest losses from 30 to 2 percent through better storage solutions could generate substantial financial returns and food security benefits.

Fifth, improving government efficiency and informal practices along the value are essential steps toward food system transformation in Nigeria. For instance, reducing informal (illegal) taxation and the number of checkpoints could significantly lower costs across the supply chain, addressing the high transportation costs identified in the cost buildup analysis. Similarly, implementing interventions, policies, and incentive mechanisms that encourage value chain actors to adopt climate-smart practices could help promote sustainable solutions for food system transformation in the region.

Finally, and most importantly, improving security in the region requires policies and investments that promote economic opportunities, job creation, human development (through education and training), security infrastructure, and good governance with accountability of the public sector. Persistent insecurity significantly restricts labor movements, driving up the cost of agricultural labor in the region. In addition, clashes between farmers and herders, commonly referred to as the farmer–herder conflict—stem mainly from competition over natural resources such as land and water and is one of the major sources of insecurity in the country, causing destruction of livelihoods and lives. Targeted, well-defined policies on tenure rights, natural resources, and livestock management could mitigate this challenge.

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Annex: Supply chain maps for selected food commodities in northern Nigeria

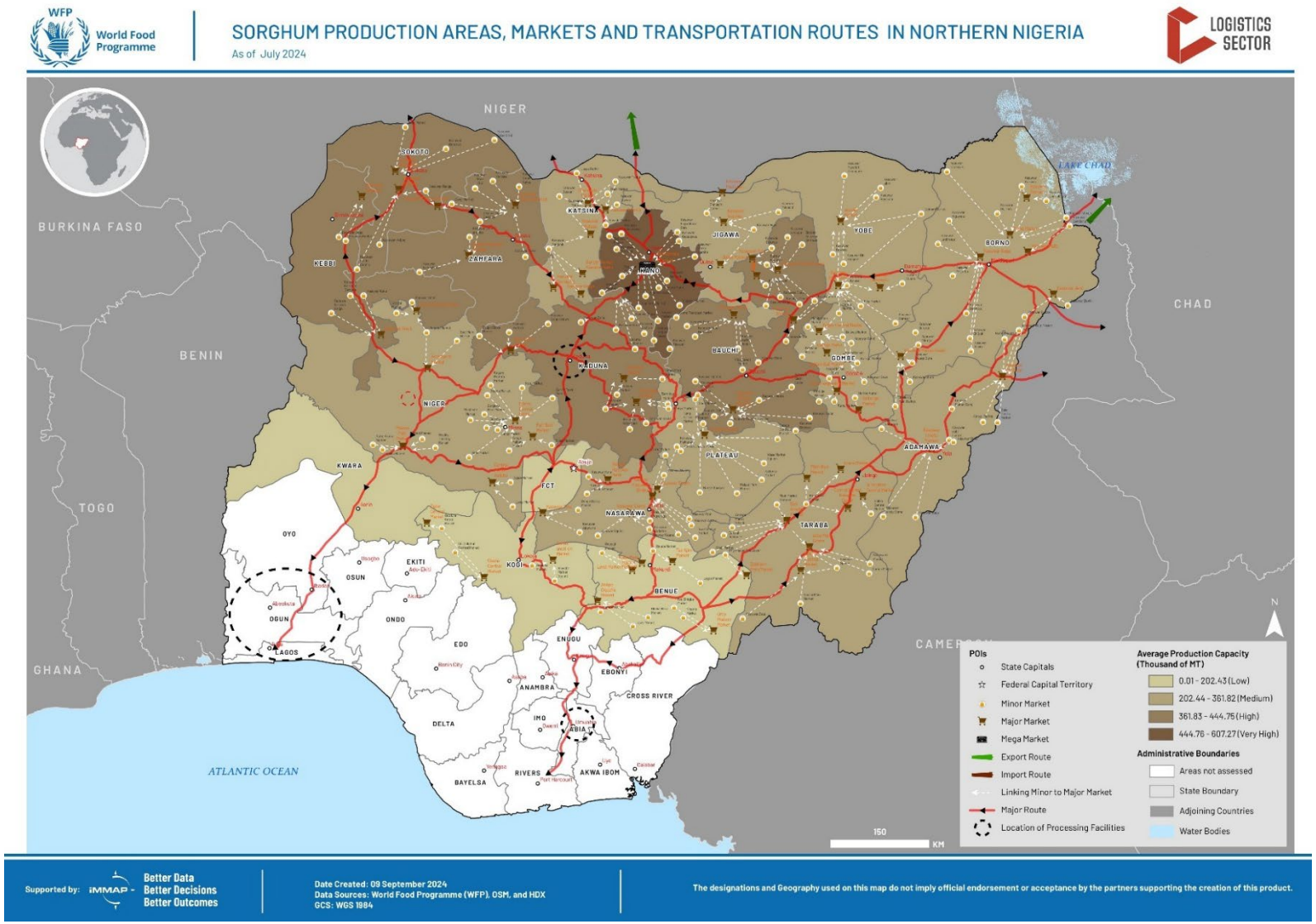

Figure A1. Sorghum—major production hubs, key market centers, and main flow routes/transport corridors

Source: WFP–Nigeria GIS team.

Annex: Supply chain maps for selected food commodities in northern Nigeria

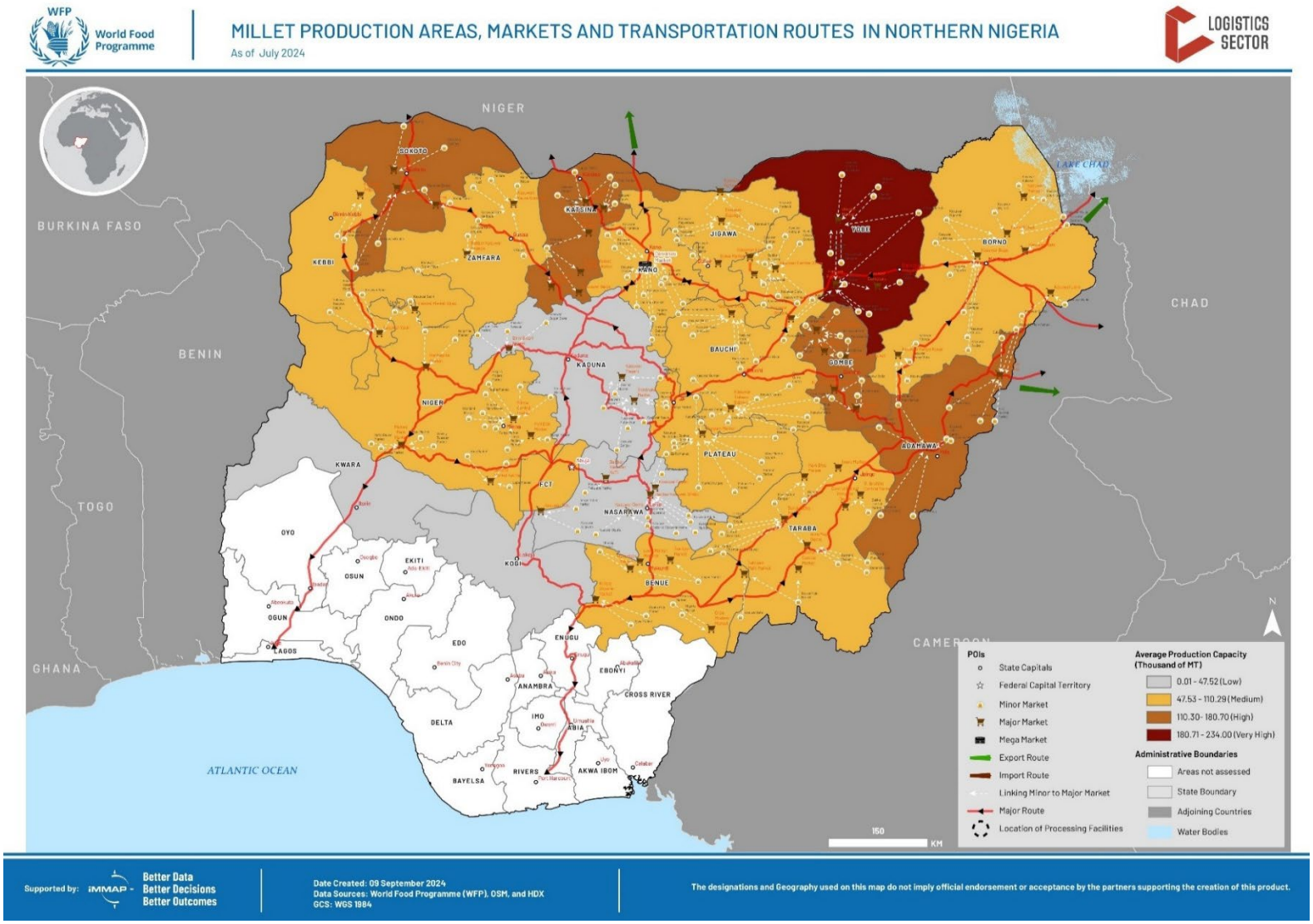

Figure A2. Millet—major production hubs, key market centers, and main flow routes/transport corridors

Source: WFP–Nigeria GIS team.

Annex: Supply chain maps for selected food commodities in northern Nigeria

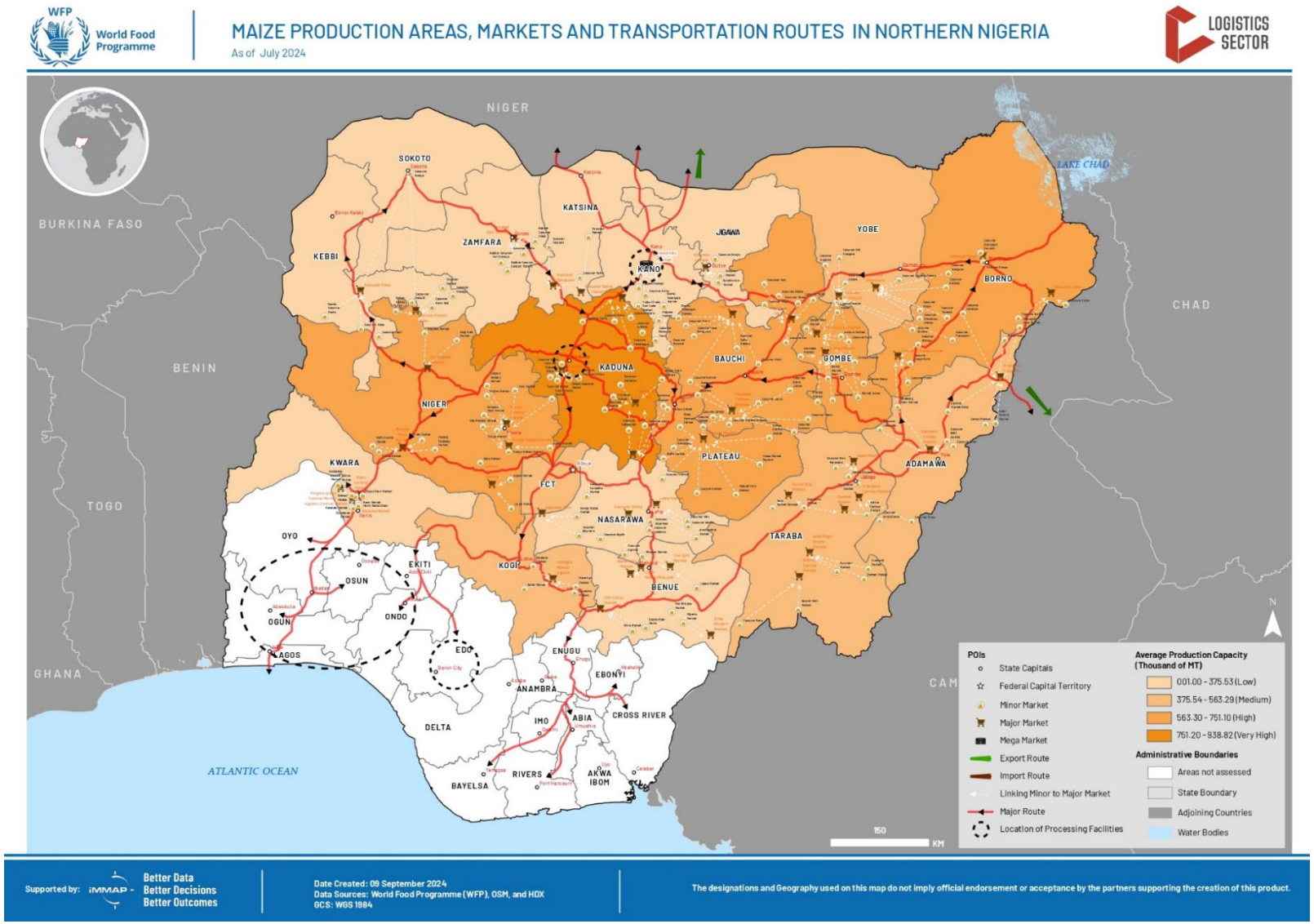

Figure A3. Maize—major production hubs, key market centers, and main flow routes/transport corridors

Source: WFP–Nigeria GIS team.

Annex: Supply chain maps for selected food commodities in northern Nigeria

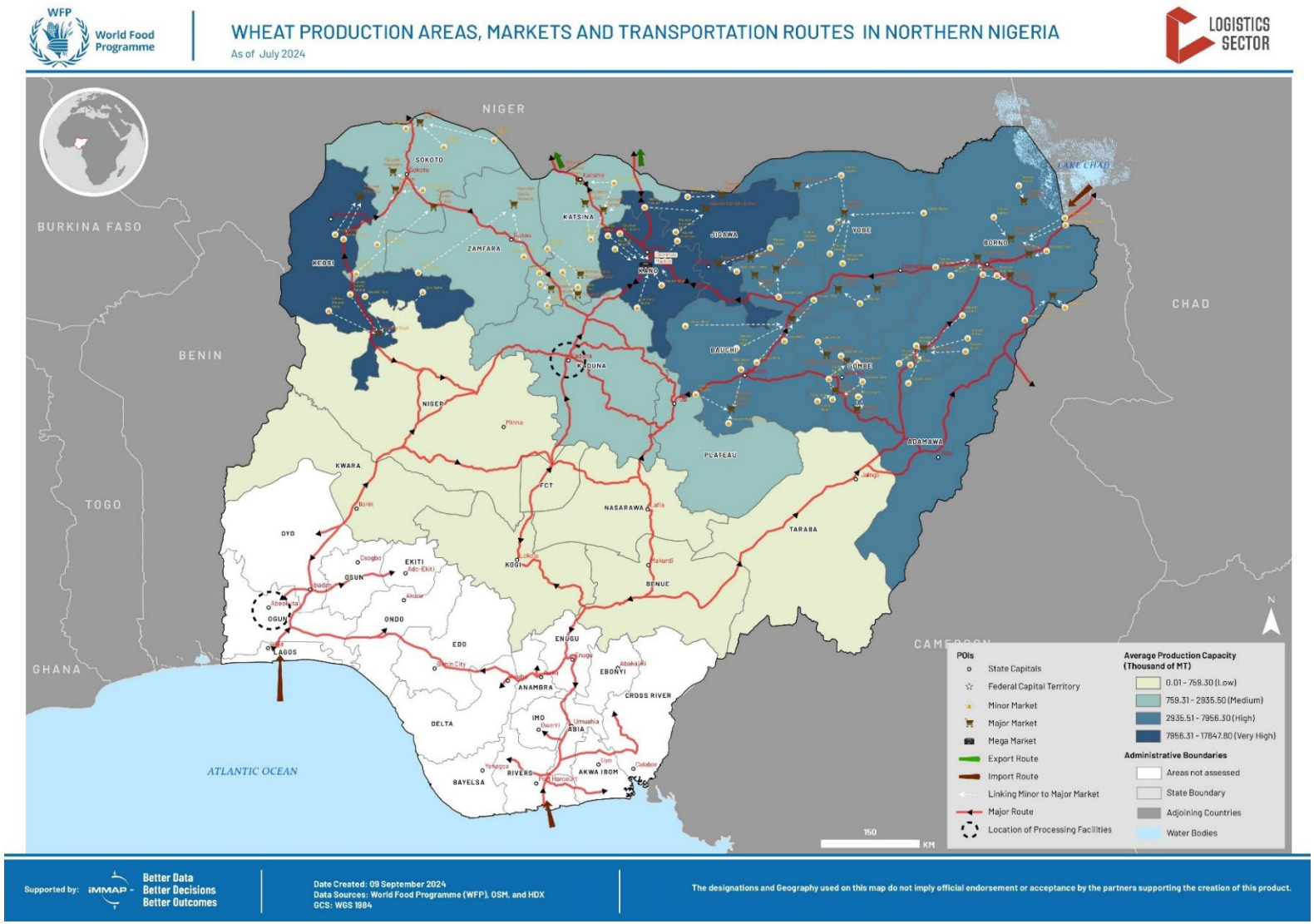

Figure A4. Wheat—major production hubs, key market centers, and main flow routes/transport corridors

Source: WFP–Nigeria GIS team.

Annex: Supply chain maps for selected food commodities in northern Nigeria

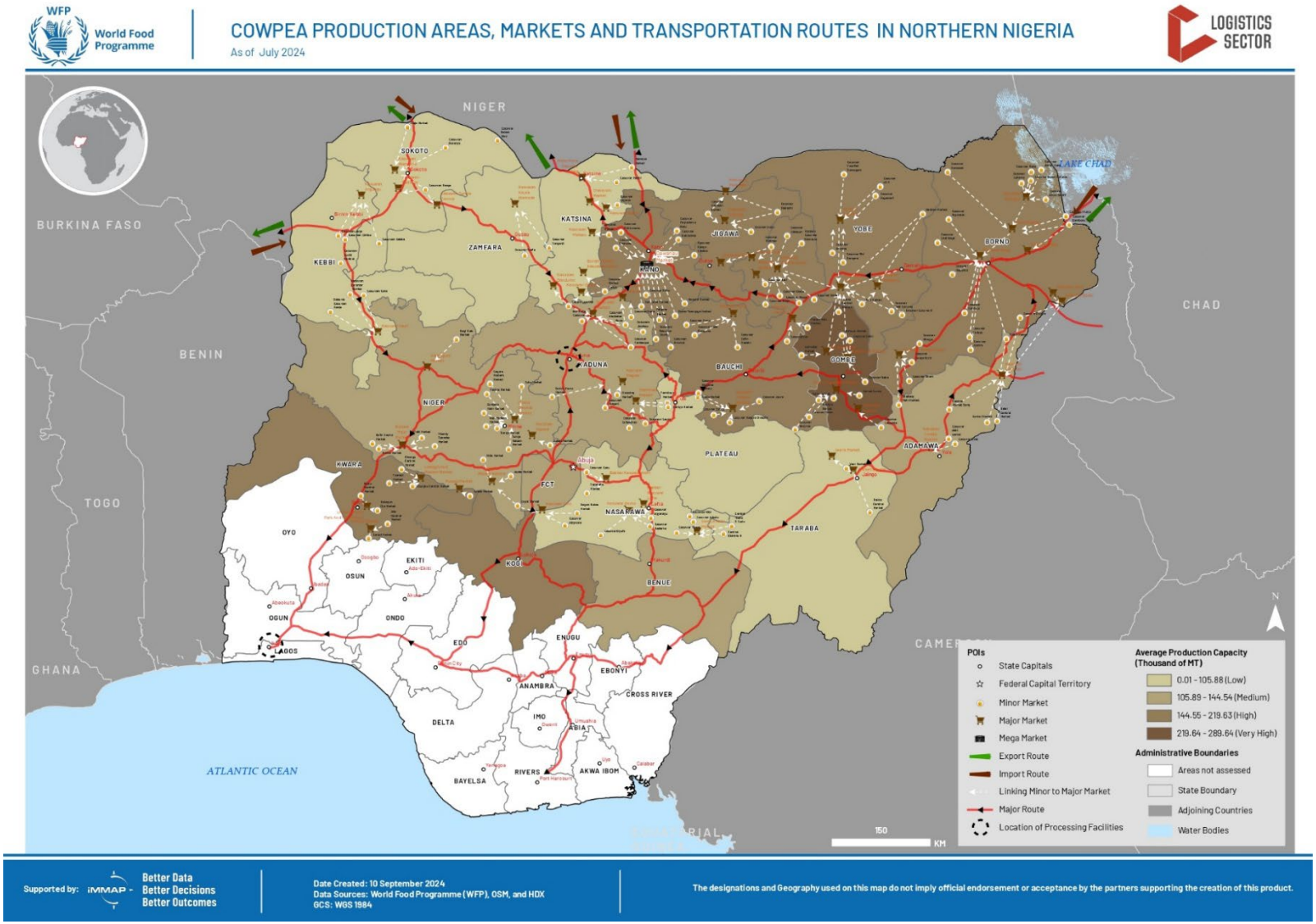

Figure A5. Cowpea—Major production hubs, key market centers, and main flow routes/transport corridors

Source: WFP–Nigeria GIS team.

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Tel.: +1-202-862-5600
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