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Sudan's Agrifood System: Structure and Drivers of Transformation

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ABSTRACT

Based on a set of Sudan's economywide databases with detailed agriculture representation, this study diagnoses Sudan's agrifood system transformation against a background of broad economic growth and transformation. Sudan's agrifood GDP observes modest growth during 2011-2019, while the agrifood system lacks transformation with little change in the structure of the system. Agricultural share of total employment fell more significantly, contributing to the structural change in the broad economy, while agriculture continuously absorbs near a half of Sudan's total employment with the lowest labor productivity, and it is still the largest component of the agrifood system. Sudan's agrifood growth was mainly driven by domestic-market-oriented value chains due to their large size and above-average growth, while exportable and importable value chains are small, and with below-average growth. Comparing sources of future growth using the IFPRI's RIAPA model shows that fruits, root crops, and cereals rank highly in the combined outcome scores, while livestock is one of few value chains with impacts on all the four outcomes.

Key words: Agrifood, agriculture, growth, poverty, diet quality, employment, Sudan.

CONTENTS

1 INTRODUCTION

Since the secession of South Sudan in 2011, the Sudanese economy has been facing unprecedented economic downturn caused by the loss of around 75 percent of oil revenue, civil strives and political instability (Alhelo et al., 2023), and more recently, by the impacts of global Covid-19 pandemic and the Russia-Ukraine war (Abay et al., 2023). The political conflict between the civilians and military entities after the fall of the Inghaz regime and the current conflict between the Sudan Armed Force (SAF) and the Rapid Support Forces (RSF) that is still ongoing has further led and will continue to lead to the deterioration of the economy (Abushama et al, 2023). The inflation rate increased from 63.3 percent in 2018 to 359.7 percent in 2021 before it slightly declined to 217.7 percent in 2022 (CBS, 2022). Exchange rates in the parallel market reached an average of SDG 550 in 2022 compared to SDG 70 and SDG 42 for one USD in 2019 and 2018, respectively. The trade deficit expanded from USD 3.6 billion in 2018 to USD 4.0 billion in 2021. Economic growth shrank by 1.9 percent in 2021 compared to an increase of 2.8 percent in 2018 (CBoS, 2022). More than 11 million people in the country faced acute food insecurity between May and September 2022 (UNOCHA, 2023).

After the 2018 revolution, the former Transitional Government of Sudan (TgoS) (2019-2021) adopted several macroeconomic measures including removing fuel subsidies (November 2021), unifying the exchange rates (February 2021) and some shock response measures such as the Sudan Family Support Program (SFSP) lunched in February 2021 with a prospect of reaching the completion point of Highly Indebted Poor Countries (HIPC) initiative in three years (Abdalla, 2021). The overthrowing of the TgoS by the military in October 2021 led to the immediate suspension/freezing of donors supports and deprived the country from expected flows of external resources in terms of debt forgiveness, development assistance and concessional loans because these were tied to realizing a transition to democracy.

Despite these dare challenges, Sudan has a great potential in agriculture with a considerable natural resources base. Sudan has plenty of arable land, around 183.3 million feddan, which is about 39.3 percent of the country's territory area. Sudan has diversified water sources – rivers, lakes, seasonal streams, and rainfalls, as well as a diversified agro-climate zones (UNEP and HCENR, 2020). While the agricultural sector has potential to grow like it occurred before 1999, the series of internal and external shocks listed above has led to an under-performed agricultural sector compared to its enormous potential during the last two decades, and achieving the sector's inclusive and sustainable growth must address a set of challenges.

The agricultural sector accounts for about one-fifth of total GDP, employs almost half of country's total labor force, and provides a main source of livelihood to around two-thirds of population (MHRDL, 2011). This study focuses on the Sudan's agrifood system transformation. The transformation of the Sudanese agriculture has been slow mainly due to the lack of political commitment by the political elite toward the sector, which is manifested in the meagre allocation of resources and the lack of commitment to implementing the announced development plans. The extremely low government expenditures on the sector have been further unfairly distributed among the subsectors, and the traditional subsector that many small farmers rely on received the smallest share of total government expenditures compared to the irrigated subsector that is dominated by large farms (WB-MFEP, 2016). Still, it is important to understand how Sudan's agrifood system has been performing, whether it has been transforming, and what is its contribution to broad economic growth and structural change.

The AFS is a complex network of actors, connected by their differing roles in supplying, consuming, and governing agrifood products and jobs. Just as economies transform, agrifood systems are expected to evolve as countries develop (Diao et al., 2010; Timmer, 1988). Subsistence farming typically dominates agriculture during the earliest stages of development, but as agricultural productivity rises, farmers start to supply surplus production to markets, thus creating job opportunities for workers in the off-farm economy (Haggblade et al., 2007), both within and outside of agrifood sectors. Rising rural incomes generate demand for more diverse products, leading to more processing, packaging, transporting, trading, and other nonfarm activities. In the early stages of transformation, the agricultural sector serves as an engine of rural, and even national, economic growth. Eventually, urbanization, the nonfarm economy, and nonagricultural incomes play more dominant roles in propelling agrifood system development, with urban and rural nonfarm consumers creating most of the demand for agricultural outputs via value chains connecting rural areas to towns and cities (Dorosh and Thurlow, 2013). However, the exact nature of this transformation process varies across countries because of the diverse structure of their economies and the unique growth trajectories of their various agrifood and nonfood subsectors.

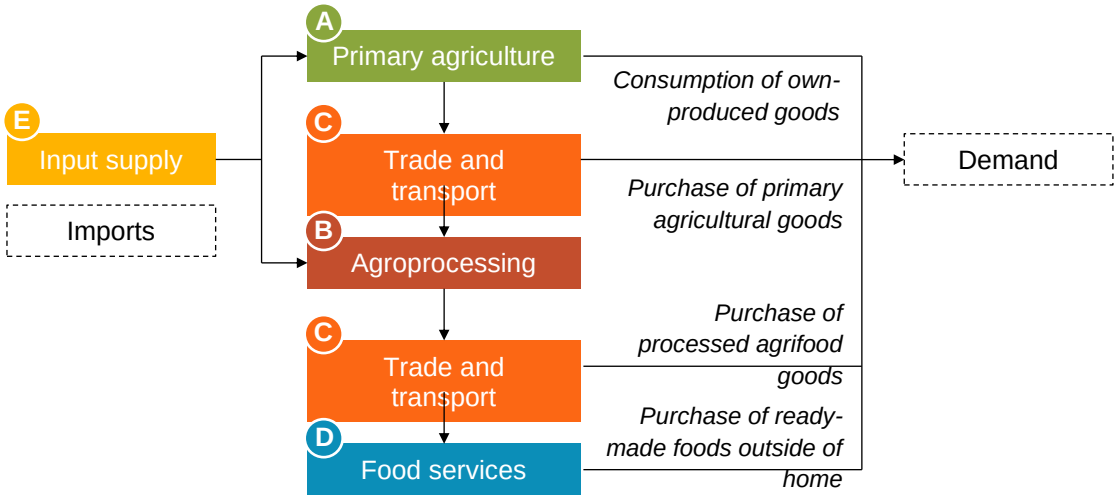
This study describes the current and changing structure of Sudan's AFS and evaluates the potential contribution of different value chains to accelerate agricultural transformation and to make it more inclusive. We focus on the period of 2011-2019, i.e., post South Sudan secession and before the global Covid-19 pandemic. We start by offering a simple conceptual framework of the AFS and apply that framework to Sudan's AFS for its current structure in Section 2. Section 2 also disaggregates Sudan's AFS across agricultural value chains, taking into consideration their different market structures and historical contribution to economic growth and transformation. Section 3 examines changes in Sudan's agrifood system and to what extent it has contributed to the broad economic transformation. Section 4 then uses a forward-looking economywide model to identify future drivers of the transformation and which value chains could be more effectively to drive the inclusive transformation. Section 5 summarizes the main findings and concludes.

2 SUDAN'S AGRIFOOD SYSTEM

2.1 A Simple Conceptual Framework

A country's AFS is a complex network of actors, connected by their differing roles in supplying, using, and governing agrifood products. A detailed conceptual description of the AFS is offered by Fanzo et al. (2020). Rather than examining all components of Sudan's AFS, we have a narrower focus in this study, i.e., the simple conceptual framework we use in the study allows us to measure the size, structure, and historical contribution of the AFS to economic growth and transformation through what is primarily a data-driven exercise. This conceptual framework emphasizes the measurement of the AFS from a supply-side perspective, which allows us to use national accounts and employment statistics to either track or simulate growth and employment changes over time.

Figure 1. A Simple Conceptual Framework of the Agrifood System



Source: Thurlow et al. (Forthcoming).

Figure 1 presents a simple conceptual framework of the AFS, made up of five components (A to E) (see Thurlow et al. 2023). *Primary agriculture* (A) is the first component of the agrifood system, and it includes the value-added generated by all agricultural subsectors, including crops, livestock, forestry, and fishing.[1] *Agroprocessing* (B) is part of the broader manufacturing sector in national accounts and includes the value-added from producing processed foods and other agriculture-related products, such as beverages, tobacco, yarn, and timber.[2] *Input supply* (E) is the value added generated during the production of intermediate inputs used directly by farmers and agroprocessors (e.g., fertilizers and financial services). Inputs that are produced by farmers and processors themselves are excluded to avoid double-counting, since these are captured in components A and B.[3] Only a portion of GDP generated by local input producers is included in AgGDP+. This portion is the share of agriculture and processing's input demand in total economywide demand for that input. For example, if farmers and processors use a third of all petroleum in the economy, then a third of the petroleum sector's GDP is considered part of the agrifood system. If all petroleum is imported, then this input does not contribute to AgGDP+, because the value-added occurs outside the country. *Trade and transport services* (C) includes all GDP generated by the transporting, wholesaling, and retailing of agrifood products between farms, firms, and final points of sale (i.e., either domestic markets or the country's border for exported goods). National accounts data do not separate the trade sector's GDP into its food and nonfood components, but these can be estimated using product-level data on transaction cost margins. Transaction costs are the main source of demand for trade services, and so a portion of trade sector GDP can be attributed to the agrifood system based on the total share of trade margins on agrifood products relative to the total margins on all marketed products. Finally, *food services* (D) is the value-added generated by the food services sector, plus a portion of the value-added generated by the hotels and accommodation sector. Producers of food services (i.e., meals prepared outside the home) run standalone operations (e.g., restaurants or stalls), whereas hotels often operate restaurants in addition

[1] Note that GDP or value-added is equal to the value of gross output minus the cost of intermediate inputs, such as the cost of seeds and fertilizers purchased and used by farmers.
[2] Note yarn and timber are the immediate downstream subsectors for cotton farming and the forestry sector.
[3] This might include seeds or planting materials produced by farmers or wheat flour used by bakeries.

to providing accommodation. The portion of GDP in the hotels and accommodation sector that is assigned to the agrifood system is based on the share of agrifood inputs in the sector's overall intermediate inputs.

Total AgGDP+ is the sum of value-added in the five components of the agrifood system and is estimated using Social Accounting Matrices (SAMs) constructed for Sudan using the latest national accounts data.[4] Estimating AgEMP+ follows a similar procedure but requires some additional data. Total employment of the agrifood system is estimated by combining GDP from the SAM's more disaggregated sectors with labor productivity estimates (i.e., GDP per worker) for 14 aggregated sectors. The employment database triangulates information from a variety of sources, including the 2008 population census (CBS, 2009), household income and expenditure surveys (CBS, 2009; 2015), and labor force survey (MHRDL, 2011), and international databases containing sectoral employment time series (De Vries et al., 2021; ILO, 2020). Our definition of employment includes all workers aged 15 years or older, with workers assigned to sectors based on their primary sector of employment.

2.2 Current Structure of Sudan's Agrifood System

The recent structure of the broad Sudanese economy is shown in Table 1, based on official national accounts data and sectoral employment statistics (MHRDL, 2011; ILO, 2020). Primary agriculture generates about 20 percent of total GDP but employs close to 50 percent of total labor force. Services are the largest sector in the economy, accounting for 58 percent of Sudan's total GDP. However, in terms of employment, the service sector ranks after agriculture with 36 percent of total labor force. Within services, trade, transport, and food services are the largest. Some such services are accounted for as part of the agrifood system, which is also elaborated in Table 1.

The size and components of Sudan's agrifood system are measured by agrifood GDP (AgGDP+) and agrifood employment (AgEMP+). The AgGDP+ was $11.1 billion in 2019 – well above the $6.5 billion of primary agricultural GDP (Table 1). Thus, within the agrifood system, for every dollar of GDP generated on the farm, there are additional 70 cents of GDP generated off the farm. A large portion of this off-farm GDP is from agro-processing, which has labor productivity (measured in GDP per worker) much higher than for the whole agrifood system ($6,301 per worker vs. $1,554 per worker, see the last column of Table 1). In general, off-farm agrifood components have labor productivity much higher than that on the farm. The labor productivity is $4,684 per worker for the total off-farm agrifood system, four times of the labor productivity of primary agriculture, which is $1,057 per worker. Off-farm labor productivity within AFS is comparable with the average labor productivity for the rest of the economy outside AFS ($4,057 per worker).

[4] A SAM is an economywide database that captures resource flows associated with all economic transactions between all agents (e.g., households, producers, or government) in an economy during a calendar year, thus providing a snapshot of the structure of an economy at a point in time (Round 2003).

Table 1. Sudan's Agrifood System (2019)

Sectors	GDP		Employment		Average GDP per worker ($)
	Value ($ billions)	Share of total (%)	Workers (millions)	Share of total (%)	
Total economy	**32.3**	**100.0**	**12.4**	**100.0**	**2,609**
Agrifood system (AgGDP+)	**11.1**	**34.4**	**7.2**	**57.8**	**1,554**
Primary agriculture (A)	6.5	20.2	6.2	49.9	1,057
Off-farm agrifood system	4.6	14.2	1.0	7.9	4,684
Agro-processing (B)	1.4	4.2	0.2	1.8	6,301
Trade and transport (C)	1.9	5.9	0.6	5.0	3,088
Hotels and food services (D)	1.0	3.2	0.1	0.9	9,780
Input supply (E)	0.3	0.9	0.04	0.3	6,844
The rest of the economy	**21.1**	**65.6**	**5.2**	**42.2**	**4,057**
Total manufacturing	3.2	9.9	0.8	6.5	4,000
Total services	18.7	58.0	4.5	36.4	4,156
Trade, transport & food services	8.4	26.4	2.6	21.0	3,231

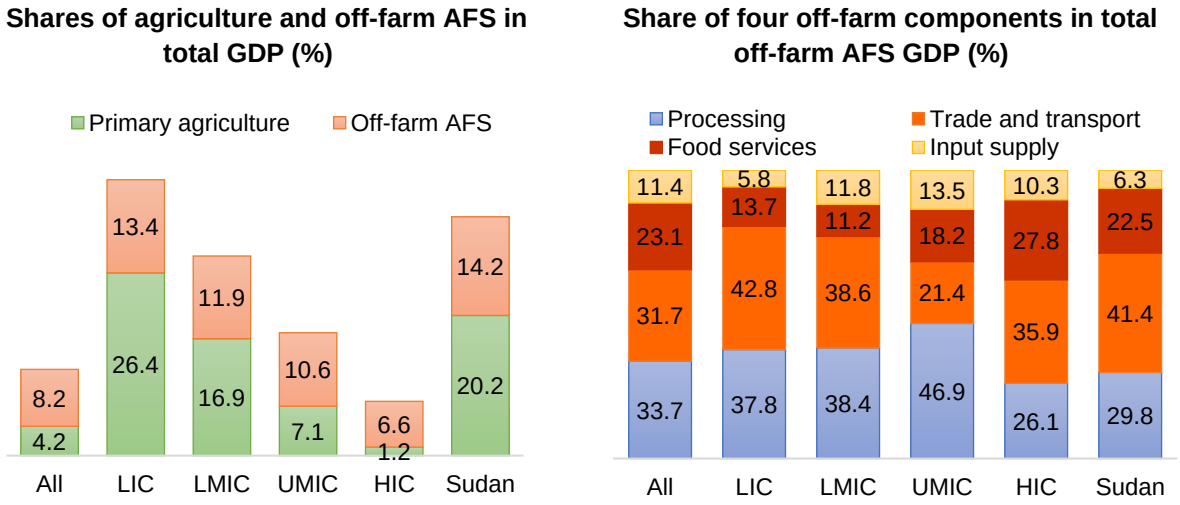
Source: Author's analysis using IFPRI's 2019 Sudan SAM.

Notes: A to E correspond with the five agrifood system components from Figure 1.

2.3 Comparing Sudan's Agrifood System to Other Countries

Importance and structure of the agrifood system varies at different stages of development. The World Bank's income groups are used here to group countries into different groups. Gross national income (GNI) is calculated according to the World Bank Atlas method in the US dollar. The low-income countries (LICs) are countries with GNI per capita falling below $1,000 in 2019, while for lower-middle-income countries (LMICs), GNI per capita is between $1,000 and $4,000. According to the level of GNI per capita, Sudan was a LMIC in most years of 2010s, but it fell to a LIC in 2019 with GNI per capita at $940. Comparing Sudan to the country groups of the world, it shows that Sudan's share of AFS in total GDP lies between LICs and LMICs (Figure 2). Within the off-farm components of the agrifood system, Sudan's agro-processing is smaller than expected, while food services are larger.

Figure 2. Comparing Sudan's Agrifood System to Other Countries (2019)



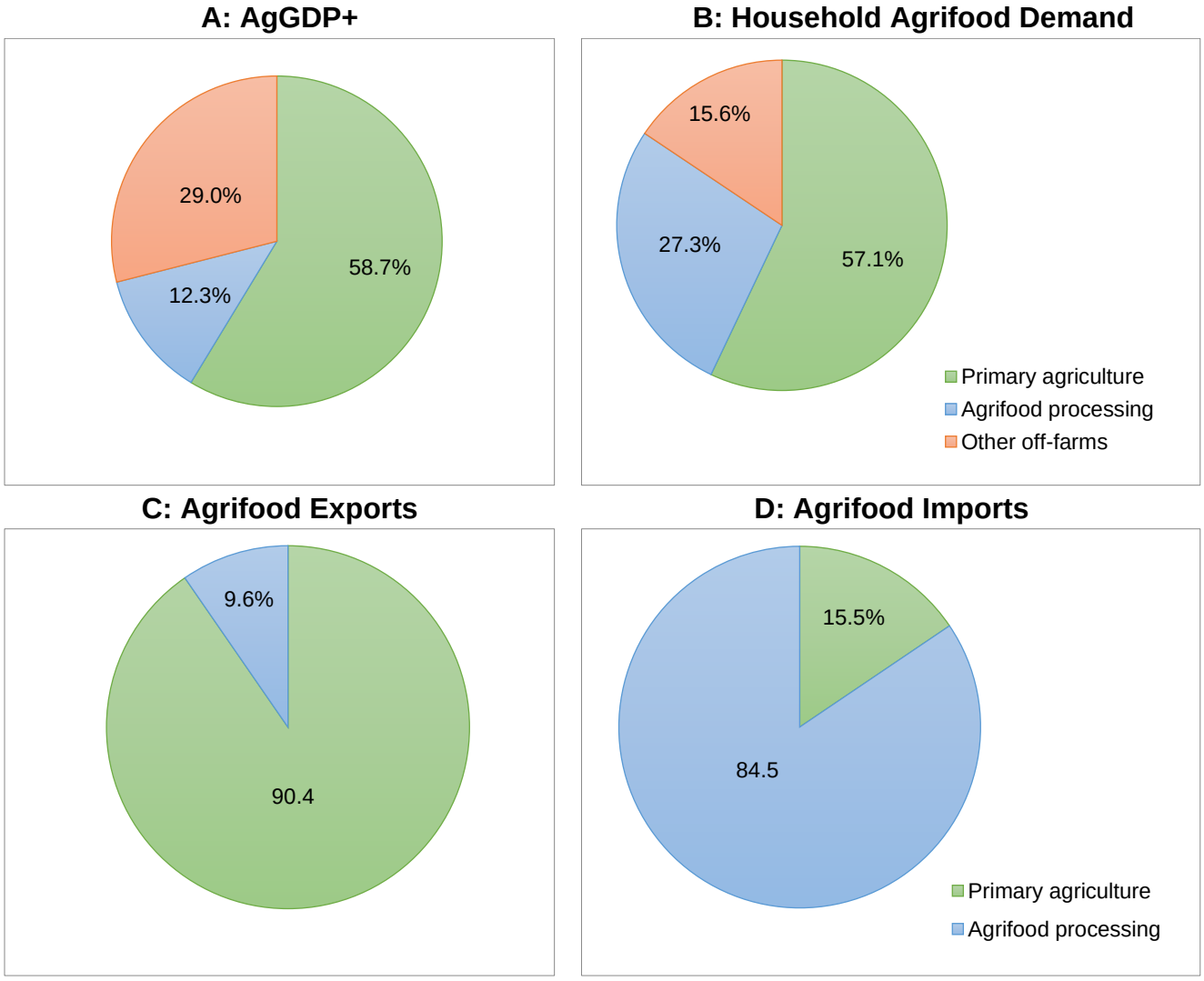
Source: IFPRI's Agrifood System Database (Thurlow et al. forthcoming) and IFPRI's 2019 Sudan SAM.

Notes: LIC are low-income countries; LMIC are lower-middle income; UMIC are upper-middle income; and HIC are high income.

2.4 Unpacking the Demand Side of Sudan's Agrifood System

The five components of AgGDP+ measure the structure of agrifood system on its supply side. On the demand, we use household agrifood demand and agrifood trade (imports) to measure the structure of agrifood system in Sudan. Panels A and B of Figure 3 compare the structure of Sudan's AFS from the supply side, as measured by AgGDP+ (Panel A), against the structure of the AFS from the demand side, as measured by household consumption of agrifood products (Panel B). While 58.7 percent of AgGDP+ is from primary agriculture, primary agricultural commodities account for 57.1 percent of household demand. In contrast, household demand for processed agrifood products accounts for 27.3 percent of total agrifood demand, even though the associated sector accounts for only 12.3 percent of AgGDP+. The bias toward processed agrifood products bias is mirrored in the high share of agrifood imports accounted for by processed products, i.e., 90.4 percent of agrifood commodity exports are primary agricultural commodities (Panel C), but 84.5 percent of imports are processed goods (Panel D). Competition with processed imports is a challenge for Sudan's agrifood system transformation.

Figure 3: Composition of Agrifood System GDP, Household Demand, and Trade (2019)



Source: Authors' calculation using IFPRI's 2019 Sudan SAM

2.5 Disaggregating the Agrifood System Across Value Chains

For a more detailed assessment of structural and historical growth patterns within the AFS, we group Sudan's agrifood system into value chain groups. The IFPRI's 2019 Sudan SAM covers 19 primary agricultural sectors/commodities and 18 agro-processing sectors/commodities. We grouped 19 primary agricultural sectors/commodities into 12 value chain groups and mapped agro-processing sectors and other components of AFS into these 12 groups according to their close relationship with each of the 19 primary agricultural sectors. There are two processed agricultural sectors – processed food and beverages – that manufacture highly processed food products with fewer or more convoluted linkages back to primary agriculture. We therefore call them as an "unattributable" standalone group as a part of off-farm AFS. Nevertheless, more than 90 percent of Sudan's off-farm agrifood system can be attributed to distinct product groups, and thus, we call these 12 groups of agricultural sectors/commodities and their related off-farm components as AFS value chains but name them according to their primary agricultural products. Table 2 presents these 12 value chains for their shares in total AgGDP+, and GDP for primary agriculture and the aggregate off-farm components.

The trade status of the 12 value chains is used to further categorize them into three types – exportable, importable, and less traded value chains. The last two columns of Table 2 present ratios of export to output and import to total consumption of primary and processing agriculture combined (excluding other off-farm components in the calculation). We use the ratio of export to output for total primary and processing agriculture (1.8 percent) and ratio of import to consumption for total primary and processing agriculture (6.3 percent) to assign the tradable status for individual value chains. Specifically, a value chain identified as exportable if it has an above-average portion of agricultural and processed products produced for foreign markets, while an importable value chain has an above-average portion of primary agricultural and processed products imported for meeting domestic demand. The rest of the value chains that are less dependent on international trade belong to the less traded group.

Table 2. Decomposing Agrifood System Across Value Chains (2019)

Value chains	Share of total GDP (percent)			Exports/ output	Imports/ consumption
	Agrifood system	Primary agriculture	Off-farm AFS		
Total	**100.0**	**100.0**	**100.0**	**1.8**	**6.3**
Exportable	**8.9**	**10.2**	**7.1**	**13.8**	**6.8**
Oilseeds	8.7	9.9	7.1	12.2	6.8
Cotton	0.2	0.3	0.1	64.3	0.0
Importable	**10.4**	**7.7**	**14.2**	**1.6**	**32.4**
Other cereals	2.4	0.9	4.5	2.6	24.2
Other crops	5.7	4.4	7.5	0.0	42.5
Forestry	2.3	2.3	2.2	3.7	11.3
Less tradable	**78.0**	**82.2**	**72.2**	**0.5**	**1.3**
Sorghum	13.8	13.7	14.0	0.0	0.0
Pulses	4.1	5.4	2.4	1.0	5.7
Roots	0.9	1.3	0.3	0.0	0.0
Vegetables	6.5	9.2	2.6	0.4	0.8

Value chains	Share of total GDP (percent)			Exports/ output	Imports/ consumption
	Agrifood system	Primary agriculture	Off-farm AFS		
Fruits	7.4	6.5	8.6	0.1	2.4
Livestock	44.1	44.9	42.9	0.7	1.1
Fish	1.3	1.2	1.4	0.5	1.3
Unattributable	**2.7**	**0.0**	**6.5**	**0.0**	**14.5**

Note: Sorghum includes sorghum and millet. Other cereals are dominated by rice and wheat, and include also maize, barley, and other cereals. Other crops include sugarcane, tobacco, tea, coffee, and other crops. Fish includes aquaculture and capture fisheries. Livestock includes cattle, raw milk, poultry, eggs, small ruminants, and other livestock.

Source: Author's analysis using IFPRI's 2019 Sudan SAM.

Table 2 shows that Sudan's agrifood system is predominantly domestic market-oriented value chains – the less traded value chains. There are only two exportable value chains that account for 8.9 percent of total agrifood GDP, 10.2 percent of primary agriculture GDP, and 7.1 percent of off-farm AFS GDP. There are three importable value chains accounting for only 10.4 percent of total agrifood GDP. However, two of the three importable value chains – other cereals and other crops – have disproportionate shares of off-farm AFS GDP. For example, other cereals account for only 0.9 percent of total primary agriculture GDP, while they account for 4.5 percent of total AFS GDP off-farm. This indicates that importable value chains compete with not only primary agricultural imports but also processed agrifood imports.

Domestic market dominates Sudan's agrifood system. There are seven less traded value chains that account for 78 percent of total agrifood GDP. Less traded value chains have relatively smaller off-farm share (72.2 percent of total) and larger on-farm (primary) share (82.2% of total), with sorghum and fruits value chain being exceptions. Livestock is Sudan's largest value chain, accounting for 44 percent of total agrifood GDP, 45 percent of primary agriculture GDP, and 43 percent of off-farm GDP. Among the less traded, sorghum, fruits, and vegetables are also sizable value chains in terms of their share of total agrifood and primary agriculture GDP. Sorghum and fruit value chains have further relatively large shares of total off-farm AFS GDP, 14.0 percent and 8.6 percent, respectively. Because of their large size of agrifood GDP both on the farm and off-farm, promoting growth in livestock, sorghum, and fruit value chains is expected not only to have important contributions to improve the country's food security, but also could be effective in driving agricultural transformation by boosting value added and employment in agrifood system off-farm.

Table 3 disaggregates each value chain group across the five components in the agrifood system. At least one third of the value-added in other cereals and fruits value chains is generated from processed agriculture, with 78 percent of other cereals value added being off-farm (41 and 33 percent, respectively generated from agro-processing and trade & transport). Trade and transport margins make up at least 20 percent of GDP in other cereals, pulses, livestock, and fish value chains, and hotel and food services generate close to or more than 20 percent of GDP in sorghum and other crops value chains. This indicates that these products are highly tradable in Sudan's domestic markets. On the other hand, more than 80 percent of GDP in root crops, vegetables, and cotton value chains are generated on the farm. Among these three value chains, cotton is an exportable value chain, and vegetables can become a highly tradable high-value value chain for the domestic market. Thus, despite the growing importance of purchased and processed foods in Sudan, many value chains still generate most of their value-added on the farm. Overall, 59 percent of the agrifood GDP is generated on-farms while another 17 percent is generated within the trade and transport value chain.

Table 3. Decomposing agrifood GDP Within Value Chains (2019)

Value chains	Primary agriculture	Agro-Processing	Trade & transport	Hotels & food services	Input supply	Agrifood system
All products	58.7	12.3	17.1	9.3	2.6	100
Sorghum	58.1	9.8	11.4	18.0	2.7	100
Other cereals	21.9	40.6	32.5	4.0	1.0	100
Roots	84.9	0.0	10.3	0.0	4.7	100
Pulses	76.3	0.1	20.1	0.0	3.5	100
Oilseeds	66.6	11.6	13.9	6.3	1.6	100
Vegetables	83.4	0.5	12.7	0.9	2.5	100
Fruits	51.7	33.6	11.8	2.7	0.3	100
Cotton	86.8	1.5	6.7	0.0	5.0	100
Other crops	45.7	9.0	12.8	31.0	1.6	100
Livestock	59.8	11.7	20.0	5.6	2.8	100
Fish	54.2	5.0	25.1	14.9	0.8	100
Forestry	59.9	10.4	28.3	0.5	0.9	100

Source: Author's analysis using IFPRI's 2019 Sudan SAM.

In summary, Sudan's agrifood system is predominantly domestic market oriented. Primary agriculture is the largest part of agrifood GDP, while off-farm components are important. For every dollar generated on the farm, there are additional 70 cents generated off the farm. The structural relationship between the on-farm and off-farm components of the agrifood system described in this section helps understand the agrifood system's linkages to the rest of the economy, which anticipates its potential contribution to economic growth and broad economic structural change. The off-farm agrifood system is more productive than farming measured by GDP per worker, which means that with the growth of agrifood system off-farm, more income could be generated to the rural economy than agriculture alone. On the other hand, because off-farm components of the agrifood system are more productive than farming, absorbing workers exited from farming requires much more rapid growth in economic activities off-farm within and outside the agrifood system. Finally, decomposing AgGDP+ across value chains helps us anticipate how different value chains and their growth might affect agricultural transformation differently. Sections 3 and 4 turn to this question by first examining past growth trends (section 3) and assessing drivers of future growth (section 4).

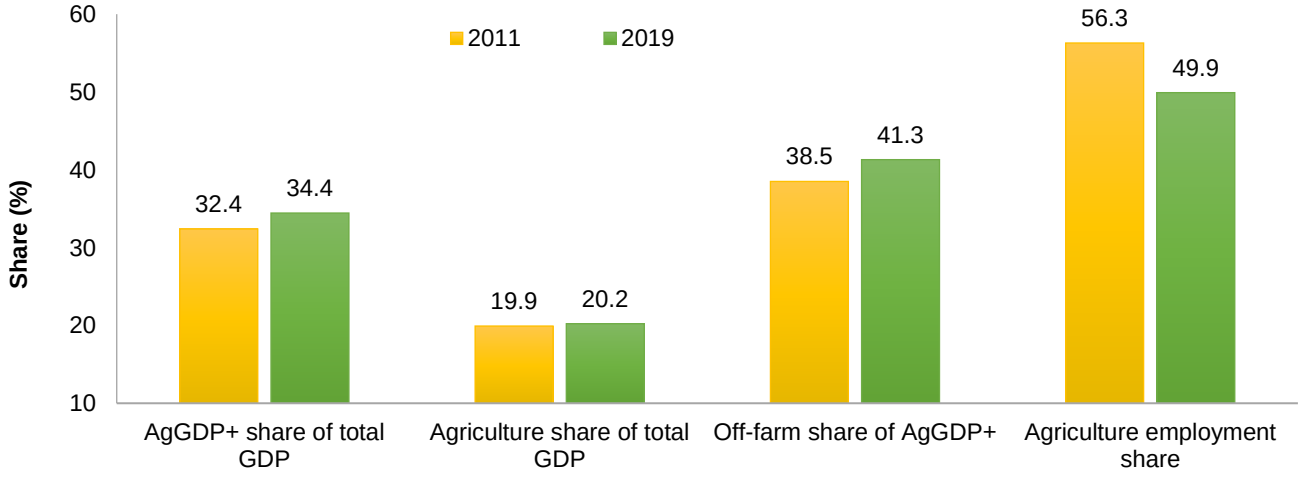
3 STRUCTURAL CHANGE IN BROAD ECONOMY AND AGRIFOOD SYSTEM AND DRIVING FORCES OF AGRIFOOD GROWTH

This section's analysis focuses on the period of 2011-2019 post South Sudan secession and before the global Covid-19 pandemic. The analysis relies on IFPRI's 2011 and 2019 Sudan SAMs that are constructed using official national accounts data for GDP and various national and international sources for employment. Although SAMs are measured in current prices, they are converted to constant prices based on the national account data in both current and constant prices across sectors to allow comparisons over time.

The performance of the agrifood system in recent years has been assessed with a focus on the structural change within the system. Agriculture generally has the lowest labor productivity in an economy, and productivity is higher off-farm both within and outside the AFS. Economic growth and urbanization are expected to lead to rapid growth among nonagricultural sectors including those off-farm components of the agrifood system. This will help create jobs for rural households with higher payments and hence to increase households' incomes including many small farmer households with some family members working off-farm.

Figure 4 compares shares of agricultural and AFS GDP in total GDP and agricultural employment share of total employment between 2011 and 2019. The figure also compares the share of off-farm components in AgGDP+ in these two years. The figure indicates that Sudan's agrifood system lacked transformation between 2011 and 2019. Both agricultural and AFS shares of total GDP did not fall, and the off-farm components in AgGDP+ were similar in these two years (at around 20 percent of agrifood GDP). The stagnant structure of Sudan's agrifood system is consistent with the country's poorly performed broad economy that will be discussed later. Agricultural share of total employment fell from 56.3 percent in 2011 to 49.9 percent in 2019, while agricultural share of total GDP barely changed. This indicates a modest improvement in agricultural productivity.

Figure 4. Changing Structure of Agrifood System GDP in Sudan (2011 and 2019)



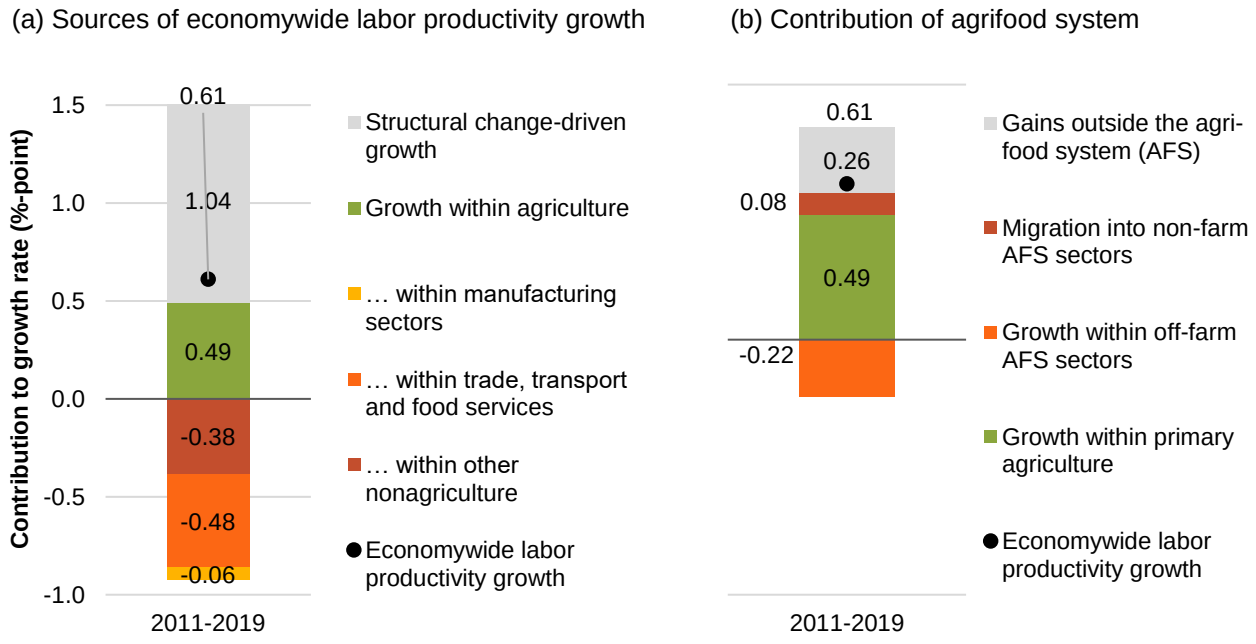
Source: Author's analysis using IFPRI's 2011 and 2019 Sudan SAMs.

The lack of structural change within the agrifood system observed in Figure 4 coincides with a period of relatively modest growth for the broad Sudanese economy. Sudan's overall economy grew at 3 percent per year during 2011-2019. While growth in primary agriculture is almost identical to overall economic growth. Such growth was led mainly by population increase, while the economywide labor productivity barely changed in this period, as shown in Figure 5.

The broad economic structural change is an indication of economic development. Productivity growth is the fundamental driver of economic development, and productivity growth comes from two channels. First, productivity can increase amongst workers within their sectors of employment. Second, economywide productivity increases when workers migrate from less to more productive sectors. As mentioned earlier, GDP per worker in agriculture is much lower than in other parts of the agrifood system and in the rest of the economy. As such, a shift in employment patterns away from agriculture and into other sectors should generally increase labor productivity economywide. These two channels are usually referred to as the "within sector" and "between sector" (or "structural change") drivers of labor productivity growth. The individual contributions of these structural drivers of growth can be estimated using a decomposition approach described in McMillan et al. (2014).

Figure 5 presents the overall findings from such a growth decomposition analysis for the broad economy. As shown in Panel (a), economywide labor productivity grew at an average annual rate of 0.61 percent during 2011-2019. Within sector productivity growth was negative for all nonagricultural sectors, and it was positive only for agriculture. This makes labor productivity growth within agriculture the second largest contributor to economywide labor productivity growth, at 0.49 percentage points, after structural change led growth that is 1.04 percentage points.

Figure 5. Decomposition of Average Annual Labor Productivity Growth Rate (2011-2019)



Source: Author's analysis using IFPRI's 2011 and 2019 Sudan SAMs and employment database.

Panel (b) estimates the contribution of the agrifood system to total labor productivity growth, which includes the contribution from primary agriculture and the rest of agrifood system. The within-sector contribution from primary agriculture is the same in both panels, at 0.49 percentage points. The migration of workers into the off-farm components of the agrifood system accounts for a small share of the structural change-led growth that took place in Sudan over the last decade (i.e., 0.08 percentage points out of a total 1.04 percentage points). However, like the nonagricultural sectors in the broad economy, labor productivity growth within off-farm AFS components is negative, at -0.22 percentage points. This causes the total contribution of agrifood system to the economywide labor productivity growth smaller than the contribution of primary agriculture, at 0.35 percentage points.

We further evaluate the growth performance across agrifood value chains. As previously, value chains are grouped according to their trade status, i.e., exportable, importable, and less traded. At the aggregate, Sudan's agrifood system observes modest growth and annual growth rate was 4.0 percent for AgGDP+ and 3.4 percent for agriculture GDP. Only processing agriculture grew more rapidly, at 7.9 percent per year during 2011-2019.

At the value chain level, there are only four value chains that achieved above-average annual growth rate (4 percent) during 2011–2019, which are marked with an asterisk (*) in Table 4. Two fast-growing value chains are in exportable (cotton) or importable (other cereals), while there are only two out of the seven less-traded value chains that achieved above-average growth. Off-farm growth was slower for fast-growing value chains, whose growth was primarily led by growth on the farm (primary agriculture).

Table 4. Value Chains Growth in Sudan (2011-2019)

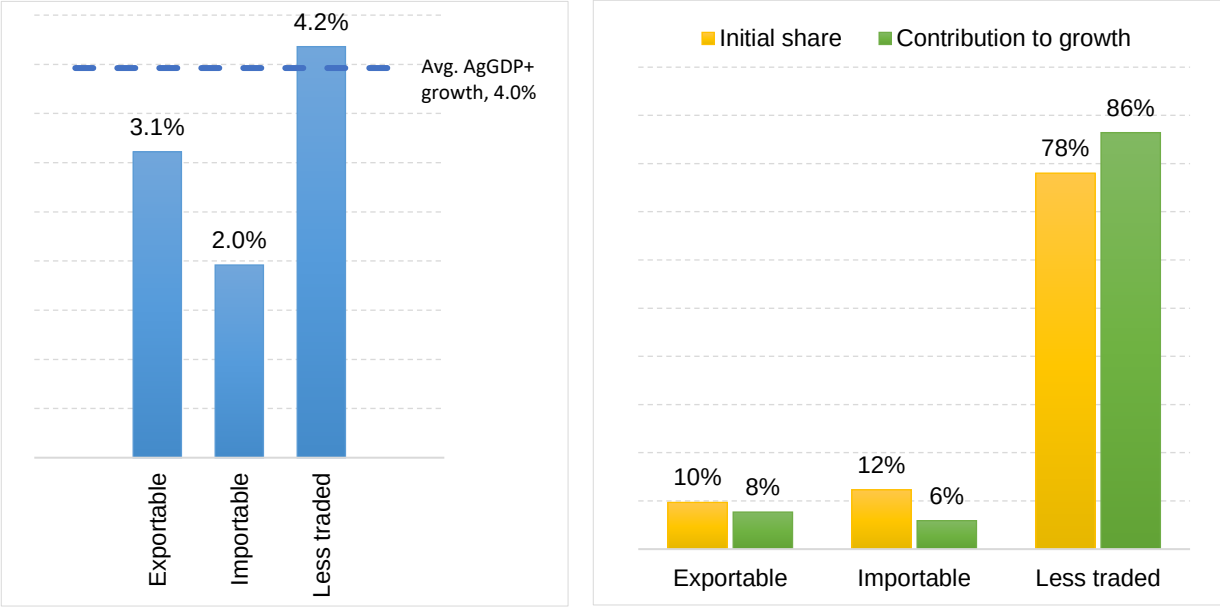
Value chains	Average annual GDP growth rate (percent)			
	Agrifood system	Primary agriculture	Off-farm AFS	Processing
Total	**4.0**	**3.4**	**4.9**	**7.9**
Exportable	**3.1**	**2.3**	**4.9**	**8.4**
Oilseeds	3.0	2.2	5.0	8.5
Cotton*	6.8	7.6	2.6	-7.0
Importable	**2.0**	**-1.7**	**5.8**	**10.0**
Other cereals*	6.7	6.5	6.7	9.2
Other crops	1.0	-4.5	9.2	11.7
Forestry	0.6	3.1	-2.3	9.8
Less tradable	**4.2**	**4.1**	**4.3**	**7.4**
Sorghum	0.6	-2.3	6.2	8.0
Pulses	-0.8	-0.1	-4.1	
Roots	2.4	3.0	0.6	9.7
Vegetables	-0.3	0.4	-3.4	10.1
Fruits	0.6	-2.4	4.9	8.5
Livestock*	7.8	10.6	4.6	6.8
Fish*	6.5	7.4	5.6	8.4

Source: Author's analysis using IFPRI's 2011 and 2019 Sudan SAMs.

Note: The value chains marked with * have their agrifood GDP growth rate above the average for total AgGDP+ (i.e., more than 4 percent per year).

Figure 6 summarizes some of the key findings of Table 4. Domestic market is the driving force for agrifood growth in Sudan in the recent years. Less traded value chains dominated the agrifood system with their large size and above average growth (4.2 percent), contributing 86 percent of agrifood growth in 2011-2019. Growth in the tradable value chains was slow, and with their small sizes in AFS, the contribution of exportable and importable value chains to total agrifood growth was modest (8 percent and 6 percent respectively).

Figure 6. AgGDP+ Growth Rates, Shares, and Contribution to Growth, by Value Chain Grouping (2011–2019)



Source: Author's analysis using IFPRI's 2011 and 2019 Sudan SAMs.

In summary, the internal and external shocks faced by the Sudanese economy have negatively affected the nonagricultural economy more than the impact on the agrifood system, and primary agriculture was especially less affected. Sudan's broad economy lacked productivity-led growth during 2011-2019. The slow growth in labor productivity resulted from the declines in productivity within nonagricultural sectors, while labor productivity growth in the agricultural sector was positive but modest. The agrifood system lacked structural change and transformation, and the growth decomposition within the agrifood system shows that there are only four value chains with above-average growth in 2011-2019. Domestic market was the driving force for agrifood growth in Sudan. Less traded value chains dominated the agrifood system with their large size and above average growth, contributing 86 percent of agrifood growth in 2011-2019. The contribution of exportable and importable value chains to total agrifood growth was modest because of their small size and below-average growth.

4 FUTURE DRIVERS OF INCLUSIVE AGRICULTURAL TRANSFORMATION

In this section we use IFPRI's Rural Investment and Policy Analysis (RIAPA) model to compare the potential contributions of growth driven by different agricultural value chains to inclusive agricultural transformation. Development outcomes are proxied by reductions in poverty, improvement in diet quality, job creation economywide, and growth in national GDP.

4.1 RIAPA model

RIAPA comprises series of interlinked datasets and models that are used to assess investment prioritization at country-level. At the core of RIAPA is an economywide computable general equilibrium (CGE) model that simulates the functioning of a market economy, including markets for products and factors (i.e., land, labor, and capital). A detailed description of the CGE model behavioral assumptions is provided by Diao and Thurlow (2012). Here we provide a summary of the salient features.

RIAPA tracks changes in household incomes and expenditures, including changes in food and nonfood consumption patterns. The 10 representative household groups in RIAPA are separated by rural and urban consumption quintiles groups. RIAPA also tracks poverty and dietary impacts using survey-based microsimulation analysis. Individual survey households map to the model's household groups. Estimated consumption changes in the model are applied proportionally to survey households, and post-simulation consumption values are recalculated and compared to a poverty line and a hunger line to determine households' poverty and hunger status. Likewise, food consumption values are compared to the cost of a healthy reference diet to estimate the improvement in diet deprivation, an index defining the extent of the consumption shortfall within and across multiple food groups. The poverty and diet quality indicators are described in more detail below.

4.2 Comparing development outcomes associated with growth driven by different agrifood value chains

RIAPA is used to simulate the economywide effects of raising productivity in ten agrifood value chains or value chain groupings. Ten of the 12 value chains groups discussed in the previous section are considered in the simulation analysis (and fishery and forestry value chains were not considered). In each simulation scenario, farm-level total factor productivity growth in a targeted value chain group is accelerated beyond its baseline growth rate such that total agriculture GDP is one percent higher than in the baseline by 2025. The ten value chains differ in size, and so to achieve the same absolute increase in total agriculture GDP in each scenario, productivity in smaller value chains (such as cotton and other cereals, 0.3 and 0.9 percent of total agriculture GDP, respectively) must grow faster than in larger ones (such as livestock and sorghum, 45 and 14 percent of total agriculture GDP, respectively). Agricultural value chains also differ in terms of their structure and downstream linkages. Therefore, while the targeted increase in agriculture GDP is one percentage in all value chain scenarios, induced growth in upstream input supply activities or downstream processing activities as well as demand for trade and transport services along agrifood value chains may differ across scenarios. The value chain scenarios may therefore have different development implications both for the entire agrifood system and the total economy.

Four outcome indicators are used to assess the impacts of agricultural productivity growth originating from various targeted value chains. They measure changes in poverty, diet quality, employment, and growth and serve as a proxy for inclusive agricultural transformation. The poverty-growth elasticity (semi-PGE) measures the percentage-point change in the poverty headcount rate associated with a one percentage growth in agriculture GDP led by the productivity growth in a targeted value chain. The poverty headcount rate is the share of the population with consumption below the international $1.90 poverty line. For comparison purposes a semi-PGE is also estimated for the poverty gap, which measures the average gap between poor people's consumption levels and the poverty line.

Diet quality improvement is measured by the improvement in diet deprivation measure – the Reference Diet Deprivation (ReDD) index (Pauw et al. 2021), which is an index that defines the extent of the consumption shortfall within and across multiple food groups. More specifically, it estimates the incidence, breadth, and depth of food consumption gaps across six food groups by comparing observed consumption against consumption levels recommended by the EAT-Lancet healthy reference diet (Willett et al. 2019). Improvement in diet quality is the percentage change in ReDD, which indicates a narrowing of the multidimensional food consumption gap and thus signifies an improvement in diet quality. The percentage change in the diet quality improvement is measured with a given one percent growth in agriculture GDP led by productivity growth in agricultural production of targeted value chains. Lastly, GDP and employment impacts are measured by the changes in GDP (in $US million) or employment (in 1,000 persons) in the total economy associated with one $US million increase in agriculture GDP of the targeted value chain.

Table 5. Estimated Poverty, Diet Quality, Economic Growth, and Employment Elasticities

Targeted value chains	Change in indicator given per unit change in agriculture GDP driven by productivity gains (value chain rank in parentheses)				
	Poverty (semi-PGE)		Diet quality	Total GDP	Total employment
	Headcount rate (%-point)	Poverty gap (%-point)	(DGE)	($million)	(1,000 persons)
Sorghum	-0.44 (1)	-0.10 (1)	0.04 (10)	1.09 (6)	-0.02 (5)
Other cereals	-0.36 (2)	-0.08 (2)	0.09 (5)	1.65 (2)	-0.19 (9)
Pulses	-0.07 (8)	-0.01 (8)	0.07 (8)	1.14 (5)	-0.06 (6)
Oilseeds	-0.10 (6)	-0.03 (6)	0.15 (4)	1.27 (4)	-0.07 (7)
Root crops	-0.29 (3)	-0.06 (3)	0.05 (9)	2.10 (1)	-0.30 (10)
Vegetables	-0.07 (7)	-0.01 (9)	0.19 (2)	1.34 (3)	-0.08 (8)
Fruits	-0.26 (4)	-0.06 (4)	1.32 (1)	0.90 (9)	0.00 (4)
Cotton	-0.15 (5)	-0.04 (5)	0.08 (7)	0.23 (10)	0.40 (1)
Other crops	-0.04 (10)	-0.00 (10)	0.08 (6)	1.01 (8)	0.01 (3)
Livestock	-0.07 (9)	-0.01 (7)	0.16 (3)	1.03 (7)	0.12 (2)

Source: Results from IFPRI's Sudan RIAPA model.

Notes: Other cereals include maize, rice, wheat, barley, and other cereals. Other crops include sugarcane, tobacco, leaf tea, coffee, and other crops. Changes in all outcome indicators are expressed in per unit of agriculture GDP growth driven by agricultural productivity growth in a targeted value chain. The two poverty growth elasticities (semi-PGE) measure percentage-point changes in the poverty headcount rate and poverty gap with a one percentage growth in agriculture GDP. Poverty is measured at the international $1.90 poverty line. The diet quality growth elasticity (DGE) measures the percentage change in Reference Diet Deprivation (ReDD) index with a one percentage agricultural growth. Changes in GDP (million $US) and employment (thousand persons) are measured as a given one million $US of increase in value-added of the targeted value chain.

Table 5 reports changes in poverty, diet quality, growth, and employment for each of the value chain growth scenarios (shown in the rows). The results show that increasing sorghum productivity reduces the national poverty headcount rate by 0.44 percentage points for every one percentage agriculture GDP growth led by sorghum productivity increase, making sorghum growth most pro-poor, followed by the growth in other cereals (that are dominated by rice and wheat) and root crops, while livestock's productivity growth has much smaller impact on poverty reduction. However, the values are negative in the first column of Table 5 for all value chains, indicating that all value chains including livestock value chain are pro-poor in their growth.

Whereas the poverty headcount rate measures the share of people below the poverty line, poverty gaps measure how far poor people are, on average, from that poverty line. As with the poverty rate, the poverty gap falls in all value chain scenarios. In general, the effectiveness of productivity growth in reducing the poverty rate versus the poverty gap is similar for all value chains with a few exceptions but their ranks only change modestly. This seems to indicate that the distributional impact of a value chain's growth is relatively consistent with its pro-poor effect. A value chain in Sudan that benefits very poor households and helps reduce the depth of poverty often raises incomes enough to help poor people rise above the poverty line.

With respect to diet quality, the largest improvement in diet quality is seen in the growth led by fruits value chain, followed by vegetables, livestock, and oilseeds value chains in order. The diet quality improves by 1.32 percent with a one percent agriculture GDP in the fruits value chain scenario, and diet quality improves by 0.19 percent, 0.16 percent, and 0.15 percent, respectively in the vegetables, livestock, and oilseeds value chain scenarios (see the third column of Table 5 for the respective value chains). Despite being the most effective value chain in reducing poverty headcount and depth, sorghum is the worst-performing value chain for diet quality improvement. Sorghum is already a dominant food item among poor households in Sudan, and so expanding its production further lowers sorghum price, shifting consumption away from other food groups important in the healthy reference diet.

The final two indicators measure GDP and employment impacts of productivity growth in different value chains. It is worth reiterating that although agricultural productivity growth originates in specific value chains, not all gains in GDP or increases in employment occur within targeted value chains. Raising root crop productivity, for example, allows farmers to diversify into other crops and activities, including working off the farm. Increasing household incomes also allows them to purchase products from other sectors or value chains, thus generating spillover effects within the broader economy. These effects are captured by the model and influence the value chain rankings.

Closer examination of the results reveals that other cereals, which are the value chain with largest off-farm components, has a large growth multiplier effect and ranks at the second in terms of growth impact on the total economy. The growth multiplier value of 1.65 in the fourth column of Table 5 for other cereals means that one million $US increase in value added of other cereals result in $1.65 million increases in total GDP. Excluding the one million $US from other cereals' on-farm value added itself, the $0.65 million GDP is the additional gains coming from linkage effect within other cereal value chains (e.g., rice and wheat milling, transporting, and trading) or spillover effect to other value chains. In contrast, cotton, which is an export-oriented value chain, could not generate additional gain in the total economy. In fact, because its growth has less impact on its price that is mainly determined by the international market, the high productivity of cotton production allows cotton to attract labor and land away from other sectors, causing a decline in some of these sectors' production. In total, the losses in

value added from other sectors that are hurt by the cotton growth are more than the value-added gain in the cotton sector. The number of 0.23 in Column four of Table 5 for cotton means the increases in total GDP are only $0.23 million, much less than the gain in cotton value chain itself, which is $1 million, i.e., the total losses in other sectors' GDP are about $0.77 million.

Both GDP and employment outcomes are measured for the total economy. However, a value chain that is effective at generating additional total GDP is not necessary to create more jobs in the total economy. In fact, additional jobs are created economywide only for the growth led by cotton, livestock, fruits, and other crops in Sudan, while total employment declines in other six value chain growth scenarios – indicating by the negative signs in the last column of Table 5 for these value chains. While cotton growth has hurt the growth of many other value chains, its growth requires hire workers more than what it competes away from other sectors. Thus, cotton growth has positive employment impact, and a $1 million increase in cotton's value added creates 400 new employment positions in the economy, in addition to employing more from other sectors. The main reason is that productivity growth in cotton does not cause cotton prices to fall, as cotton is grown mainly for exports and faces a price determined by the international market. This makes the cotton sector more attractive for hiring more workers. On the other hand, most other agricultural sectors are domestic market oriented. Productivity growth in many of such sectors generally lowers their prices, especially for the agricultural products with inelastic demand when households' income increases such as root crops and sorghum. Growth from such an agricultural sector benefits households as consumers, but it may lower the wage rate, and hence, lowers the opportunities for creating jobs.

It is evident from these results that significant trade-offs exist for many value chains in terms of their growth impacts on different development outcomes. Thus, policy choices with respect to value chain prioritization and investments may be sensitive to the relative importance decisionmakers attach to different outcome indicators.

4.3 Prioritizing value chains

Figure 7 compares the relative effectiveness of growth in each value chain in achieving each of the four development outcomes. For the poverty dimension we use the poverty headcount rate as outcome indicator rather than the poverty gap. Since the outcome indicators have different underlying units, it is necessary to normalize individual outcome scores so that they are directly comparable. The values of each indicator are therefore scaled so that the most effective value chain is given a score of one and the least effective is given a score of zero. Normalization does not alter the relative effectiveness of value chains within each outcome category but converts the indicators to the same scale to facilitate their comparison. For examples, sorghum and other crops were, respectively, the most and least effective value chains in reducing national poverty (see Table 5), and they remain so after their poverty elasticities are normalized. Moreover, for a value chain that has an adverse effect on an outcome, the normalized score is assigned to zero for this outcome. For examples, cotton led growth causes the change in total GDP less than the $1 million of the increase in its own value-added (i.e., the number is less than 1 in the fourth column of Table 5), and root crops, sorghum, and four other value chains led growth causes total employment to fall (i.e., the numbers are negative in the fifth column of Table 5 for these value chains), then the GDP score is assigned to zero for cotton, while the employment score is assigned to zero for root crops, sorghum, and other four value chains.

Figure 7. Normalized Value Chain Scores for Different Outcomes

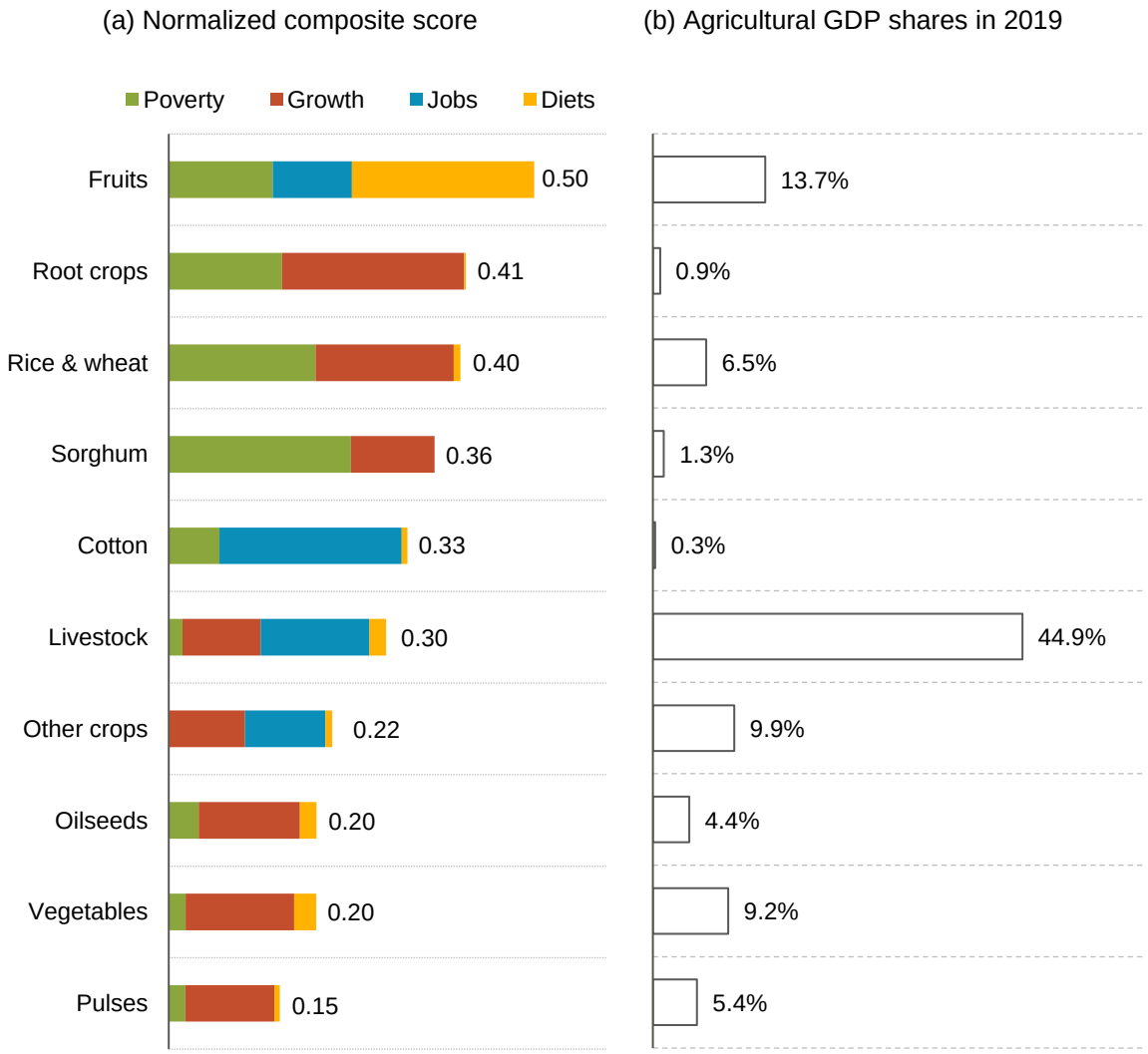
Source: Results from IFPRI's Sudan RIAPA model.

Notes: Scores for each outcome category are normalized such that the value chain whose growth is most effective at improving that outcome has a score of one, while the least effective value chain has a score of zero. Moreover, for a value chain that has an adverse effect on an outcome, the normalized score is assigned to zero for this outcome. The value chains are ordered here by the poverty outcome indicator.

In Figure 7, value chains are ordered based on the poverty outcome, with sorghum appearing at the top in Panel (a). While sorghum is the most effective value chain at achieving poverty outcomes, it is the least effective with respect to diet quality improvement and it also lacks a capacity in creating jobs. Root crops are third most effective at achieving poverty reduction, while it is most effective in GDP growth but lack of positive impact on employment. Similarly, cotton is most effective at creating jobs, while it is least effective in GDP growth and the third least effective at improving diet quality. This variation across outcomes further reflects the trade-offs in most value chains on their impacts on different development outcomes.

To narrow down the number of value chains whose growth is more effective across multiple outcomes, a composite score across different outcome indicators is created. In the composite score, which value chains that could have the highest score depend on the importance (or weights) attached to each of the four outcome areas. Figure 8 shows composite scores estimated by assuming that each of the four outcomes are equally important. In other words, the composite score in the left-hand-side panel of Figure 8 is a simple average of the four normalized scores in Figure 7. The value chains are reranked based on the composite score, and different color sections of each bar in the figure indicate the contribution of each outcome to the value chain's final score. The fruits value chain emerges as the top-ranked one as it has the highest score for diet quality, the fourth best score for poverty reduction, and the fourth best score for job creation outcomes. The second top-ranking value chain is the root crop, mainly driven by its strong contribution to GDP growth (in which it is the most effective value chain) and poverty reduction (ranked at the third). The pulses value stays at the bottom of the composite score rank despite never scoring the least in individual indicators. This is because it has no strong contribution to any individual indicator with the best contribution being in GDP growth in which it ranks fifth.

Figure 8. Composite Score Ranking Based on Equally Weighted Outcomes.



Source: Results from IFPRI's Sudan RIAPA model.

Notes: The composite score is a simple average of the normalized scores for the four focus outcome indicators in Figure 7.

The analysis of Figure 8 suggests that if development outcomes are considered equally important, then fruits, root crops, rice, wheat, and sorghum (and millet) should be prioritized for achieving maximum impacts of inclusive agricultural transformation. However, among the top-ranking value chains, there is no single value chain for which each of the four outcome indicators makes an important contribution to its combined score. Fruit value chain has relatively large impact on diet quality, poverty, and growth, but it does not have any contribution to job creation. For the other three top-ranking value chains, the combined scores are determined by their relatively large impacts on poverty and growth without impacts on diet quality and job creation. On the other hand, while livestock ranks the 6th according to its combined score, it is one of few value chains with visible growth impacts on all the four outcome indicators. This indicates that while combined scores allow us to rank value chains considering multiple outcomes, trade-offs still exist and are visible in the combined scores.

5 CONCLUSION

This study diagnoses Sudan's agrifood system transformation against a background of broad economic growth and transformation. Sudan's agrifood GDP observes modest growth during 2011-2019, while the agrifood system lacks transformation with little change in the structure of the system. Agricultural share of total employment fell more significantly, contributing to the structural change in the broad economy, while agriculture continuously absorbs near a half of Sudan's total employment with the lowest labor productivity, and it is still the largest component of the agrifood system.

Sudan's agrifood growth is driven by domestic-market-oriented value chains during 2011-2019. Less traded value chains dominate agrifood growth with their large size and above-average growth. Both exportable and importable value chains are small, and with below-average growth, their contribution to agrifood growth is modest.

Comparing sources of future growth using the IFPRI's RIAPA model shows that there is no single value chain group that is the most effective in achieving all outcomes (i.e., poverty, diet quality, jobs, and GDP). The fruits, root crops, and cereals rank highly in the combined outcome scores, while livestock is one of few value chains with impacts on all the four outcomes. These value chains supply mainly to the domestic market, and some of them had above-average growth in the past. In conclusion, promoting multiple value chains offers an effective way of achieving broad-based outcomes.

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Appendix Table: Value chain groups and agricultural sectors in individual value chain groups

Value chain group and shares of AFS GDP	Individual products and their share of group's agriculture GDP
Sorghum (13.8%)	Sorghum and millet 100%
Other cereals (2.7%)	Maize 2.4% | Rice 11.9% | Wheat & barley 6.5% | Other cereals 79.2%
Oilseeds (8.7%)	Groundnuts 60.6% | Other oilseeds 39.4%
Pulses (4.1%)	Pulses 100%
Roots (0.9%)	Sweet potatoes 40.1% | Other roots 59.9%
Vegetables (6.5%)	Vegetables 100%
Fruits and nuts (7.4%)	Nuts 1.8%| Bananas 23.2% | Other fruits 75.0%
Cotton (0.2%)	Cotton 100%
Other crops (5.7%)	Sugarcane 37.2% | Tea 1.6% | Other crops 61.2%
Livestock (44.1%)	Cattle meat 28.8% | Raw milk 35.2% | Poultry meat 2.5% | Eggs 1.5% | Small ruminants 20.8% | Other livestock 11.2%
Fish (1.3%)	Aquaculture 10.7% | Capture fisheries 89.3%
Forestry (2.3%)	Forestry 100%

Source: Author's analysis using IFPRI's 2019 Sudan SAM.

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