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Determinants of Resilience for Food and Nutrition Security in South Sudan

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ABSTRACT

The paper analyzes the determinants of long-term individual and community resilience for food and nutrition security in South Sudan using data from multiple sources including key informant interviews, household and community surveys, and georeferenced secondary data on climate, agricultural production, irrigation, and market access. Major agricultural development constraints as well as incidence of and responses to shocks and conflict are described. Climate-crop modeling and simulation methods are used to evaluate the constraints and to identify crop investment options. Then, a spatial typology of food and nutrition security is used to evaluate the constraints along the production-to-nutrition pathway to identify interventions that target different segments of the chain and options for improving agriculture and broader development outcomes. These are classified into production, access, and utilization efficiencies, and whether the underlying constraints are structural (i.e., level of efficiency remains the same over time) or stochastic (i.e., level of efficiency changes over time). The analysis is focused on about a dozen selected counties.

The results show that development challenges are being compounded by climate change, with significant increases in the mean annual rainfall and daily maximum temperature for the warmest month. Between 1975 and 2016 for example, the mean annual rainfall in the selected counties increased by 40-111 mm/year, with a rise in the intensity of 0.2-1.3 mm per event. The daily maximum temperature for the warmest month increased by 2.0-3.2°C. If these trends (especially for temperature) continue to 2050, crop yields are projected to decline in the selected counties on average by 12-23% for sorghum, 9-18% for maize, 19-30% for groundnuts, and 16-24% for cassava. In general, there is an inverse-U-shaped the relationship between temperature and yields. While the peak of the inverse U varies by crop, time of the growing season, and other factors, crops in South Sudan are typically on the downward sloping side of the inverse U implying that increases in temperature will decrease yields (and at an increasing rate).

Results of a spatial typology show that a majority (78%) of the selected counties are classified as having medium production efficiency and 22% as low production efficiency, none with high production efficiency. With respect to access to nutritious food, 55%, 29%, and 17% of the counties are classified as low, medium, and high access efficiency, respectively. And regarding the conversion of food access into nutritional status, 37%, 26%, and 37% are classified as low, medium, and high utilization efficiency, respectively. Whereas production efficiency mostly remains constant over time, (with only 24% of the counties recording substantial changes in efficiency level), access and utilization efficiency appear more volatile (with substantial changes observed in 52% of the counties). These results suggest that the access segment of the production-to-nutrition value chain is the most constraining, followed by the utilization segment.

The differences in the results across counties reflect differences in development constraints across the country, which are also described. Implications of the results for building long-term individual and community resilience are discussed, in addition to areas for further research. Given the complex nature of crises facing South Sudan, our findings call for a comprehensive policy approach to address not only the urgent humanitarian crisis but also to help restore agricultural production systems as well as support communities to cope, recover, and build their

resilience to shocks and crises. This is in line with the Partnership for Recovery and Resilience (PfRR) integrated programme framework for resilience which comprises four pillars: i) re-establish access to basic services, ii) rebuild trust in people and institutions, iii) restore productive capacities, and iv) nurture effective partnerships.

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ABBREVIATIONS AND ACRONYMS

AfDB	African Development Bank
AGRA	Alliance for a Green Revolution for Africa
BCC	Beijing Climate Center
CBO	Community-Based Organization
CFSAM	Crop and Food Security Assessment Mission
CMIP	Coupled Module Intercomparison Project
CMIP6	Version 6 of the Coupled Model Intercomparison Project
CNRM	Centre National de Recherches Météorologiques
CSO	Civil Society Organization
DSSAT	Decision Support System for Agrotechnology Transfer crop modeling system
FAO	Food and Agriculture Organization of the United Nations
FBO	Faith-Based Organization
FCS	Food Consumption Score
FNS	Food and Nutrition Security
FSNMS	Food Security and Nutrition Monitoring System
GAM	Global Acute Malnutrition
GIEWS	Global Information and Early Warning System
HIV	Human immunodeficiency virus
IFPRI	International Food Policy Research Institute
KII	Key Informant Interview
MAFCRD	Ministry of Agriculture, Forestry, Cooperatives and Rural Development
M&E	Monitoring and Evaluation
MESP	Monitoring and Evaluation Support Project
MIROC	Model for Interdisciplinary Research on Climate
MSI	Management Systems International
MWRI	Ministry of Water Resources and Irrigation
NGO	Non-Governmental Organization
PfRR	Partnership for Recovery and Resilience
RIMA	Resilience Index and Measurement Analysis
RSS	Republic of South Sudan
SAFER	Sustainable Agriculture for Economic Resiliency
SAGE	Sustainable Agriculture Education
SCORE	Social Cohesion and Reconciliation
SMART	Standardized Monitoring and Assessment of Relief and Transitions
UN	United Nations
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
WCMC	World Conservation Monitoring Centre
WFP	World Food Programme

1. INTRODUCTION

Since its independence in July 2011, South Sudan has been hampered by a series of armed conflicts that created a massive humanitarian crisis leaving tens of thousands of people dead, displaced millions more, and worsened food and nutrition insecurity in the country. In addition to political conflict and violence, South Sudan faces recurrent climatic shocks—prolonged droughts and floods as well as pest infestations—that further destabilize its food system. For example, in 2017, parts of South Sudan, particularly in the north, experienced a famine that affected roughly half of the population (WFP, 2019). In January 2019, an estimated 54 percent of South Sudan's population (6.3 million people) faced emergency acute food insecurity. In October 2019, the country declared a state of emergency due to flooding in 30 counties as an estimated 72,600 metric tons of cereal could not be harvested because of the floods (WFP, 2019). Due to conflict and other crises, South Sudan also experienced forced migration which results in a high number of internally displaced persons (IDPs). In November to December of 2018 for example, a total of 1,275,868 IDPs were identified across the country (IDMC, 2019).

The livelihood of the majority of South Sudanese depends on the agricultural sector which accounts for 36 percent of the country's non-oil Gross Domestic Product (GDP) (GoSS, 2012). Although conflict and economic collapse have largely driven the country's dramatic increase in food insecurity, health risks, exposure to heightened climate variabilities, lack of access to information and technical services contribute also significantly to the erosion of household and community resilience while increasing their vulnerability to food and nutrition insecurity.

Restoring the country's food system efficiency is therefore crucial as growth in the agricultural sector is identified as the most effective driver for poverty reduction and restoring livelihoods (World Bank. 2019). Given the complex nature of issues facing South Sudan, a comprehensive approach is required to address not only the urgent humanitarian crisis but also to gradually restore the country's production systems and help communities rebuild their resilience capacity to shocks and crises. In April 2018, development partners operating in South Sudan setup a Partnership for Recovery and Resilience (PfRR[1]) program, a comprehensive platform with a shared commitment to reduce vulnerability and build resilience through geographically-focused resilience projects in areas where local leaders are committed to creating the conditions for change (PfRR, 2019). Seven counties (Yambio, Aweil West, Torit, Wau, Bor South, Yei, and Rumbek East) were selected for implementing program. Resilience profiles for these areas were developed and a Resilience Analysis Measurement and Monitoring Unit (RAMMU) was established in 2018 to collect data and generate analytical and knowledge products to facilitate benchmarking, monitoring & evaluation, and learning (PfRR, 2019)

The PfRR's Theory of Change, as described in the diagram 1, aims to show the added value of the Partnership's new way of working in moving South Sudan towards self-reliance and a transition to development.

[1] PfRR partners include: South Sudan, African Development Bank, Canada, EU, Germany, Japan, Netherlands, NGO Forum, Norway, Sweden, Switzerland, UK, United Nations, USA, World Bank

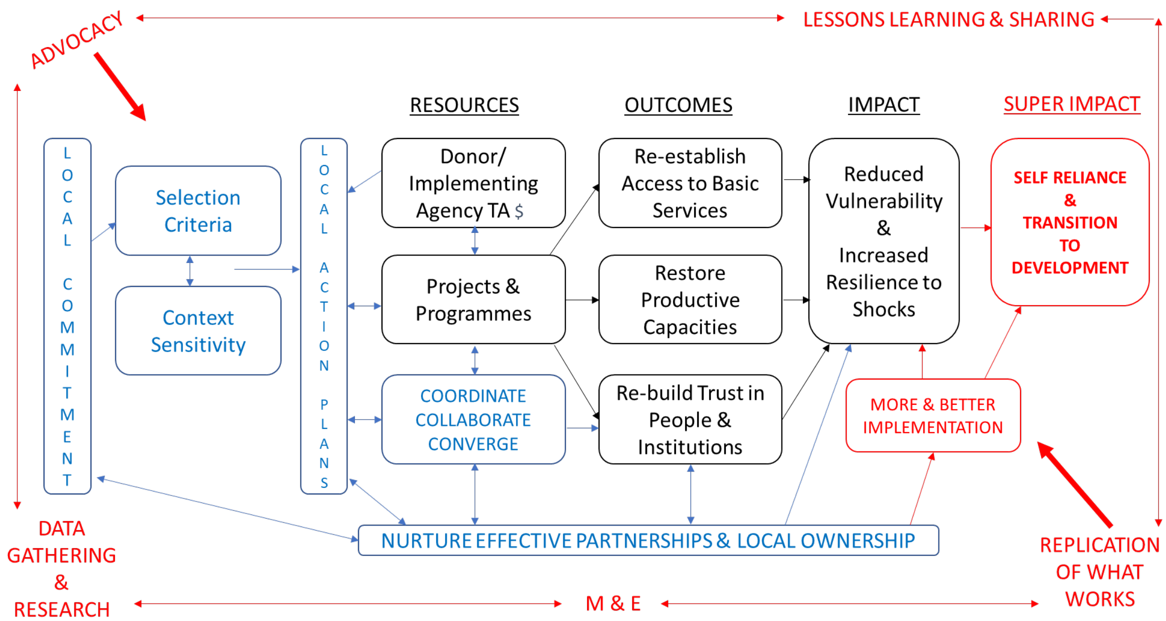
- *If* recovery and resilience projects are area-based and designed to re-establish basic services; restore productive capacities and re-build trust in people and institutions;

- *and if* local ownership is prioritized and community aspirations accounted for and guide the joint-work of cooperating partners;

- *and if* there is a collective action to raise awareness to reduce vulnerabilities, and advocate for additional investment in resilience, and prioritize evidence-based programming through M&E and promote learning among partners;

- *then* recovery and resilience initiatives will deliver more effective results in reducing vulnerabilities and building self-reliance toward development.

Diagram 1: Theory of change



Source: PfRR (2019)

Note: M & E: Monitoring and evaluation.

The objective of this study is to analyze the determinants of long-term individual and community resilience for food and nutrition security (FNS) in South Sudan. This is achieved by addressing four main questions:

1. What are the major constraints to agricultural development in different locations?
2. What agricultural value chain opportunities exist in those locations and what are the existing investment options to enhance the value chains?
3. What opportunities exist to link agricultural activities with nonfarming development assistance (health, education, humanitarian relief, democracy and governance, conflict mitigation, etc.) to increase the resilience of households and communities?

Three different but complementary methods, with data from multiple sources, are used to address the research questions and overall objective. Analysis of stakeholder opinions and perceptions from different survey data is used to describe the major agricultural development constraints, access to services and ownership of productive assets, the incidence of and responses to shocks and conflict, and options for improving agriculture and broader development outcomes. Then, climate-crop modeling and simulation methods are used to evaluate the major agricultural development constraints and to identify the suitable crops to invest in. This analysis contributes to addressing the research questions from the climate and biophysical environments perspective. Looking at the issues from an outcome's perspective, spatial typologies of food and nutrition security are used to evaluate the major constraints along the production-to-nutrition pathway and then to identify interventions that target different segments of the chain. These are classified into production, access, and utilization efficiencies, and whether the underlying constraints are structural (i.e., level of efficiency remains the same over time) or stochastic (i.e., level of efficiency changes over time).

The data used are from multiple sources including key informant interviews conducted for this study, a number household and community surveys associated with different projects in South Sudan, and secondary and administrative data on several factors including climate, agricultural production, irrigation, market access, and organizations operating in different locations. The analysis is focused on about a dozen selected counties.

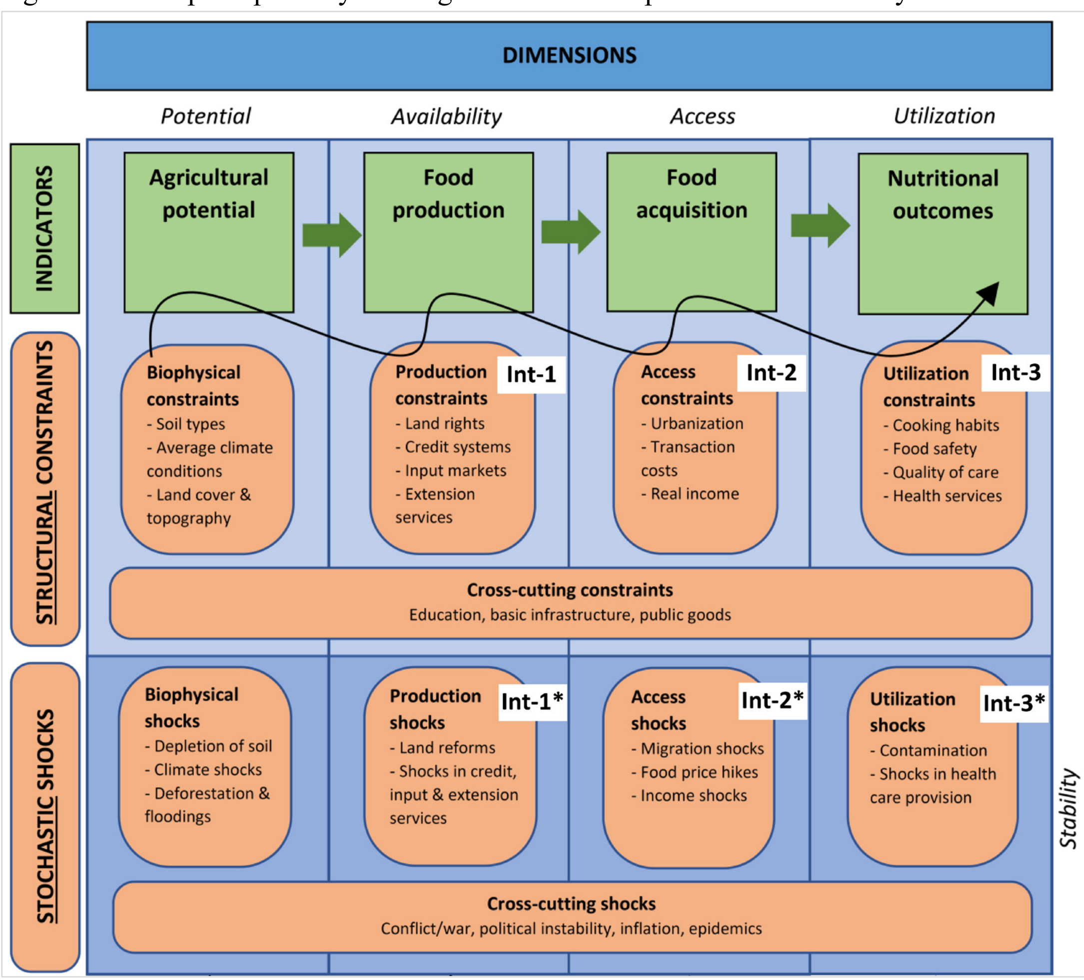
Briefly, the results show that the development challenges are compounded by climate change, with significant increase in the mean annual rainfall (40-111 mm/year between 1975 and 2016) and daily maximum temperature for the warmest month (2.0-3.2°C). If these trends (especially for temperature) continue to 2050, crop yields are projected to decline in the selected counties on average by 12-23% for sorghum, 9-18% for maize, 19-30% for groundnuts, and 16-24% for cassava. Results of spatial typology show that majority (78%) of the selected counties are classified as having medium production efficiency and 22% as low production efficiency, without any as high production efficiency. With respect to access, 55%, 29%, and 17% are classified as low, medium, and high access efficiency, respectively. And for utilization, 37%, 26%, and 37% are classified as low, medium, and high utilization efficiency, respectively. Whereas production efficiency is mostly structural, (76% of the counties), access and utilization efficiency seem balanced (48% structural and 52% stochastic). These suggest that the access segment of the production-to-nutrition value chain is the most constraining, followed by the utilization segment, and that different strategies will be needed to address the constraints in different counties.

The conceptual framework used to organize the study is presented next, followed by the empirical approach, data, and results. Conclusions and implications are then presented.

2. CONCEPTUAL FRAMEWORK

The overall framework to guide investments in the agriculture sector that lead to improved food and nutrition security (FNS) is based on both the broad view that agriculture has a central role to play in tackling FNS and that FNS relies on the environments (physical, biological, socio-political, economic, etc.) that also drive agricultural development. This is illustrated in Figure 1, which shows that the causal chain from agriculture to the well-known dimensions or pillars of FNS (availability, access, utilization, and stability) are influenced by different and interrelated constraints and shocks (Pangaribowo et al. 2013). Regarding availability for example, a common indicator is food production, which farmers and food producers need sustained access to seeds, fertilizer, extension, etc. if they are to realize the agricultural potential of their land, for example. Even if food supply is adequate in the aggregate, access to food could be constrained by transaction costs, poor transport infrastructure, and high prices. Similarly, even when households have secured access to food, poor nutrition could result from cooking habits, intrahousehold allocation issues, food safety and health issues, and sanitation conditions.

Figure 1: Conceptual pathway from agricultural development to food security and nutrition



Source: Authors' illustration adapted from Pangaribowo et al. (2013).
Notes: Int = areas of intervention. Stability captures the absence of shocks.

Because we expect the constraints and shocks—including climate and biophysical, economic (especially access to land, infrastructure, and markets), technological, institutional, financial, social, and cultural—to vary in different locations, different strategies may be needed to seize existing opportunities or develop new ones in different locations. Climate change, as in many African countries, is one of the biggest threats to agricultural development in South Sudan. Thus, the amount and pattern of rainfall in different locations for example, will be a significant factor in determining the value chain opportunities in different locations. Insecurity and conflict too are prevalent but vary across the country. Thus, building the resilience of individuals, households, and communities to climate and other shocks will be a fundamental strategy for improving food and nutrition and security in South Sudan. For any value chain however, we can expect different strategies to target different segments of the chain depending on how they fit into the socio-economic and cultural environments of different communities.

3. EMPIRICAL METHODS

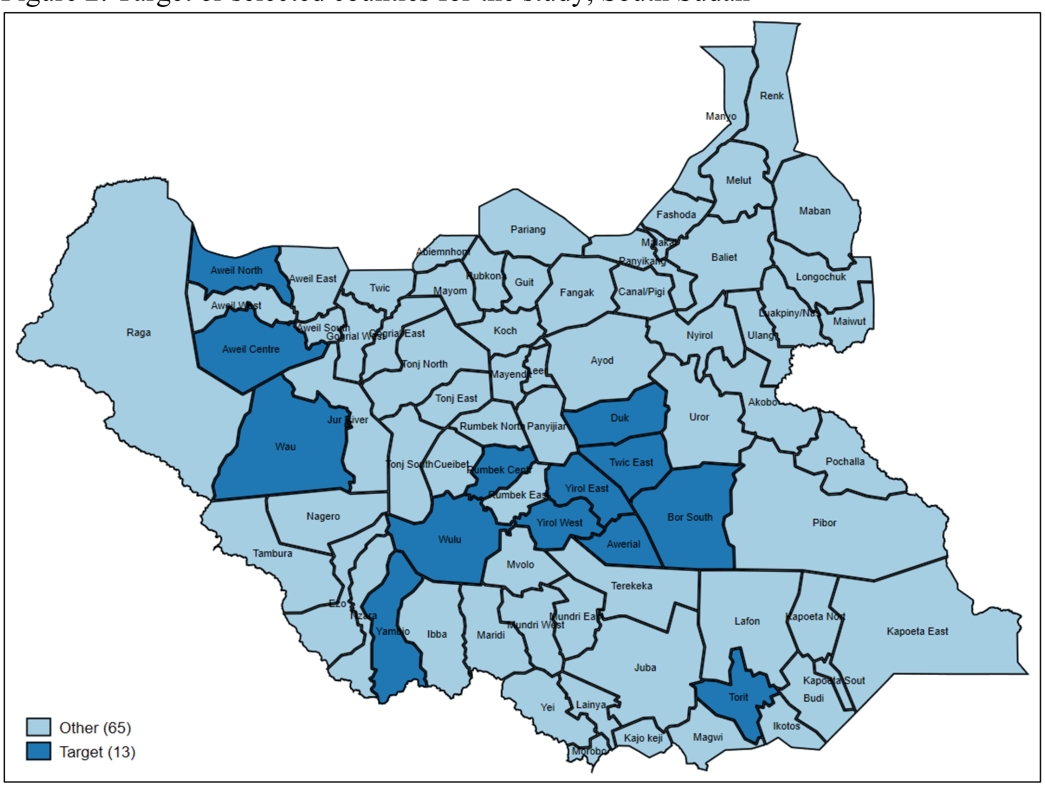
Different analytical tools and data from multiple sources are used to address the research questions. First, data on the opinions and perceptions of stakeholders from different surveys are used to obtain a general description of different parts of the production-to-nutrition pathway in the framework (Figure 1). For the modeling and spatial typologies work, agricultural potential, which is the indicator for first dimension of the production-to-nutrition pathway, is classified using two complementary approaches, one based on climate (rainfall and temperature) patterns and the other based on agricultural land converted into kilocalorie production. These are then used respectively in the climate-crop modeling of agricultural production and spatial typology of FSN. Therefore, the climate-crop modeling evaluates the constraints and opportunities from a climate and biophysical perspective, with options for improving recommended commodities, whereas the spatial typologies work evaluates the constraints and opportunities from a nutrition perspective, with options for improving different segments of the value chain.

Details of each of the techniques are discussed below, following a description of the selected counties on which the study is conducted.

3.1. Target counties

The analysis is based on 13 counties (see Figure 2) for which most of the data used are available. The target or selected counties include Aweil Centre, Aweil North, Awerial, Bor South, Duk, Rumbek Centre, Torit, Twic East, Wau, Wulu, Yambio, Yirol East, and Yirol West.

Figure 2: Target or selected counties for the study, South Sudan



Source: Authors' illustration based on key priority areas defined by USAID/MSI.

3.2. Classification of agricultural potential

Rainfall-temperature pattern measure

Typically, agricultural productivity or yield potential is assessed based on soils and climate (Fischer et al. 2021). Due to lack of data on soils in each county of South Sudan, we assess agricultural potential based on climate—temperature and rainfall. Many crops are sensitive to heat and yields decline beyond 29 to 30 degrees Celsius (^{0}C) (Schlenker and Roberts 2009; Lobell, Bänziger, Magorokosho, and Vivek 2011; Lobell, Schlenker, and Costa-Roberts 2011). Beyond 32^{0}C, each 1^{0}C increase in mean daily maximum temperature in the warmest month leads to approximately a 10 percent reduction in maize yields, for example (Thomas 2015). We used temperature and precipitation data for the June to August period, which is roughly the wettest three month and the coolest three months for the target counties, for the analysis. Yield potential is classified based on weighting the precipitation against the temperature and scaled into five levels of increasing potential: low, low-moderate, moderate, moderate-high, and high (see Table 1 for details). Areas classified as having lower agricultural potential (e.g., low and low-moderate) mean that the potential for growing most grains, legumes, or oil crops, for example, is lower in those areas due to climate constraints, compared to areas with higher agricultural potential (e.g., moderate-high and high). However, there are certain grains, legumes, or oil crops that may be heat tolerant. Millet, for example, is known for its ability to thrive in high temperatures. Many research institutions around the world are developing heat-tolerant varieties of maize, wheat, and other crops (e.g., CIMMYT 2016). Furthermore, irrigation in low potential areas may raise the potential there, by compensating for the lower rainfall as well as reducing the temperature near the irrigated plants. Agroforestry too may lower temperatures and reduce evaporation, and thereby increase agricultural potential.

Table 1: Agricultural potential based on climate variables, South Sudan

Agricultural potential	Precipitation (mm per month in growing period)	Temperature (^{0}C, mean daily maximum temperature of warmest month in growing period)
Low	<40	< 22 and >38
Low-moderate	40-75	22-24 and 36-38
Moderate	75-100	24-27 and 35-36
Moderate-high	100-150	27-29 and 34-35
High	>150	29-34

Source: Authors' assumptions based on yield response curves created by the authors using regressions on rainfed sorghum yields from DSSAT crop modeling system (Jones et al. 2003) and monthly weather variables.

Area-kilocalorie conversion measure

For this measure of agricultural potential, we relied on two remote sensing data sources at 30 meters spatial resolution—extent of crop land in 2015 (Xiong et al. 2017) and the area of forest that had been cleared between 2000 and 2015 (based on a methodology described in Hansen et al. 2013). We assumed that the cleared forest land had been or would soon be used for agriculture (Salih, Kornich, and Tjernstrom 2013). This estimate of arable land was then triangulated with official data on the area of land under cereal crops in 2015 (FAO/WFP 2016) and further allocated to either sorghum, maize, millet, or rice, following the national food consumption pattern as derived from the High Frequency Survey of South Sudan (WB 2015) and by applying potential yield factors as they are broadly defined in reference to those available for neighboring countries—Ethiopia, Kenya, and Uganda (WB 2012). We settled on using Kenya as the reference because the results were average in the range obtained for the three countries (50 percent for Uganda, 100 percent for Kenya, and 200 percent for Ethiopia). The resulting output was converted into daily potential kilocalorie production (Stadlmayr et al. 2012), summed up by county and divided by the corresponding population estimate. To observe differences more easily across counties, we applied a fourth-root transformation[2] on total potential kilocalorie production.

3.3. Desktop review of policies, plans, and reports

This involves analysis of public administrative data on policies, strategies, plans, and sector-wide performance indicators to evaluate to context in which agricultural development is taking place. Performance of South Sudan in key indicators are compared with those of neighboring countries in the region to provide additional context of agricultural development and achievement of the broader development objectives.

3.4. Analysis of stakeholder opinions and perceptions

This involves analysis of means of data collected from households, communities, and key informants from different surveys on their opinions and perceptions related to different variables of interest in the study. The variables cover factors related to agricultural development constraints, access to basic public services (education, health, water and sanitation, etc.), ownership of productive assets, incidence of and responses to shocks and conflict, trust in government and institutions for conflict resolution, and investment options for improving agriculture and broader development outcomes.

3.5. Spatial modeling of agricultural production

Spatial modeling and simulation tools are used to analyze several factors that determine the comparative and absolute advantages of different crops as they exist now in different locations and then in the future due to climate change.

Market access. As a measure of comparative advantage, this involves constructing a cost friction grid that considers roads, water, vegetation, and urban areas, and then using ArcGIS (ESRI, 2021) to compute the most efficient route to the nearest market from each point in the county. This is used to measure the level of market access in terms of the number of hours to travel to different population-sized cities and towns from a given location.

[2] A fourth-root transformation (or 1/4-power transformation) is a data transformation technique which helps to better capture variation and correct for right skewness in the data.

Cultivated areas and yields. The Spatial Production Allocation Model (SPAM, You et al. 2014) is used to map cultivated areas with associated yields for different crops to identify existing potential for different crops in different locations.

Climate-induced changes in precipitation, temperature, and yields. This analysis captures the impact of climate change and weather variability on agricultural production. It includes analysis of rainfall and temperature trends from 1948 to 2016 using the Princeton Global Forcings dataset (Sheffield, Goteti, and Wood 2006) looking for statistically significant changes over time using a regression trendline. Trends in the onset and duration of rains are also analyzed. The results are used with the Coupled Model Intercomparison Project5 (CMIP5, Taylor et al. 2012) models as well as the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT, Robinson et al. 2015) or the new CMIP6 models (Eyring et al. 2016) to compute yields of selected crops in 2050. As the data are limited, this is done for sorghum, maize, and groundnuts only.

3.6. Spatial typology of food security and nutrition

Combined with the area-kilocalorie conversion measure of agricultural potential as described above, the focus of this spatial typology is to account for geographical heterogeneity of constraints at different segments of the production-to-nutrition value chain. This is then used to analyze the opportunities and interventions for addressing the respective constraints (Marivoet et al. 2019).

For the *availability* segment of the chain, production of cereals in 2016 was used, as estimated by the Crop and Food Security Assessment Mission (CFSAM) following a national crop allocation procedure (FAO/WFP 2017). In line with the measure on agricultural potential, the resulting values were converted to kilocalories per person per day using the same food composition table as compiled by Stadlmayr et al. (2012) and by also applying a fourth-root transformation. After estimating the mean performance in converting agricultural potential into agricultural production, counties are classified in terms of production efficiency using the following cutoff points: low production efficiency for counties with values lower than 75% of the mean performance, medium production efficiency for counties with values in the range of 75% and 125% of the mean performance; and high production efficiency for counties with values greater than 125% of the mean performance. *Access* was measured by food acquisition, using the WFP's Food Consumption Score (FCS) from the 2017 Food Security and Nutrition Monitoring Surveys (FSNMS) (WFP 2017).[3] Based on the mean estimated performance in converting agricultural production into food access, the same procedure as done for availability is used to classify counties as low, medium, and high access efficiency. For *utilization*, we use a measure of nutrition—prevalence of under-five children weight-for-height, based on a series of SMART surveys conducted in 2017 by various NGOs. Here too, the same procedure is used to classify

[3] This indicator is based on recall data of food group consumption frequencies in the previous seven days (WFP 2008). Given the short recall period, the score does not account for seasonality and may only provide a rough indication of access during the lean season when such surveys are typically implemented.

counties as low, medium, and high utilization efficiency but this time with respect to the mean estimated performance in converting food access into nutritional status.

The efficiency (and the underlying constraints by extension) in a location are deemed structural or stochastic, based on whether the classification of low, medium, or high efficiency remains the same or changes over time. The above indicators were computed using the same typology over three consecutive time periods (i.e., from 2014-2015 to 2016-2017). The classification of low, medium, or high efficiency is denoted as structural if it remains the same across all three periods, and denoted stochastic if it changes in any one of the three years. Taking the case of access efficiency for example, if a county is characterized as low access efficiency in the most recent period, then it is classified as structural if the low access efficiency is also observed in the previous two periods. However, if low access efficiency is not observed in both previous two years, then the county's low access efficiency is classified as stochastic. Of course, if historical data were available to apply the typology over more periods of time, then the distinction between structural and stochastic could receive a more long-term interpretation.

Depending on how a county is classified according to the above structural or stochastic efficiency in availability, access, or utilization, recommended interventions to mitigate the underlying constraints are made based on the cluster of interventions identified at each segment of the value chain presented in the conceptual framework in Figure 1. For example, low utilization efficiency in a county that is due to poor knowledge of basic hygiene or lack of good sanitation practices is structural and may be resolved by investing in corresponding awareness and education campaigns. On the contrary, low utilization efficiency that is due to a health pandemic or major disease outbreak is stochastic and may require other responses such as emergency relief or programs focusing on increasing resilience. As such, the responsible intervention agencies may also differ, where development agencies may be better in solving structural problems whereas humanitarian agencies would deal more with stochastic problems.

3.7. Data and their sources

The data used in the analysis are drawn from key informant interviews conducted for this study, as well as from several household and community survey data associated with other projects, in addition to secondary and administrative data on climate, agricultural production, irrigation, markets, etc. Table 2 summarizes how the different methods and data are associated with each of the research questions.

Key informant survey data

To obtain additional information on the current challenges, constraints, and opportunities for development in selected counties, key informant interviews (KIIs) were conducted with knowledgeable individuals or officials including local leaders, development and sector specialists and workers, local academics, government employees, missionaries, agro-dealers, and farmers. The locations for the field data collection were selected based on SAFER footprint, population, telephone network coverage and overall accessibility. These areas include Jonglei State (Bor South, Duk, and Twic East counties), Lakes State (Yirol East, Yirol West, Awerial, Rumbek Centre, Rumbek East, and Wulu counties), Northern Bahr el Ghazal State (Aweil North and Aweil Centre counties), Western Equatoria State (Yambio, Tambura, and Nzara counties), Eastern Equatoria State (Torit county), and Western Bahr el Ghazal State (Wau and Jur River counties). The KIIs included traders and farmers associations (80), community leaders and local authorities (58), and government officials and experts, agricultural field experts (52). See annex 1 for details on the survey instrument used.

Household and community survey data from previous projects

Sustainable Agriculture for Economic Resiliency (SAFER) project

The SAFER project (USAID, 2019) has operated in 14 counties since August 2017: Bor South, Duk, and Twic East in Jonglei State; Yirol East, Yirol West, Awerial, Rumbek Centre, Rumbek East, and Wulu in Lakes State; Aweil North and Aweil Centre in Northern Bahr el Ghazal State; and Yambio, Tambura, and Nzara in Western Equatoria State. Two rounds of data have been collected, with a sample of 900 households at baseline (November–December 2017) and 1,200 households in the second round (January–February 2019). The sample size of the data used in this study contained 1,288 households, of which 888 (69%) were beneficiaries of the project and 400 (31%) were nonbeneficiaries. Key variables analyzed included access to basic services (water, health, and education), productive assets (agricultural inputs), social safety nets (access to credit, access to borrowing opportunity and frequency, access to transfers), and adaptive capacity (number of income sources, coping strategy).

Partnership for Resilience and Recovery (PfRR) project

Under this project, a community and household resilience survey was completed in 2018 in seven counties in South Sudan: Yambio, Aweil West, Torit, Wau, Bor South, Yei, and Rumbek East (MESP 2018). The objective of the survey was profiling community resilience related to conflicts, livelihoods, poverty, shocks, and markets, and their distinct impacts on men, women, children, and elders. Survey data were collected from 4,177 households. For this study, resilience profiles were created using the household-level survey data collected on several pertinent issues including access to basic services (such as education, health, water, sanitation, hygiene, etc.), sources of livelihood, food security, institutions, conflict, and governance.

Food Security and Nutrition Monitoring System (FSNMS)

The FSNMS is a nationwide survey that covers over 8,000 households in all accessible counties in South Sudan (FAO-WFP, 2019). The exercise is conducted twice a year (June–July and November–December) during the lean and postharvest seasons, respectively. A typical FSNMS survey includes modules such as household demographics, migration, housing, livelihoods, food consumption, expenditures, main activities, coping strategy, and nutrition. For this study, the data are used to give a snapshot of the resilience capacities of counties.

Social Cohesion and Reconciliation (SCORE) index

The SCORE index is based on a participatory research approach and relies on multilevel stakeholder consultations, focus groups, and interviews (UNDP, 2019). The SCORE index intends to explain social cohesion by investigating factors that contribute to resilience and peaceful citizenship (or lack thereof) at the individual and community level. The SCORE for South Sudan was calibrated in September 2019 to establish a coherent research framework that incorporates different stakeholder perspectives, socioeconomic challenges, and competing hypotheses about root causes of sociopolitical tensions and obstacles to inclusive economic growth and human development. The index was estimated from three parallel surveys equally administered among 45 bomas (lowest level administrative divisions) in the three SCORE pilot regions. The data used in this study include personal attitudes and ideologies (such as attitudes toward other ethnic groups or perceptions about gender equality), communal relations (such as the intergenerational harmony, level of services, and ownership of assets), and attitudes and behaviors of the chief.

Secondary and administrative data

These data, most of them being geo-referenced, cover several aspects of the production-to-nutrition pathway. They include crop production, food consumption, and nutrition [e.g., Crop and Food Security Assessment Mission (CFSAM, FAO/WFP 2015, 2016) and Standardized Monitoring and Assessment of Relief and Transitions (SMART) surveys (AAH, 2018)]; satellite imagery on agricultural land, rainfall, and temperature and simulation models of climate change from the Coupled Module Intercomparison Project, Phase 6 (CMIP6—see Table 2 for details); and public administrative data and official reports on irrigation schemes, government agricultural development plans, and performance measures (e.g., AfDB 2013, MEDIWR 2015, AUC 2020).

Table 3 summarizes which of the different methods and data are used in the analysis for addressing each of the research questions.

Table 2: Coupled Module Intercomparison Project, Phase 6 (CIMP6) climate models

Model	Institution
BCC-CSM2-MR	Beijing Climate Center, Beijing 100081, China
CNRM-CM6-1	Centre National de Recherches Météorologiques, Toulouse 31057, France
CNRM-ESM2-1	Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique, Toulouse 31057, France
CanESM5	Canadian Centre for Climate Modelling and Analysis, Environment and Climate Change Canada, Victoria, BC V8P 5C2, Canada
IPSL-CM6A-LR	Institut Pierre Simon Laplace, Paris 75252, France
MIROC-ES2L and MIROC6	Japan Agency for Marine-Earth Science and Technology, Kanagawa 236-0001, Japan); Atmosphere and Ocean Research Institute, The University of Tokyo, Chiba 277-8564, Japan; National Institute for Environmental Studies, Ibaraki 305-8506, Japan; and RIKEN Center for Computational Science, Hyogo 650-0047, Japan
MRI-ESM2-0	Meteorological Research Institute, Tsukuba, Ibaraki 305-0052, Japan

Source: Authors' illustration based on WorldClim website[4] and Fick and Hijmans (2017).

[4] https://www.worldclim.org/data/cmip6/cmip6climate.html

Table 3: Research questions and the associated data and methods used

Research question	Data sources and key variables analyzed			Analytical methods
	Key informant interviews	Household and community surveys from other projects	Secondary geo-referenced and administrative data	
1. Agricultural development constraints	Opinions and perceptions of development constraints	Opinions and perceptions of development constraints	Policies, climate, irrigation, infrastructure, crop production, food consumption and nutrition, sector-wide performance	Descriptive analysis of policies, sector-wide performance, and opinions and perceptions; climate-crop modeling and simulations; and spatial typology of food security and nutrition
2. Value chains opportunities and investment options	Opinions and perceptions of value chain opportunities and livelihoods	Opinions and perceptions of value chain opportunities; agricultural production; food consumption and nutrition	Policies, climate, irrigation, infrastructure, crop production, food consumption and nutrition, sector-wide performance	Descriptive analysis of policies, sector-wide performance, and opinions and perceptions; climate-crop modeling and simulations; and spatial typology of food security and nutrition
3. Nonfarm opportunities for building resilience	Opinions and perceptions of livelihoods, shocks, and responses to shocks, and access to services	Opinions and perceptions of livelihoods, ownership of assets, shocks, and responses to shocks, and access to services	Policies and sector-wide performance	Descriptive analysis of resilience profiles of households and communities

Source: Authors' illustration.

4. RESULTS

The results of the analysis are presented and discussed under four main sections, starting with the classification of agricultural potential which forms the basis for disaggregating the results for different parts of the country. This is followed by results according to the three objectives of the study—agricultural development constraints, value chains opportunities and investment options, and farm and nonfarm linkages for building resilience. Under each of the objectives, the results from using the different methods (stakeholder opinions and perceptions, climate-crop modeling and simulation, and spatial typology of food security and nutrition) are presented.

4.1. Agricultural potential

The spatial distribution of the three main factors used in classifying agricultural potential are shown in Figure 3 (rainfall), 4 (temperature), 5 (cropland), and 6 (population). With respect to rainfall, the pattern of the mean number of days with rain per year increases from northeast to southwest. The amount of rainfall per year in millimeters follows the same pattern, with the highest rainfall in the southwest, which decreases as one moves northeast. The major difference in these patterns is along the border with Kenya in the southeast part of South Sudan where the number of rainy days is moderate, and the amount of rainfall is relatively low compared to the rest of the country. In the central-eastern area, rainfall displays an increasing pattern.

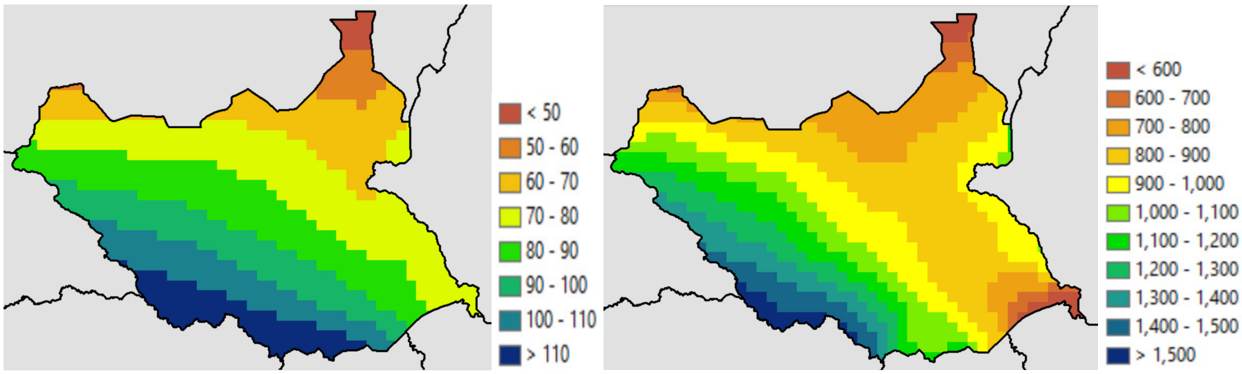
The temperature patterns (Figure 4) are like the rainfall patterns in the sense that the lowest temperatures are found in the southwest and they increase in the northeasterly direction. In many countries, the growing season occurs during the hottest months, because that is also when there is ample precipitation to support rainfed agriculture. High temperatures, particularly those in the range observed for most of South Sudan, are a major constraint on the yields of many grains. In the hottest parts of the country, which are also the driest, GIEWS (FAO 2021) and SAGE (Sacks et al. 2010) cropping calendars suggest that the planting window for South Sudan begins in April and concludes in May. In the southern parts of the country, which receive bimodal rains, the planting window is in March and April, with a second window in August and September.

Figure 5 shows the distribution of cropland area based on 20- and 300-meter resolutions, which show a high concentration of cropland in the northern part of the state of Upper Nile where irrigation is common.

The distribution of the population in South Sudan (Figure 6) is concentrated along the diagonal cutting through in the middle of the country from northwest to southeast, which is in and around the White Nile basin where the rainfall and temperatures are moderate. With the White Nile being a major transportation channel, the pattern of the distribution of the population is not surprising.

Figure 3: Mean number of rainy days and annual precipitation in South Sudan, 1985–2015

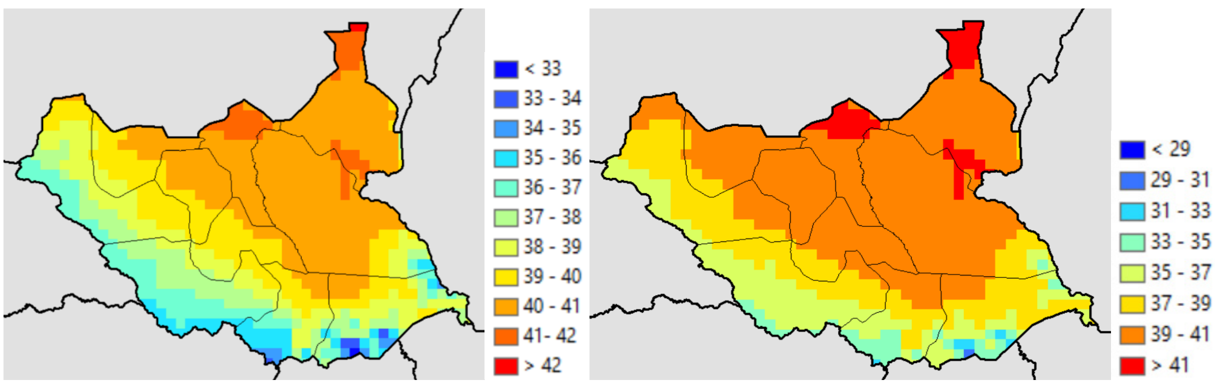
3a: Precipitation (number of days) 3b: Precipitation (mm)



Source: Authors' based on data from Princeton Global Forcings (Sheffield et al. 2020).
Notes: Daily data were summed to get annual values and then averaged across the 31 years.

Figure 4: Mean daily maximum temperature in South Sudan (°C), 1985–2015

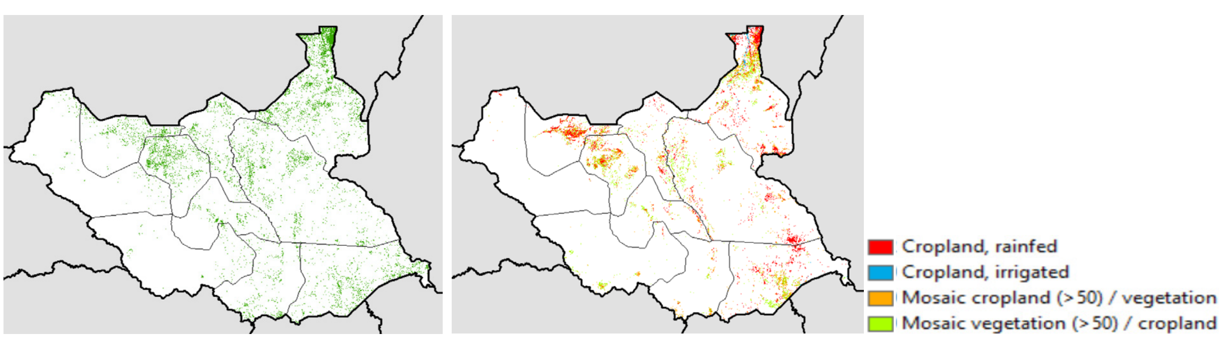
4a: Warmest month 4b: March to May



Source: Authors' based on data from Princeton Global Forcings (Sheffield et al. 2020).
Notes: Daily data were averaged by month over the 31 years and then the values for the warmest month were selected.

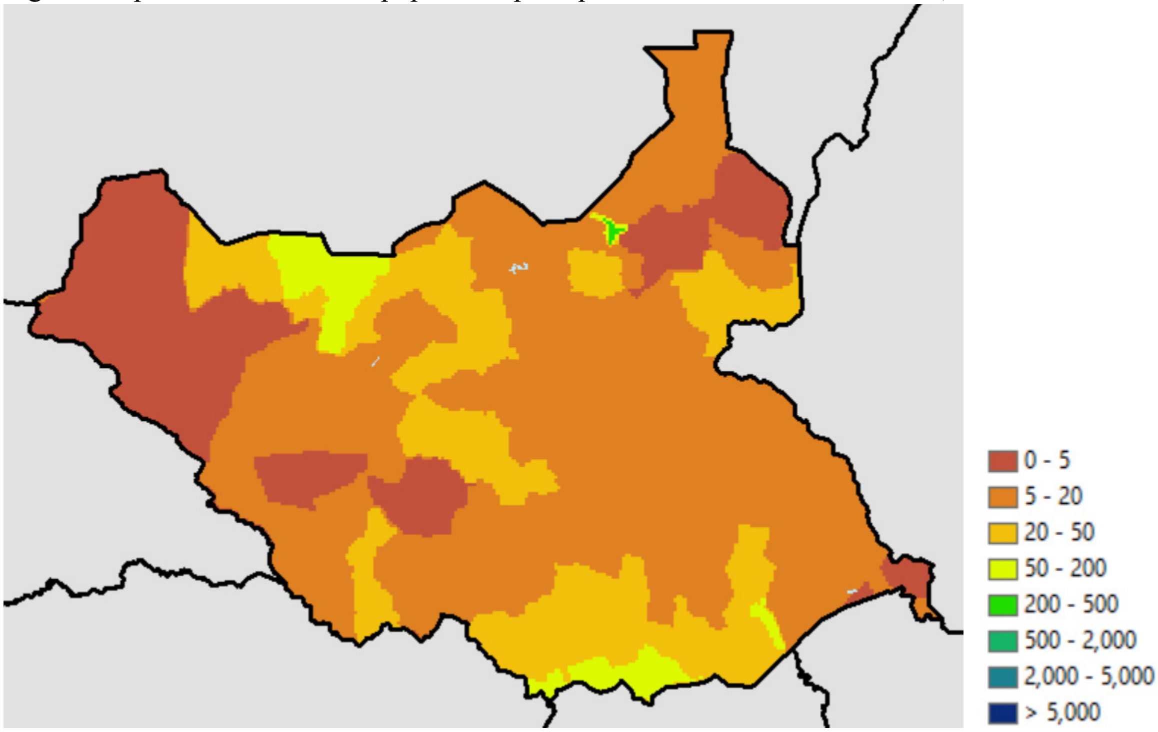
Figure 5: Spatial distribution of cropland in South Sudan, 2015

5a: 20-meter resolution 5b: 300-meter resolution



Sources: Sentinel satellite imagery (ESA 2016) and CCI (ESA, 2018).
Notes: Cropland is in green for the 20-meter resolution. For the 300-meter resolution, mosaic numbers are percentage of pixel.

Figure 6: Spatial distribution of population per square kilometer in South Sudan, 2010



Sources: Authors' illustration based on the Gridded Population of the World, version 4 (CIESEN 2018).

Based on the above indicators, Table 4 shows the classification of agricultural potential for the selected counties using the two measures—rainfall-temperature pattern and area-kilocalorie conversion. For the rainfall-temperature pattern measure, Torit, Wau, and Yambio are classified as having the highest potential. Regarding the area-kilocalorie conversion measure, the high potential classification reflects more the availability of agricultural land or lower population densities of the relevant counties. Based on both measures then, Torit and Wau counties can be classified as the two with the highest agricultural potential in terms of both favorable climate and agricultural land availability, whereas Bor South, Duk, and Twic East are of the lowest agricultural potential.

Table 4: Agricultural potential for selected counties in South Sudan

County	Method of classification	
	Rainfall-temperature pattern	Area-kilocalorie conversion
Aweil Centre	Moderate	High
Aweil North	Low-moderate	High
Awerial	Low-moderate	High
Bor South	Low-moderate	Low
Duk	Low-moderate	Low
Rumbek Centre	Moderate	n.a.
Torit	Moderate-high	High
Twic East	Low-moderate	Low
Wau	Moderate-high	High
Wulu	Moderate	n.a.
Yambio	High	n.a.
Yirol East	Moderate	n.a.
Yirol West	Moderate	High

Source: Authors' illustration based on model results.
Notes: n.a. = not analyzed due to data constraints.

4.2. Agricultural development constraints

Over the years, conflict and violence have prevented farmers from sowing, planting, and harvesting crops (World Bank, 2019); this has contributed to the food shortages and chronic food insecurity in South Sudan. Across the country, the prolonged conflict led to abandoned farms, a breakdown in agricultural supply chains, and depletion of knowledge and infrastructure (AfDB 2013). In this section, we discuss some of the main constraints.

National context and enabling environment

Following independence of South Sudan in July 2011, protracted conflict since 2013 has eroded progress made on institutionalizing state functions to achieving peace and broad-based, sustained development and prosperity, which remains the central objective of the government of South Sudan (RSS 2018). Currently driven by the 2018 Revitalized Peace Agreement (IGAD 2018) and National Development Strategy (RSS 2018), the economy is dominated by the oil sector, which accounts for 70 percent of GDP and more than 90 percent of public revenues. Agriculture accounts for 15 percent of GDP, whereas the service and other sectors account for the remaining 15 percent. The role of agriculture is substantial however, as it employs 80 percent of the population. Collapse of global oil prices has slumped public revenues, and performance in agriculture and other sectors was slowed down in 2020 by locust invasions, floods, and the COVID–19 pandemic (AfDB 2021).

Comparing the performance of South Sudan to its bordering countries (Central African Republic, DRC, Ethiopia, Kenya, Sudan, and Uganda) and to the average performance of countries in East Africa, SSA, and all of Africa in several indicators on implementing the Malabo Declaration on accelerating agricultural growth and transformation for shared prosperity and improved livelihoods, Table 6 shows South Sudan is far behind. The indicators cover a range of policies and institutions related to planning and implementation, public investment, trade facilitation, food safety, and social protection and resilience building. Others include agricultural intensification on access to services and input use, as well as broader outcomes on nutrition. The only indicator that South Sudan is ahead on performance is government agriculture expenditure measured as a percentage of agriculture value added, which most likely is due to the relatively small size of the agriculture sector there. The relatively poor performance of South Sudan reflects the multiple agricultural development constraints facing the country as well as previously discussed civil war and conflict. This includes low capacity for evidence-based decision making, which is also reflected in the lack of data on several of the indicators for tracking performance in the sector.

Table 5: Selected performance indicators on agriculture transformation in Africa, 2019

CAADP BR Indicator	South Sudan	Central African Republic	Congo, Dem. Rep.	Ethiopia	Kenya	Sudan	Uganda	East Africa	SSA	Africa
Policy										
CAADP process completion index, 0-100	57.1	85.7	71.4	100.0	85.7	100.0	100.0	83.3	85.1	85.4
Evidence-informed policies and corresponding human resources, 1-100	44.4	75.0	100.0	87.2	67.4	69.4	99.1	73.3	79.7	77.9
Government agriculture expenditure, % of government total expenditure	2.8	3.6	10.0	10.0	4.0	7.8	3.1	5.9	5.1	5.2
Government agriculture expenditure, % of agriculture value added	13.3	1.7	8.3	7.5	2.9	15.9	3.1	8.6	9.4	9.3
Government agriculture research expenditure, % of agriculture value added	n.d.	0.1	0.4	0.2	0.2	1.0	0.2	0.5	0.5	0.5
Food system safety index, 0-100	63.3	57.5	64.4	85.1	96.7	83.1	66.3	69.3	69.2	69.8
Trade facilitation index, 0-100	n.d.	8.7	28.1	57.8	61.6	17.9	56.6	52.6	47.6	47.1
Budget lines on social protection, % of total resource requirements for coverage of vulnerable social groups	n.d.	7.8	49.9	95.2	100.0	58.4	84.9	77.3	58.6	61.8
Government budget lines for spending needs on resilience building initiatives, % of total required	36.3	66.7	76.7	100.0	83.5	66.7	70.9	74.7	77.8	77.2
Index of capacity to generate and use agriculture statistical data and information, 0-100	n.d.	n.d.	n.d.	75.5	68.3	33.0	60.5	66.2	57.3	59.0
Intensification										
Proportion of men and women engaged in agriculture with access to financial services, %	n.d.	n.d.	0.1	38.4	89.0	0.1	57.8	45.1	30.0	31.7
Proportion of men and women engaged in agriculture with access to financial services, %	n.d.	n.d.	4.7	51.3	77.0	11.2	45.0	51.4	45.4	49.7
Fertilizer consumption (kilogram per hectare of arable land)	n.d.	n.d.	3.2	33.3	48.6	n.d.	5.6	24.8	18.0	20.6
Outcome										
Growth rate of agriculture value added, %	n.d.	3.0	3.1	3.8	3.6	-2.2	5.4	2.5	2.3	2.1
Prevalence of stunting, % of children <5 years old	15.1	42.3	41.8	0.4	19.4	36.6	27.9	29.5	27.8	26.7
Prevalence of underweight, % of children <5 years old	0.0	21.3	23.1	0.2	11.0	29.0	10.2	12.9	13.8	13.3
Prevalence of wasting, % of children <5 years old	15.8	n.d.	6.6	0.1	4.0	14.1	3.3	8.2	7.6	7.3
Prevalence of undernourishment, % of population	15.8	n.d.	n.d.	0.2	18.8	12.3	39.7	17.3	17.2	16.1

Source: Authors' calculation based on World Bank (2021) for growth rate of agriculture value added and AUC (2020) for all other indicators.

Notes: CAADP = Comprehensive Africa Agriculture Development Programme. BR = biennial review. n.d. = no data.

Stakeholders' opinions and perceptions on constraints

Findings from the key informant interviews show that pests and diseases are the major factors hindering agricultural development in the selected counties, followed by insecurity, bad roads, flooding, and lack of markets and storage facilities (Table 6). However, the distribution of these constraints is uneven across the selected counties, with Awerial, Yambio and Yirol being the most constrained in terms of proportion of respondents that identified many of the factors as a constraint.

Table 6: Factors constraining agricultural development, % of key informants responding

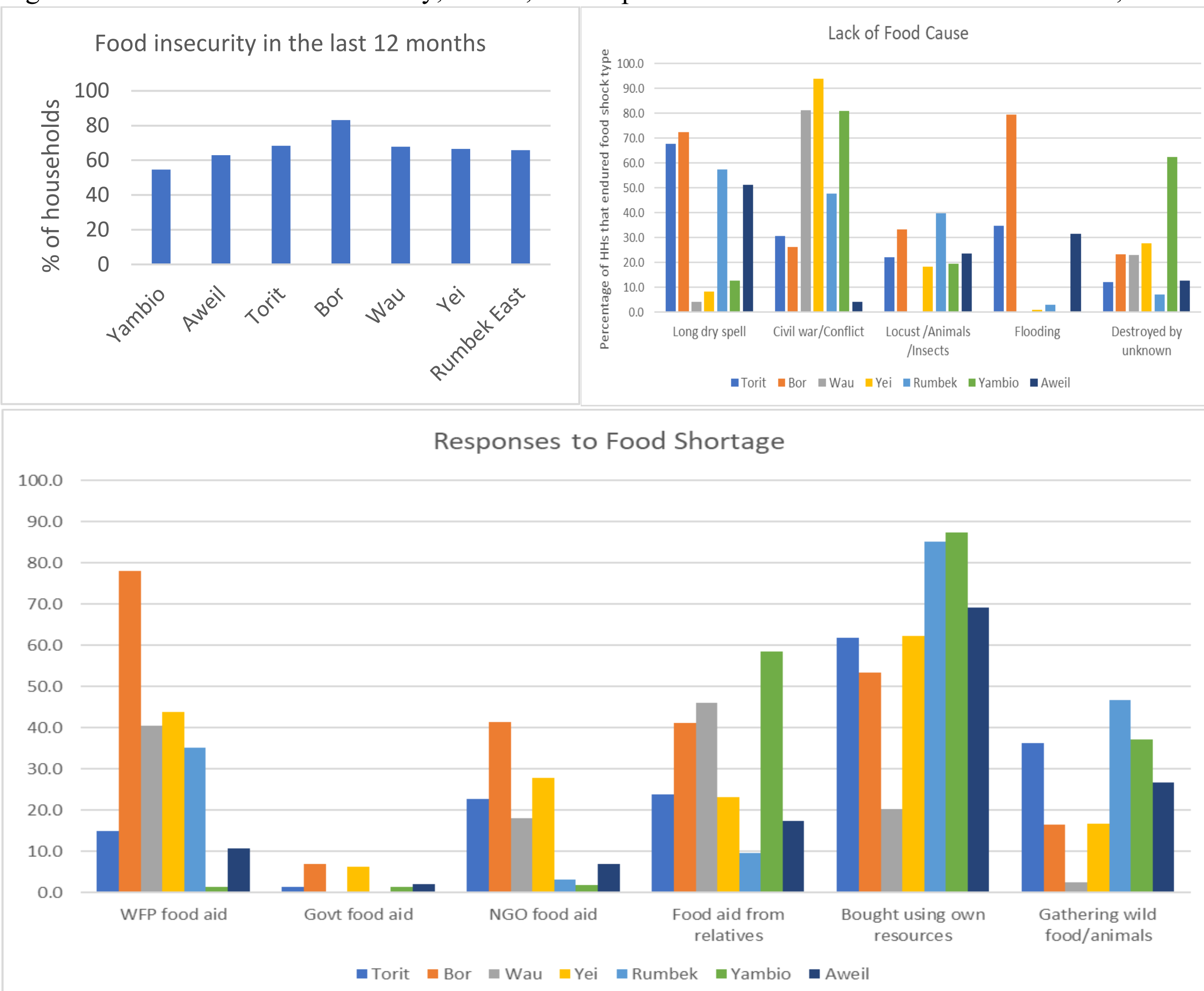
Counties	Insecurity	Bad roads	Limited access to the market	High taxes	Lack of inputs	Pests diseases	Lack of skilled labor	Lack of land security	Lack of storage facilities	Flooding	Drought
Aweil North	9.1	9.1	9.1	0.0	18.2	27.3	9.1	0.0	9.1	18.2	36.4
Aweil centre	10.8	63.1	43.2	0.0	43.2	69.3	36.9	13.9	32.4	64.8	44.6
Awerial	66.7	66.7	66.7	83.3	66.7	100.0	66.7	25.0	83.3	83.3	66.7
Bor	74.6	64.3	51.2	14.7	52.8	71.4	19.8	18.3	42.1	78.6	42.1
Duk	50.0	50.0	50.0	0.0	0.0	50.0	50.0	0.0	0.0	50.0	0.0
Rumbek central	36.7	16.7	10.0	56.7	36.7	73.3	20.0	0.0	26.7	70.0	30.0
Rumbek East	100.0	100.0	100.0	0.0	100.0	100.0	50.0	25.0	75.0	100.0	100.0
Torit	19.6	92.9	66.1	0.0	64.3	92.9	78.6	14.3	80.4	66.1	12.5
Twic East	87.5	87.5	62.5	12.5	37.5	62.5	62.5	12.5	37.5	87.5	0.0
Wau	100.0	79.2	56.3	47.9	50.0	79.2	47.9	29.2	35.4	18.8	27.1
Wulu	83.3	50.0	33.3	0.0	50.0	100.0	0.0	25.0	50.0	33.3	58.3
Yambio	100.0	100.0	100.0	62.5	87.5	100.0	87.5	62.5	100.0	41.7	12.5
Yirol	100.0	62.5	75.0	0.0	87.5	87.5	75.0	0.0	87.5	87.5	75.0

Source: Authors' calculations based on key informant surveys.

Most households in the surveyed counties lacked food in the 12-month period priority to the survey (Figure 7). Civil war and conflict are the main drivers of food insecurity in most of the counties, followed by climate shocks like drought. Majority of households in Torit, Bor, Rumbek, and Aweil counties claimed droughts as the largest cause of food insecurity, whereas those in Tori, Bor and Aweil cited flooding. Pests, diseases, and unknown causes were rated as modest causes of food insecurity. In addition to these social and environmental factors, human activities can threaten soil —and therefore food security and resilience—as well as threaten human health and livelihoods due to pollutants and destruction of natural resources. Bush burning, for one, is prevalent in all seven counties. Prevalent charcoal burning further threatens air quality and respiratory health. Timber lumbering exists in all counties, but especially in Rumbek and Yambio, further threatening land and biodiversity resilience. Most counties also suffer significant overgrazing, with its long-term resilience consequences. Finally, mining, toxic dumping and fishing chemicals affect selected regions in counties.

Most of the affected households responded to food insecurity by purchasing food with their own resources (savings) or relying on relatives (Figure 7). In Bor, and, to a lesser extent, Wau, Tori, and Yei, households relied on food aid from the World Food Programme (WFP) and NGO. Food aid from the government played a minimal role—only in Bor and Yei did it reach more than 5% of the households. In some communities, food from wild plants and animals play a notable role in addressing food shortages. For communities dependent on foraging, protection from regional violence and community access to local natural resources has added importance.

Figure 7: Incidence of food insecurity, causes, and responses in selected counties of South Sudan, 2018



Source: Authors' calculation based on MESP (2018).

Access to other services (education, health, and water sanitation) also, in addition to being low, is unevenly distributed as shown in Figure 8 for the counties surveyed under the PfRR project. With respect to education, households and communities in Torit and Wau have the best access to a primary school, whereas those in Bor and Rumbek East have the worst access (Figure 8). These patterns and differences are consistent with access to a secondary school, school attendance rates, and overall literacy rates. However, households in Bor and Rumbek East identified cultural barriers rather than distance to schools as the predominant reason not to attend school.[5] Other obstacles to school attendance include a low value placed on education or need for the youth to help support the family. The range of expressed obstacles, however, varies more in communities with higher education levels as well as by gender. Most schools are funded or operated by the

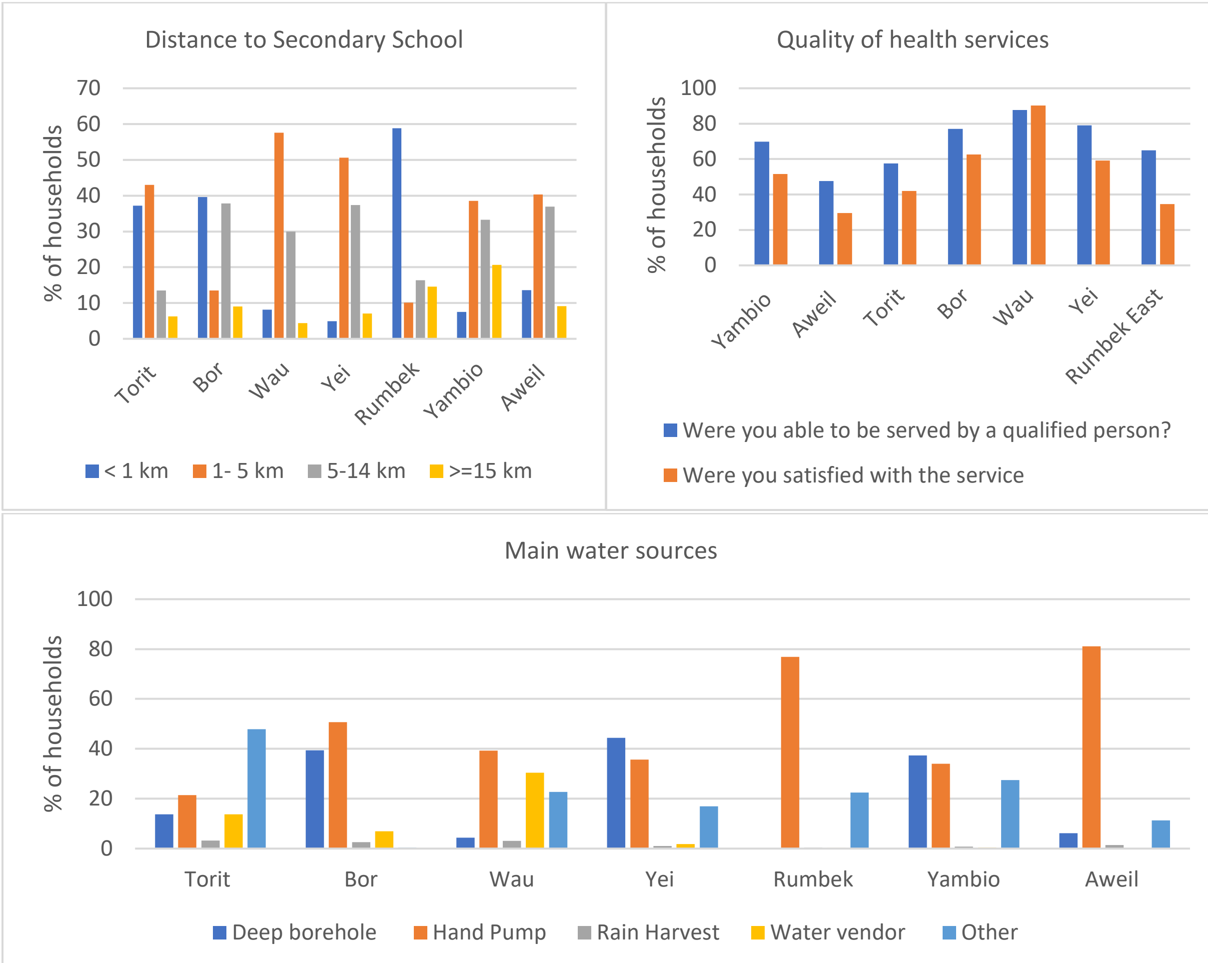
[5] see details to education services and outcomes in Annex 6.

government, with a modest proportion of the schools being privately. Faith-based schools are most common in Yei, Wau, and Yambio.

On access to health care services, a higher percentage of households in Wau, Yei and Bor expressed having experienced quality healthcare services, as measured by different parameters including timeliness, sufficient information provided to patients, and availability of a qualified health provider (Figure 8). Households in Aweil and Torit expressed the lowest overall quality of healthcare services. Focus group discussions were consistent with the viewpoints of households on the poor quality of health services, noting long distances to hospitals, absence of drugs in pharmacies, and that doctors have “given up because of low pay or no facilities.” Other factors affecting health outcomes were provided. For example, respondents indicated knowing the risks of HIV, but social stigma has led to little HIV testing. Informal healthcare services have also declined. For example, respondents described less community investment in caring for the sick and disabled, stating for example that “our energy has been cut in half; we are not checking on them often.”

Regarding access to water, multiple sources are available in each community, but most households depend on one or as two of them primary sources. Hand pumps provide the predominant water source for all the seven surveyed counties, followed by deep boreholes without a network, shallow wells, and water vendors (Figure 8). Most households have their primary source of water within a travel time of less than 30 minutes. Many respondents manifested concern for community management to protect separate boreholes for humans and livestock and called for NGO or government support to bring boreholes to distant rural communities.

Figure 8: Access to services in selected counties of South Sudan, % of respondents (2018)

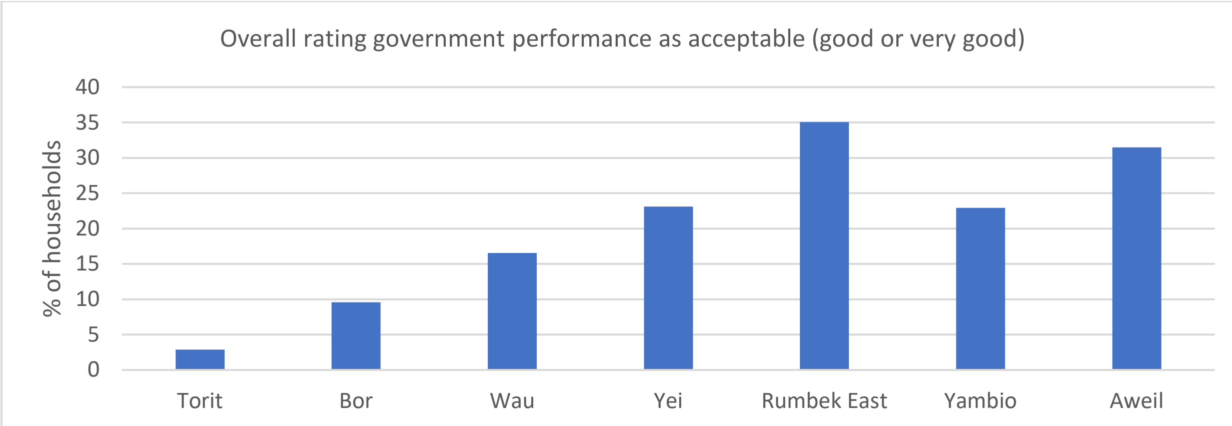


Source: Authors' calculation based on MESP (2018).

Performance of the government was evaluated as being "poor" or "very poor" by majority of the households in most of the counties (Figure 9). There were differences in the rating for different functions (including for job creation, social equity, HIV prevention, road and bridge maintenance, electricity provision, price stability, and fighting corruption) as well as for different levels of government (district, county, national). For example, HIV prevention, addressing educational needs, and national defense received the highest ratings of very good, followed by maintenance of roads and bridges, improving health services, crime reduction, price stability, and job creation which received modest ratings.[6] District government received lower ratings.

[6] See Annex 7 for details on the ratings for different government functions in the surveyed counties.

Figure 9: Rating of government performance in selected counties of South Sudan, % of respondents (2018)



Source: Authors' calculation based on MESP (2018).

Spatial modeling of climate and biophysical constraints

Many of the constraints identified by the key informants, such as pests and diseases, flooding, bad roads, and lack of markets, are corroborated by the spatial analysis on climate change and market access. These are presented below.

Climate change

Climate change is being experienced to a statistically verifiable degree. Figure 10 shows changes in rainfall and temperatures computed at each pixel using data from 1948 to 2016, using regression analysis with a change in slope at 1975. The results show many areas with statistically significant changes at the 10 percent level in the mean annual rainfall amount and intensity as well as in the mean daily maximum temperature for the warmest month.

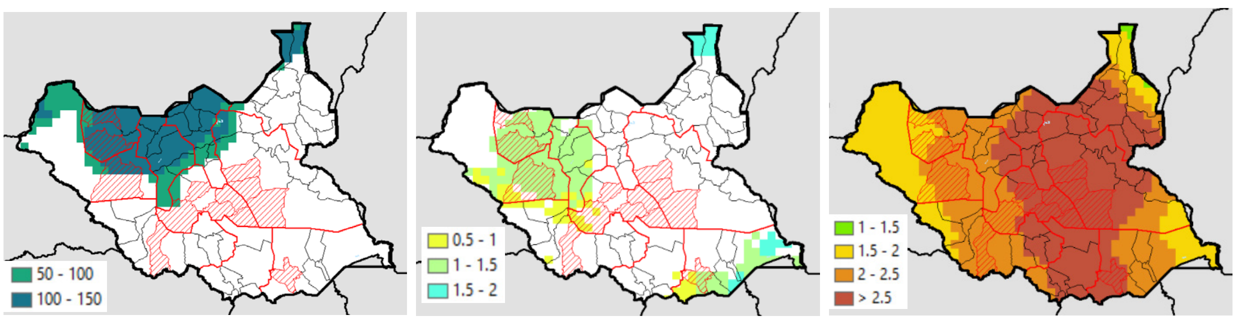
The mean annual rainfall increased by more than 100 mm/year between 1975 and 2016 in the northern part of Upper Nile State and in most of Northern Bahr el Ghazal, Warrap, and Unity, along with the northernmost part of Western Bahr el Ghazal (Figure 10a). The northern part of Upper Nile State and a small portion of southern Eastern Equatoria experienced an increase of more than 1.5 mm per event of rainfall on average during the same periods (Figure 10b). Parts of Northern and Western Bahr el Ghazal and Warrap, along with other parts of southern Eastern Equatoria, experienced an increase in rainfall intensity of 1.0 to 1.5 mm per event. More intense and heavy rainfall often leads to flooding, and less likely to soak into the ground in a manner that is beneficial agriculture. Erosion of the topsoil reduces soil fertility and the sediments that are carried in the runoff and deposited downstream can adversely affect dams and irrigation.

With respect to temperature, all areas in South Sudan have experienced a statistically significant increase in the mean daily maximum temperature for the warmest month in 1975 to 2016 (Figure 10c). The highest changes—above 2.5°C—are observed in areas from north to south in the central part of the country, including parts of Central Equatoria, Jonglei, Lakes, Unity, and Upper Nile. Both east and west of this large band are areas that have experienced change in the

2.0°C to 2.5°C range, with the westernmost and small sections in the easternmost regions experiencing a 1.5°C to 2.0°C temperature change.

Figure 10: Areas of significant change in mean rainfall and daily maximum temperature for the warmest month in South Sudan, 1975–2016

10a: Annual precipitation (mm) 10b: Rainfall intensity 10c: Temperature (ºC)



Source: Authors' based on data from Princeton Global Forcings (Sheffield et al. 2020).
Note: Based on a linear regression of data from 1948 to 2016, with a change of slope in 1975. Colored areas are those with a change of 10% statistical significance level.

Looking at the selected counties (Table 7 and Figure 10), Aweil Centre, Aweil North, Wau, and Torit are those that have experienced a statistically significant increase in annual rainfall or intensity. All of them, however, have experienced significant increase in the daily maximum temperature for the warmest month of at least 2ºC, with eight of them (Awerial, Bor South, Duk, Rumbek Centre, Torit, Twic East, Yirol East, and Yirol West) experiencing an increase of more than 2.5ºC.

Table 7: Increase in mean rainfall and temperatures for selected counties in South Sudan, 1975–2016

County	Rainfall		Temperature (ºC)
	Annual (mm)	Intensity (mm/event)	
Aweil Centre	111	1.3	2.0
Aweil North	103	1.1	2.0
Awerial	46	0.6	2.9
Bor South	40	0.6	2.9
Duk	60	0.1	3.2
Rumbek Centre	75	0.7	2.6
Torit	61	1.0	2.6
Twic East	50	0.2	3.1
Wau	95	1.1	2.1
Wulu	66	0.8	2.4
Yambio	46	0.7	2.3
Yirol East	56	0.4	2.9
Yirol West	59	0.6	2.7

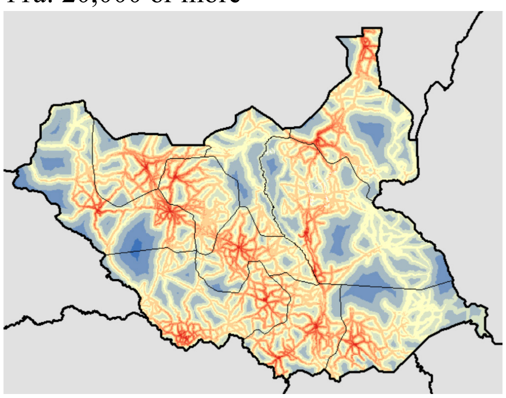
Source: Authors' based on data from Princeton Global Forcings (Sheffield et al. 2020).
Note: Temperature is daily maximum for the warmest month. Based on a linear regression of data from 1948 to 2016, with a change of slope in 1975. Changes are at the 10% statistical significance level. Changes are for a 40-year period. N.s. = change is not statistically significant.

Market access

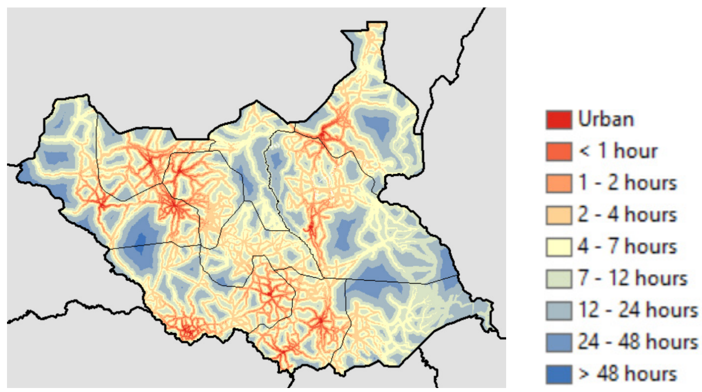
Markets provide the channels for farmers buy their inputs (seeds, fertilizers, pesticides, etc.) and sell surplus produce. Markets are also where farm households can buy food for their families and can sometimes find employment to supplement or even replace farm income. Using population size of towns and cities to represent different market sizes, Figure 11 shows the distribution of travel times to the nearest market of different sizes. Access to relatively small markets, represented by travel time to cities and towns with 20,000 or more people (Figure 11a), is low for many areas, which deteriorates further for access to larger markets, represented by travel time to cities and towns with 100,000 or more people (Figure 11c) or 250,000 or more people (Figure 11d). Then, travel times are at least 4 hours for most of South Sudan.

Figure 11: Travel time to towns and cities of various population sizes in South Sudan, 2014

11a: 20,000 or more



11b: 50,000 or more



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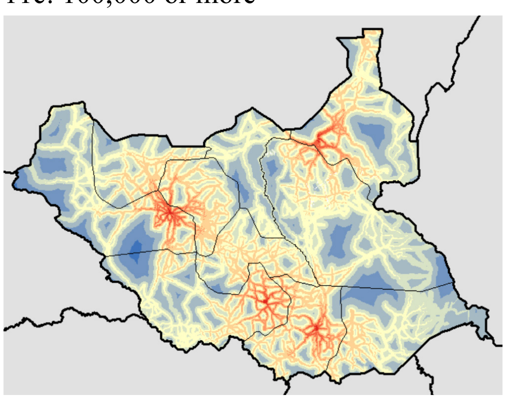
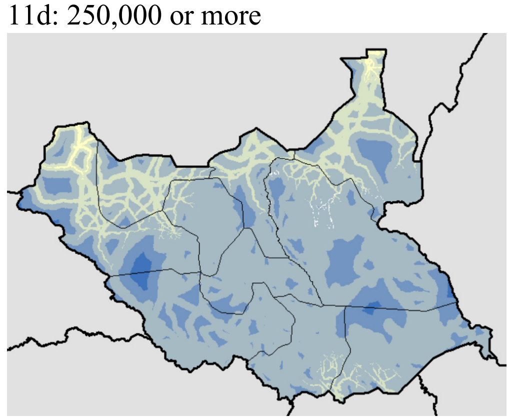


11d: 250,000 or more



Source: Guo and Cox (2014).

Focusing on the selected counties, Table 8 shows that the average time to even a small town is multiple hours, with the smallest being Rumbek Centre at 3.3 hours. Keep in mind this is average travel time per each location in a county rather than each person. Since population will tend to concentrate in cities and towns, the per person rate would be much lower. Nonetheless, it appears that poor road networks increase travel time for rural areas to reach services offered by urban areas, which implies the costs of agricultural inputs to farmers would be high, due to having to pay higher transport costs for greater distances – and the probably farmgate price for those selling to urban markets would be low, again because of higher transport costs. Wau, by far, is the most isolated. Aweil North, Bor South, and Wulu are also fairly disconnected from markets. Rumbek Centre and Torit appear to be the best connected.

Table 8: Average travel time to cities and towns for selected counties in South Sudan, 2014 (hours)

County	Agricultural potential	Cities and towns with population of:			
		20,000 or more	50,000 or more	100,000 or more	250,000 or more
Aweil Centre	Moderate	5.6	5.6	7.1	13.9
Aweil North	Low-moderate	10.4	10.4	12.8	16.7
Awerial	Low-moderate	5.1	5.4	5.6	19.1
Bor South	Low-moderate	10.7	11.7	12.7	24.2
Duk	Low-moderate	6.4	6.5	8.7	18.1
Rumbek Centre	Moderate	3.3	6.3	6.3	17.4
Torit	Moderate-high	3.7	5.7	5.7	14.9
Twic East	Low-moderate	5.2	5.4	8.3	18.6
Wau	Moderate-high	15.5	15.5	15.9	26.1
Wulu	Moderate	8.5	9.5	9.7	22.4
Yambio	High	5.5	5.5	8.5	19.4
Yirol East	Moderate	5.1	6.1	6.1	17.9
Yirol West	Moderate	5.5	6.0	6.0	19.6

Source: Authors' calculation based on Guo and Cox (2014).
Note: Travel time is average of pixel data on the counties. Agricultural potential is based on the rainfall-temperature measure.

FSN typology of value chain inefficiencies and constraints

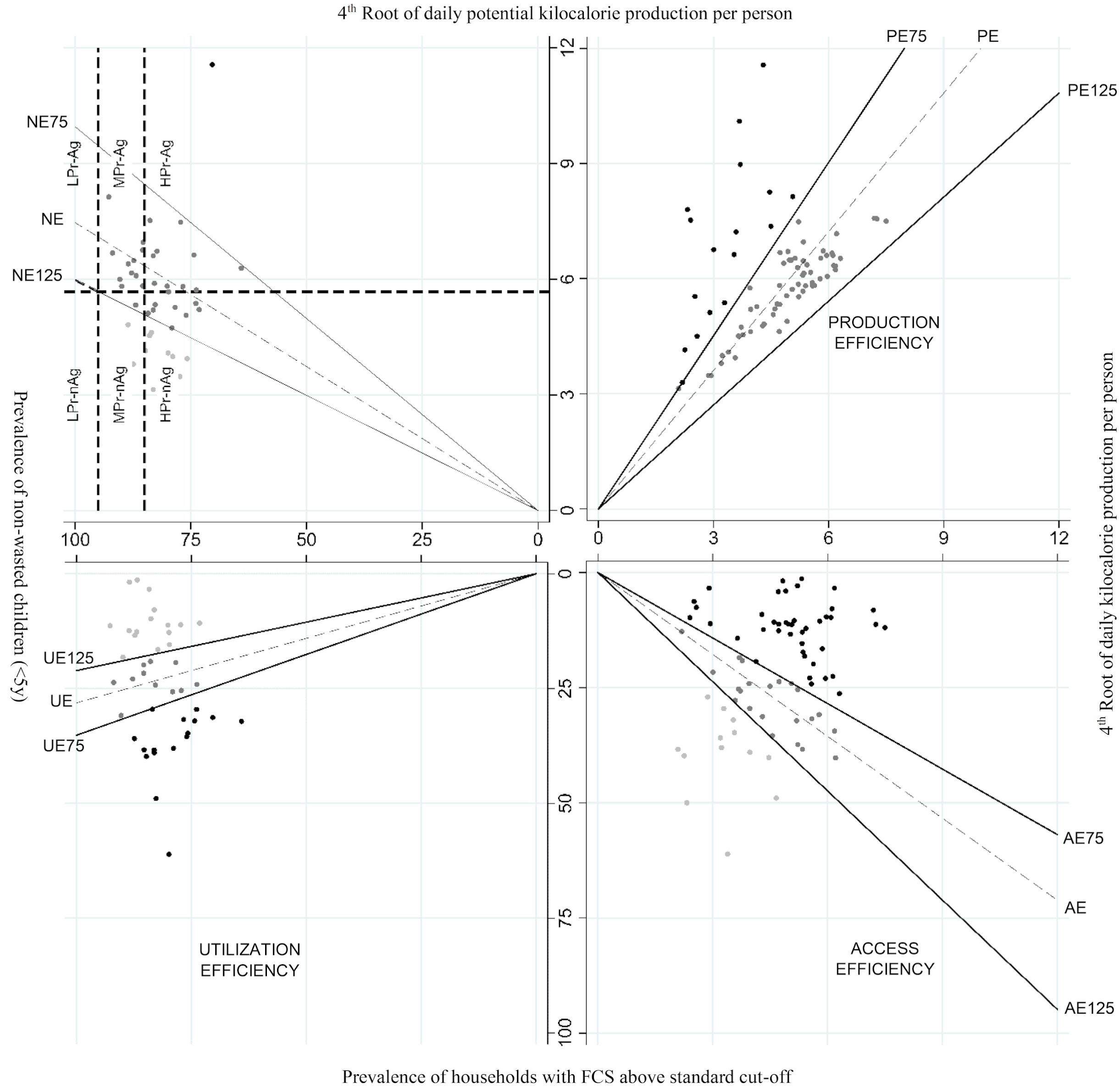
Here, the efficiencies at each segment of the production-to-nutrition value chain are rated as low, medium, or high for the most recent period investigated (i.e. 2016-2017), and then classified as structural (when the underlying constraints are stable over the past three periods) or stochastic (when the underlying constraints are variable over that same time period). The 2016-2017 results for all the counties in the country are presented in Figure 12 by plotting each indicator on a different axis, thus creating a four-dimensional scatterplot.

Starting from the top vertical axis (which measures the agricultural potential) and going clockwise, the upper-right panel describes the relationship between agricultural potential and food availability (which is measured by food production). In this panel, the diagonal line of production or availability efficiency indicates the level of food production one can expect based on each county's agricultural potential. In a similar vein, the diagonal of access efficiency (lower-right panel) reflects the expected levels of food acquisition based on a county's level of food production. Then, utilization efficiency (lower-left panel) represents the expected levels of nutrition status derived from the county's level of food acquisition. The upper-left panel shows the plot for nutrition outcomes to classify counties into three priority levels.[7] The results or the efficiencies are thus relative and compare counties in South Sudan to each other.

[7] See Annex 2 for the distribution of global acute malnutrition (GAM) among children below the age of five years in South Sudan.

By drawing a “fork” around the lines of average efficiency, the three levels of efficiency (low, medium, and high) are identified as presented in the empirical section, where low efficiency is for counties with values lower than 75% of the average efficiency, medium efficiency is for counties with values in the range of 75% and 125% of the average efficiency; and high efficiency is for counties with values greater than 125% of the average efficiency. For counties classified as medium production efficiency for example (represented by the dots that fall within the “fork” of production efficiency in the upper-right panel of Figure 12), it means that the level of food production is roughly what you would expect based on their agricultural potential. For counties that fall outside of the “fork” however, food production performance is either worse (low production efficiency) or better (high production efficiency) than the average (medium production efficiency) observed throughout the country.

Figure 12: Combined scatterplot of county value-chain efficiencies, South Sudan (2016–2017)



Source: Authors' illustration based on results from the spatial typology of food security and nutrition. Notes: LPr, MPr, HPr = low-, medium-, and high-priority counties, respectively. Ag and nAg = high and low agricultural potential, respectively. PE, AE, UE, and NE = production (or availability), access, utilization, and nutrition efficiency, respectively, of estimated lines based on population-weighted ordinary least squares regressions with intercept through the origin, with respective slopes of 1.204, 0.169, 0.281, and 13.387. E75 and E125 lines are derived from the previous lines with slopes being 75% and 125% of the size of the estimated slopes.

From the results, none of the counties are classified as having high production efficiency. 22% and 78% are classified as low and medium production efficiency, respectively. With respect to access, 55%, 29%, and 17% are classified as low, medium, and high access efficiency, respectively. And for utilization, 37%, 26%, and 37% are classified as low, medium, and high utilization efficiency, respectively. Thus, it seems that the access segment of the production-to-nutrition value chain is the most constraining, followed by the utilization segment. This is consistent with the earlier results of poor market access or long travel times to large cities and towns across the country and is indicative of the challenges in moving food from the farm to consumption areas.

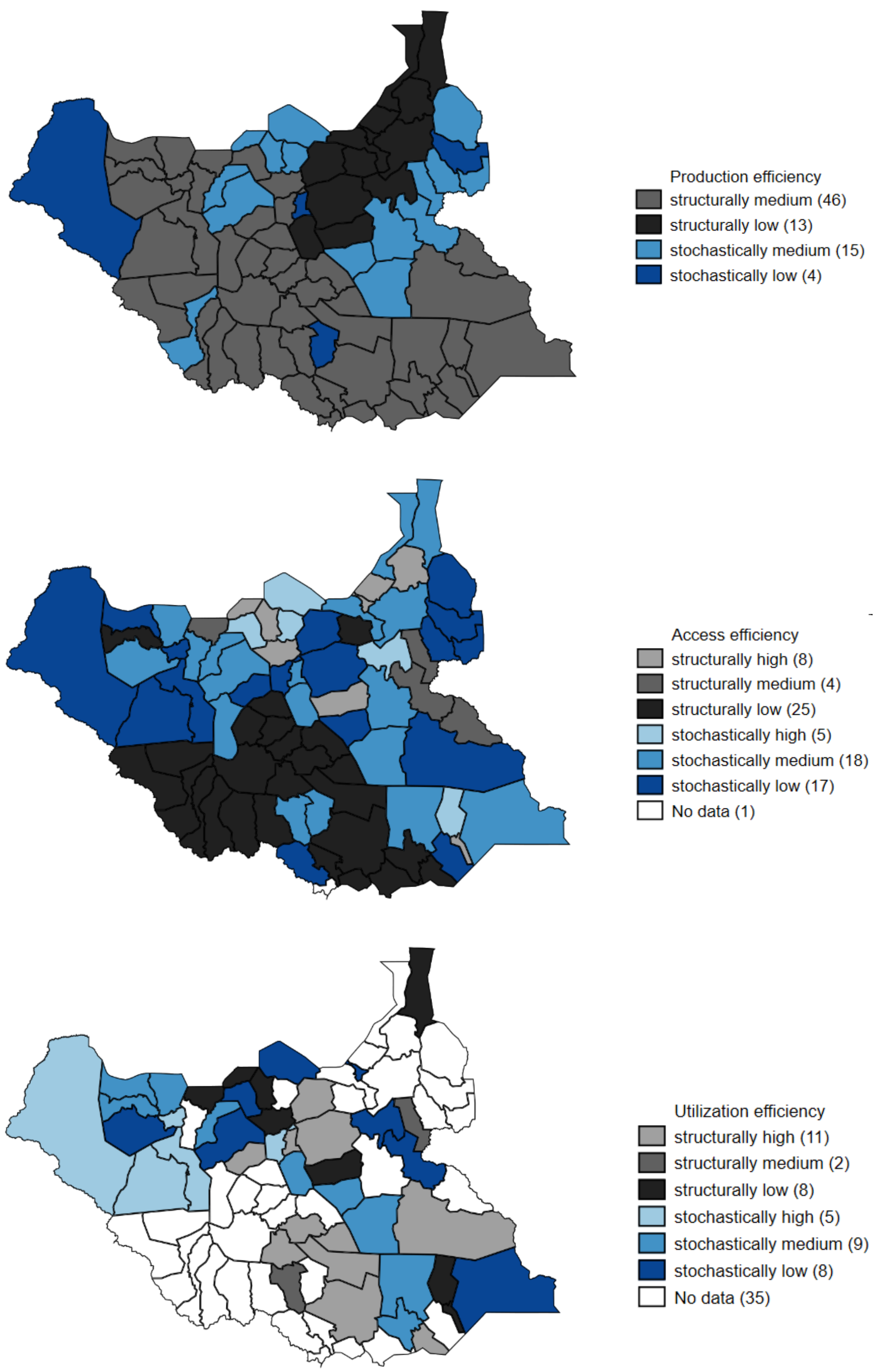
Results of distinguishing the efficiencies as structural or stochastic are presented in Figure 13, with detailed results in tabular format presented in Annex 3. With respect to production or availability efficiency, most (76%) of the counties are classified as structural and the remaining 24% as stochastic. On the contrary, for access and utilization efficiency, the number of counties is almost evenly split (48% structural and 52% stochastic). In terms of spatial distribution, the production constraints are structurally high in a cluster of counties bordering Ayod in the north-central part of the country, and up to Malakal and Renk in the country's northeast. In contrast, the high production inefficiencies in Raga, Leer, Mundri East and Longochuk seem to be merely stochastic. With respect to access, the highest structural inefficiencies are mainly located in the southern part of the country—which is especially remarkable for Terekeka and Juba given their relative proximity to the capital city—while the same level of access constraint seems transient in various counties scattered across the country. Regarding utilization constraints, no clear pattern emerges, with both types of high inefficiency levels (that is, structural and stochastic) being observed in different parts of the country.

Table 9 shows the results for the 13 selected counties, where the majority are classified as structurally medium availability efficiency (77% of them) or structurally low access efficiency (54%) or stochastically medium utilization efficiency (44%). With access efficiency (whether structural or stochastic) being mostly low in 77% of the counties, this segment of the production-to-nutrition value chain, as in most parts of South Sudan, is the most challenging among the selected counties of analysis. Duk county, which is widely acknowledged as one of the most marginalized counties in South Sudan (reflected by its characterization of low agricultural potential, structurally low availability efficiency, and structurally low utilization efficiency), is the only one of the selected counties to be characterized as having high access efficiency. The county is part of the eastern plains, sorghum and cattle livelihood zones (FEWSNET, 2018). The main crops grown are sorghum, maize, groundnut and cowpeas. There is a traditional livestock migration from Ayod County into the Sudd wetlands of Duk County. However, seasonal floods pose a significant livelihood hazard as they can limit fishing activities and reduce crop, livestock, and wild foods production (FAO /WFP, 2019). On the utilization end of the value chain, Aweil Centre is the other county characterized as having low utilization efficiency, although it is stochastic.

4.3. Value chain opportunities and investment options

As with the constraints, the presentation here is organized according to the different methods used—desktop review of development plans and reports, stakeholder opinions and perceptions from surveys, climate-crop modeling and simulation, and spatial typology of food security and nutrition.

Figure 13: Structural and stochastic value-chain efficiencies by county, South Sudan (2015–2017)



Source: Authors' illustration based on results from the spatial typology of food security and nutrition.
Notes: Structural means underlying constraints associated with the level of efficiency are stable between 2014 and 2017, and stochastic means the underlying constraints are variable over that same time period.

Agricultural policies, strategies, and production

This is based on the results of the desk review, which focuses on the major crops (including their spatial distribution in South Sudan as well as comparing their yields with the averages for the East Africa region and for all of Africa), seeds sector, and irrigation development at the national level.

Table 9: Summary of value chain efficiencies in selected counties of South Sudan (2014–2017)

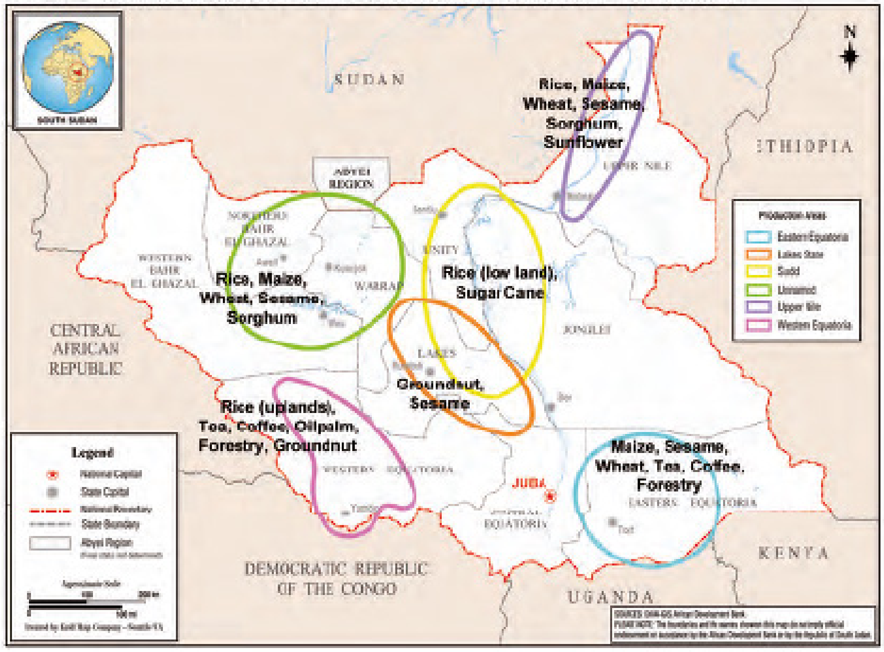
County	Agricultural potential	Efficiency at value-chain segment:		
		Availability	Access	Utilization
Aweil Centre	High	Structurally medium	Stochastically medium	Stochastically low
Aweil North	High	Structurally medium	Stochastically low	Stochastically medium
Awerial	High	Structurally medium	Structurally low	Structurally high
Bor South	Low	Stochastically medium	Stochastically medium	Stochastically medium
Duk	Low	Structurally low	Structurally high	Structurally low
Rumbek Centre	n.a.	Structurally medium	Structurally low	n.a.
Torit	High	Structurally medium	Structurally low	Stochastically medium
Twic East	Low	Stochastically medium	Stochastically low	Stochastically medium
Wau	High	Structurally medium	Stochastically low	Stochastically high
Wulu	n.a.	Structurally medium	Structurally low	n.a.
Yambio	n.a.	Structurally medium	Structurally low	n.a.
Yirol West	High	Structurally medium	Structurally low	Structurally high
Yirol East	n.a.	Structurally medium	Structurally low	n.a.

Source: Authors' illustration based on results from the spatial typology of food security and nutrition.
Notes: Agricultural potential is based on area-kilocalorie conversion measure. n.a. = not analyzed due to lack of data. Structural means underlying constraints associated with the level of efficiency are stable between 2014 and 2017, and stochastic means the underlying constraints are variable over that same period.

Major crops

Crops vary by agricultural zone (Figure 14), with the northern part of Upper Nile having a high concentration of cropland, especially in the irrigated areas. Taking sorghum for example, it is grown intensively in parts of the states of Jonglei, Lakes, Eastern Equatoria, and Northern Bahr el Ghazal. For all South Sudan, the 10 leading crops based on area cultivated are sorghum, sesame seeds, maize, groundnuts, cassava, fruits, vegetables, melon seed, pulses, and sunflowers (Table 10). The area under sorghum and sesame seeds together exceeds all the others, followed by maize and groundnuts. A significant amount of area is also devoted to cassava and various fruits, vegetables, and pulses. Compared to neighboring countries in the east Africa region or all Africa, the average yields for the major crops in South Sudan are only higher for Sunflower seed and other pulses and fresh fruits (Table 10). Thus, there are opportunities for closing the yield gap for several crops with neighboring and other African countries, especially those that have similar agroecological factors. Improving the quality of seed and tapping the irrigation potential are two key areas to invest in.

Figure 14: Distribution of crops grown in South Sudan, 2013



Source: AfDB (2013).

Table 10: Top ten crops by area cultivated in South Sudan compared to Africa (2012-2015 average)

Crop	South Sudan			East Africa	Africa
	Area cultivated (ha)	Production (tons)	Yield (kg/ha)	Yield (kg/ha)	Yield (kg/ha)
Sorghum	731,795	783,000	1,121	1,544	1,011
Sesame seed	660,468	197,376	300	589	483
Maize	254,809	177,750	752	1,879	1,983
Groundnuts	227,433	127,500	559	705	961
Cassava	85,931	124,964	1,465	6,718	8,727
Fruit, fresh, other	62,180	357,614	5,743	4,561	4,310
Vegetables, fresh, other	50,893	380,971	7,436	6,524	7,748
Melonseed	35,028	21,386	618	671	468
Pulses, other	34,501	29,411	854	755	627
Sunflower seed	27,910	47,000	1,700	1,115	1,136

Source: FAO (2021).

The seed sector

As pointed out by the World Bank (2019), the quality of seed is perhaps the most important factor to boost agricultural productivity in South Sudan. Although the amount of seed produced in South Sudan has increased in recent years, farmers still lack access to quality seed. In 2018 for example, private seed companies produced about 2,000 tons of seed, but this was only 17 percent of the 12,000 tons needed by the farming sector (FAO 2017). Moreover, private seed companies tend to focus on maize and sorghum, leaving a large gap in meeting the demand for the other major cultivated crops. Most of the seeds are sourced from savings from previous cultivation, borrowed from family/friends, or provided by NGOs and UN agencies. The Ministry of

Agriculture and Food Security (MAFS) has approved about 30 varieties of seeds for release to farmers, but lack of a system for seed multiplication and marketing has prevented that (World Bank, 2019). As such, majority of improved seeds used in South Sudan are imported from neighboring countries including Kenya, Uganda, and Sudan.

Four types of seed systems operate in South Sudan: formal, informal, relief, and community-based market-oriented. The formal seed system is less functional and operates mainly for imported seeds. Informal system—farmers' saved seed from previous harvests and seed aid from NGOs, etc.— provide the largest portion of seed for most farmers in the country. Under the community-based market-oriented system, three farmer seed production initiatives were transformed into sustainable market-driven local seed businesses to address new crops and varieties, quality, marketing, and organizational aspects. The Alliance for a Green Revolution in Africa (AGRA) is supporting five crop breeding programs (cassava, maize, rice, sorghum, and cowpeas) and three seed companies (Century Seed, Green Belt Seed, and Afroganics) (FAO, 2019). The breeding programs have short-term plans to quickly evaluate improved crop varieties for release and adoption by the local farming communities to improve seed availability. Maize, rice, and cassava programs have a total of nine selected varieties for release—four for maize, four for rice, and one for cassava. These programs also distribute basic seeds and supplies to the seed companies and some individual farmers. The three seed companies have begun seed multiplication, sales, and awareness creation on the use of quality seeds of improved crop varieties. Seed is distributed through various channels, including the government, NGOs, the international commercial sector, relief agencies, and farmers' own production and exchange with relatives or friends. For several years, relief seed markets have been at the center of seed assistance schemes in South Sudan. Without a commercial farming sector, development of a formal seed system is difficult. Apart from hybrids (primarily maize), the nascent seed industry generally markets only vegetable seeds and some cash crops such as sunflower.

Irrigation potential and development

The irrigation potential for South Sudan is estimated at 1.5 million ha for both smallholders and commercial farming (AfDB 2013), which is distributed across four main areas (Figure 15): the Nile-Sobat River Basin (with a potential of 654,700 ha); the Western and Eastern Flood Plains in Warrap, Unity, and Jonglei States (with a potential of 600,000 ha); the Mangalla region, which is 45 km from Juba, at the confluence of the White Nile and one of its tributaries in Central Equatoria State (with a potential of 250,000 ha); and the Green Belt zone (with a potential of 500,000 ha). The Green Belt zone's agricultural production usually exceeds subsistence level, so modern irrigation techniques could further increase its production, although small streams and irregular land impede large-scale irrigation.

Other areas with potential for irrigation include (AfDB 2013):

- Lowlands, where farmers make use of flooding to supplement water to grow rice.
- Areas adjacent to river floodplains, where farmers cultivate short-maturing varieties of sorghum.
- Areas around swamps or marshes, where extension of the growing season is possible by planting in moist soils left by receding floods.

- Floodplains in Sudd wetlands, where the potential is estimated to be up to 1.6 million ha but would require extensive work.

For the floodplains, the suggested investments include constructing dikes and canals, although the demand from communities for irrigated farming, initial capital, and maintenance costs, including the willingness and capacity of the communities to be part of the management of maintenance, need to be carefully evaluated (Fernando and Garvey 2013).

Figure 15: Area with high potential for gravity irrigation, South Sudan

Source: GoSS (2015)

Past irrigation projects

Before the second civil war broke out in 1983, the plan for irrigation development in South Sudan was to irrigate about 270,000 ha of land (AfDB 2013). Because of political instability, however, development of irrigated agriculture was constrained except for a few formal irrigation schemes constructed in the 1970s as pilot agro-industrial projects. These have never been fully operational. They were neglected during the periods of civil conflict and war and are now largely nonfunctional, but plans do exist to revive them. These irrigation projects include the following (GoSS, 2015):

- **Melut sugar scheme**: This project was initially intended to develop 35,000 feddans (14,700 ha) of irrigated land to grow sugarcane. In 1979-1980, only 42 ha were cultivated. While construction of the irrigation infrastructure started in 1979, implementation had stopped by 1983. There were plans to restart it in the 2010s with the help of the pre-2011 Sudan Kenana Sugar Company, with an initial capacity of 40,000 tons of sugarcane that was to be increased to 110,000 tons, or 50 to 60 percent of South Sudan's consumption.

- **Aweil rice scheme**: This project was located on the southern bank of the Lol River in Northern Bahr el Ghazal. It was founded in 1944 by British officials, expanded in 1976 by the Government of Sudan with the help of international aid, and partially rehabilitated in 2007. At its peak in the 1980s, the scheme benefitted about 1,000 tenant farmers, but operations ceased in 1986. A rehabilitation project encompassed an area of 4,500 ha in 2010; it was to be extended to 6,500 ha, benefitting around 2,000 households. In 2012, around 600 ha were planted with rice and doubled the following year. It relies on semi-natural flood irrigation that does not affect Nile volumes as it uses water that would otherwise evaporate.
- **Mangalla sugar and agro-industrial project**: This was an experimental station in Central Equatoria established in the 1950s to grow sugarcane. After 1956, however, production shifted to the north of Sudan, where much less favorable conditions prevailed, requiring heavy irrigation.
- **Wau fruit and vegetable canning factory**: The irrigation pump here had the capacity to water only one feddan (0.42 ha).
- **Penykou rice pilot project**: This was in Jonglei, where around 125 ha of rice were planted in 1980–1981 under irrigation, yielding a maximum of 4.5 tons/ha.
- **Upper Talanga tea project**: A planned area of 500 ha was to be under tea cultivation in the 1980s, including 85 ha farmed by smallholders. Phase 1 of this project was completed, with 80 ha of tea and 30 ha of cereals.

Existing irrigation infrastructure and schemes

The current area equipped for full control irrigation is only 32,100 ha:

- About 12,700 ha are in Upper Nile State, which includes the Renk scheme of about 2,000 ha in Gaiger, Magara, and Abu Khadra, where cotton, sunflowers, and other crops are irrigated.
- 300 ha are in Jonglei State and 500 ha in Western Equatoria State.
- The remaining 18,600 ha are small parcels of land across the country, mostly individual farmers in isolated locations with simple water-lifting techniques from rivers to support perennial fruit and vegetable production.

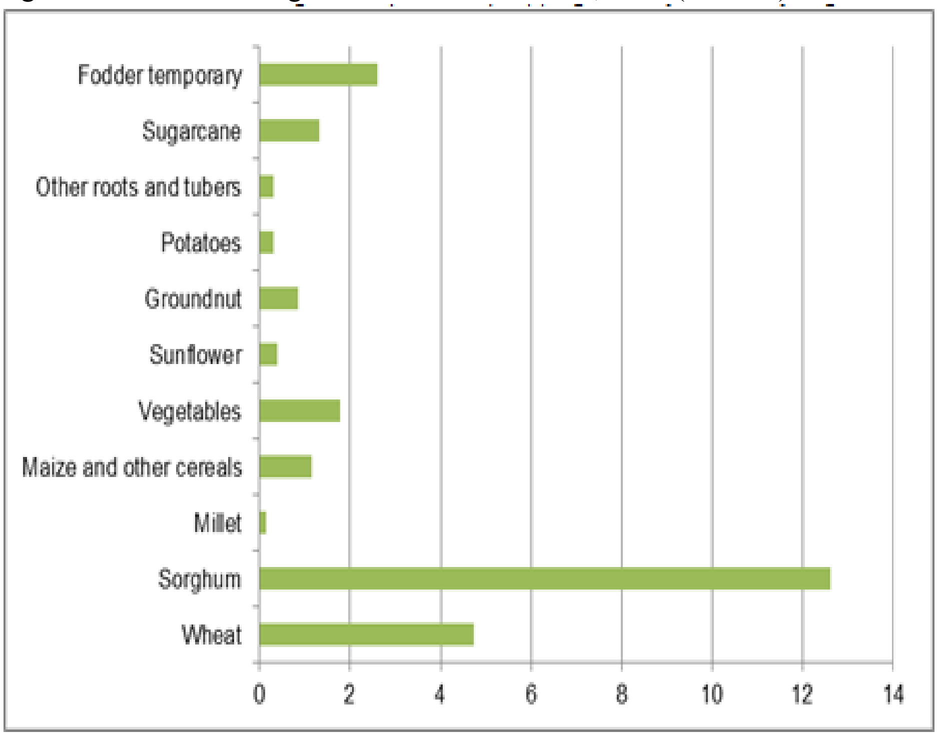
These 32,100 ha accounts for 84 percent of the total irrigated area. The remaining 16 percent (6,000 ha) is made up of spate irrigation that is confined primarily to Northern Bahr el Ghazal (Aweil) and used for rice production. Modern irrigation techniques involving improved flood control measures or pumping water into gravity schemes were introduced in the 1970s in the above-listed pilot projects to gradually substitute for traditional flood irrigation.

In the floodplain areas of the country, small vegetable gardens are also irrigated using traditional methods with water from hand pumps, storage ponds, or lakeside moisture (with the help of drains. In the wet season, floodwaters are diverted into rice fields, and sugarcane and banana are grown on dikes that protect fishing camps and lowland settlements. During the dry season, vegetables and tobacco are grown along the river and are irrigated through manual and small pump-driven lift irrigation sets, and maize and cowpeas are grown using receding floodwater. Irrigation has therefore played a critical role in traditional farming systems; it has been a means to secure food supplies, especially in drought-prone areas.

The main irrigated crops include sorghum, wheat, fodder, vegetables, and sugarcane (Figure 16). Two harvests are possible each year in the bimodal rainfall area of Western and Central

Equatoria, where the growing season is long. Further north, only one harvest is generally practiced in the unimodal rainfall areas, though two harvests are possible in areas where water is readily available for irrigation.

Figure 16: Harvested irrigated area in South Sudan, 2011 (1000 ha)



Source: GoSS (2015)

Existing irrigation activities in South Sudan may be divided into government-supported medium- and large-scale developments and small-scale individual farmer initiatives. There are two government-supported irrigation schemes are the Northern Upper Nile Irrigation Schemes (NUNIS) and the Aweil Irrigation Rice Scheme (AIRS) (MEDIWR 2015)—see Table 11 for details.

The Northern Upper Nile Irrigation Schemes (NUNIS) was initiated in the 1940s as part of the White Nile Pump Schemes. They are relatively huge and complex, and consist of 23 schemes which can be categorized as:

- Nine private-government schemes ranging from 100 to 1,000 ha each, accounting for over 50 percent of the total irrigated area in the schemes. The Ministry of Electricity, Dams, Irrigation and Water Resources (MEDIWR) supplies irrigation water up to the major canal from where private operators/owners convey and distribute the water to their tenant farmers who cultivate 2.1 ha.
- Fourteen public schemes, which make up the other almost 50 percent of irrigable area in NUNIS.

Under the private-government schemes, the private owners operate under 15-year leases that are issued by the State Ministry of Agriculture. In turn, these private owners place tenant farmers on their land under a sharecropping arrangement. In public schemes, the government, through the

Ministry of Agriculture, Forestry, Cooperatives and Rural Development (MAFCRD), has a similar sharecropping agreement with its small-scale tenants.

For both categories of irrigation scheme, the government is responsible for the cost of operating and maintaining the pumps as well as major irrigation infrastructure. The private owner and the government are responsible for providing production services and inputs to their respective tenants, including land preparation, irrigation water, seed, fertilizers and crop protection, and marketing. Later, the private owner and the government reimburse themselves from joint accounts that they maintain with individual tenants. The Aweil Irrigation Rice Scheme (AIRS) is the oldest irrigation development in South Sudan. Started in 1945 as a prison farm of 1.6 ha, it has since expanded to a gross area of 9,240 ha. The infrastructure of the scheme was destroyed and abandoned during the civil unrest but was partially rehabilitated through €5 million of funding from the International Service (IS) of the German development agency GIZ between 2008 and 2012. In October 2012, GIZ IS formally handed over the scheme to MAFCRD, together with 300 large- and small-scale tenant farmers and 92 staff members.

Table 11: Main features of Northern Upper Nile Irrigation Schemes, South Sudan

Location	Source of water	Water lift technology	Gross area (ha)	Net irrigable area (ha)
Upper Nile State (Renk Manyo, and Malut counties)	White Nile through controlled intake into a wide channel/reservoir parallel to command area	20 lift pumps located at intervals on right and left banks of the wide channel/reservoir	654,700	196,410
Northern Bahr el Ghazal State (Aweil West and Aweil Centre counties)	Lol River (until recently water was channeled through uncontrolled entry points into fields; more recently some control gates have been installed)	Seasonal floods between June and October	9,240	4,620

Source: Authors' based on GoSS (2015).

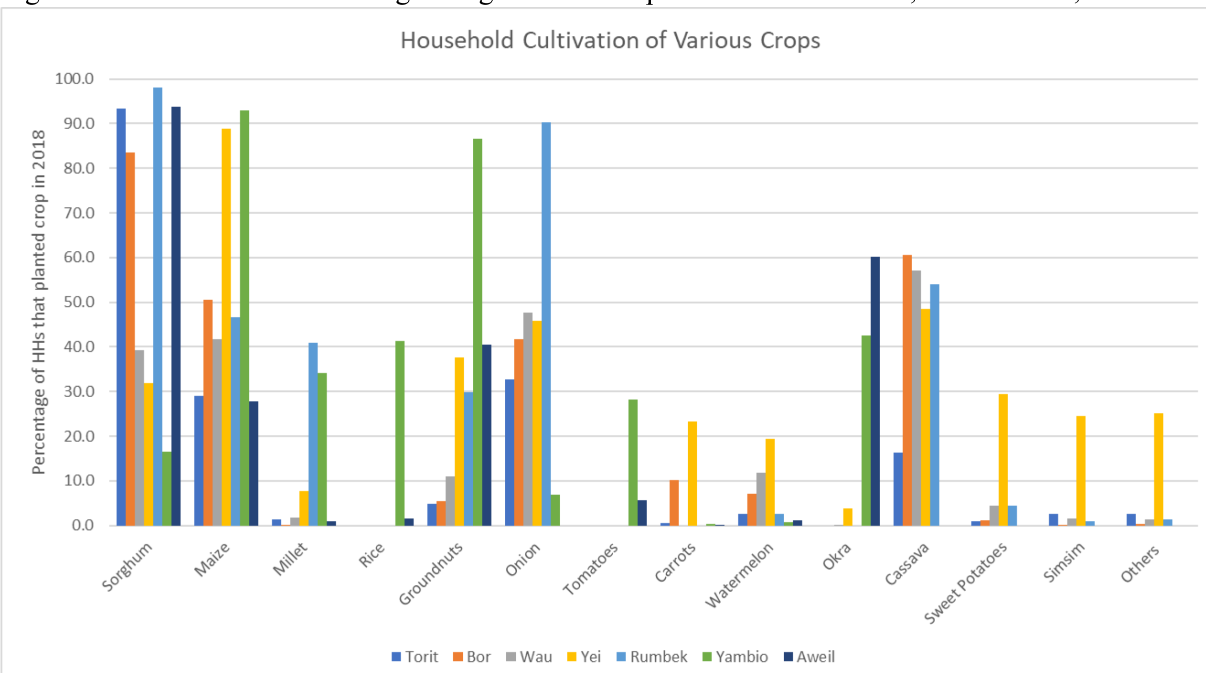
Government efforts to develop irrigation systems

The Ministry of Water Resources and Irrigation (MWRI) and the Ministry of Agriculture, Forestry, Cooperatives, and Rural Development (MAFCRD) signed a joint memorandum of understanding (MOU) with the Japanese International Cooperation Agency (JICA) and launched a two-year process leading to the irrigation development master plan (GoSS, 2015). The expected outputs of the IDMP are: water resources assessment; formulation of a strategic framework for irrigated agriculture; zoning for irrigation development; identification of appropriate zone-specific irrigation models and proposed organization management structures for irrigation schemes; assessment and planning for the required human resources; and formulation of implementation plans for priority projects.

Practices, opinions, and perceptions on farming and value chains

The SAFER and PfRR survey responses show that households focus on carbohydrate-dense grains as the most important crops (Figure 17). While households in most of the households in the counties surveyed relied on sorghum as the priority crop, maize was prioritized in a few counties only, including Yambio. Households in Wau indicated more diversity, growing vegetables and groundnuts as well as sorghum and maize. In all the counties however, many households cultivated additional crops, particularly groundnuts, onions, and cassava, with certain counties indicating a higher household production of rice, tomatoes, carrots, watermelons, okra, sweet potatoes, and sesame.

Figure 17: Percent of households growing different crops in selected counties, South Sudan, 2018



Source: Authors' calculation based on MESP (2018).

Focus group discussions also highlighted the role of agriculture with respect to food security, cultural identity, peace, and dignity. As an acting paramount chief in Aweil said, "Farming to me is the only way for community resilience." Male farmers in Aweil echoed this sentiment, saying that "If peace comes, everyone will go to the farm—farming is everything in the country." Many respondents reported relying on farming for food security, both communally ("The only way now is to focus on agriculture, because it is the only thing that people can depend on.") and at the household level ("Right now, the only way that I am surviving is through agriculture. I have survived with kids because I work on people's farms."). Others expressed a sense of vulnerability in their survival as agriculturalists ("The way of life has changed because most of the people now don't have their own style of food security, but they depend on the food given by the international agencies or by local NGOs.").

Many respondents involved in agriculture expressed a sense of collective strength, reporting information sharing, coordination with external support ("NGOs say 'stay in cooperatives so we can help'."), and collective cultivation that was being coordinated by cooperatives, CBOs, or congregations. They highlighted the role of food security in strengthening reintegration into host communities. Some respondents mentioned the risk of losing agronomic knowledge: they referred to more diverse cropping by previous generations and spoke of the need to maintain agronomic education and training centers for vegetable growing, fishponds, and beekeeping.

Several value chain opportunities exist in the targeted areas. From the key informant interviews, the main one is groundnut and sesame processing into paste, followed by fish, honey, flour, dairy, meat, cassava chips, and vegetables (Table 12). However, there are differences across counties. Groundnuts and sesame paste are the only ones perceived to have a moderate-to-high potential in all the targeted counties. Cassava chips, fish and flour come next except in Duk. With respect to dairy, it has no potential in Torit and Wau. Similarly, honey processing has no potential in Bor and Torit.

Table 12: Value chain potential in selected counties of South Sudan, % of key informants responding

Counties	Groundnut and sesame paste	Cassava chips	Fodder production	Vegetables processing/ drying	Fish processing/ drying	Meat processing	Dairy processing	Honey processing	Hides and skins processing	Flour milling
Aweil Centre	54.5	18.2	9.1	54.5	45.5	36.4	36.4	36.4	27.3	36.4
Awerial	100.0	50.0	0.0	100.0	100.0	100.0	50.0	50.0	50.0	100.0
Bor	100.0	33.3	11.1	88.9	100.0	44.4	88.9	0.0	0.0	66.7
Duk	50.0	0.0	0.0	0.0	0.0	50.0	50.0	50.0	50.0	0.0
Rumbek centre	100.0	33.3	0.0	100.0	66.7	66.7	100.0	66.7	0.0	100.0
Torit	100.0	75.0	0.0	25.0	50.0	0.0	0.0	0.0	0.0	25.0
Twic East	62.5	25.0	62.5	50.0	87.5	87.5	75.0	75.0	75.0	50.0
Wau	100.0	66.7	0.0	0.0	33.3	0.0	0.0	66.7	16.7	33.3
Wulu	100.0	66.7	0.0	100.0	33.3	66.7	66.7	100.0	0.0	66.7
Yambio	100.0	100.0	0.0	33.3	66.7	33.3	33.3	100.0	0.0	66.7
Yirol East	100.0	100.0	0.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Authors' calculations based on key informant surveys.

Simulated climate change on crop production

Projected changes in rainfall and temperatures at 2050, compared to the baseline climate of 1960-1990, were used to simulate yields in sorghum, maize, groundnuts, and cassava under rainfed conditions (Figure 18).[8] For sorghum, much of the northern half of the country is projected to experience yield losses of more than 20 percent between the baseline (1960-1990) and 2050, whereas the rest of the country is projected to have yield losses of 10 to 20 percent.

For maize, a smaller yield reduction is obtained. While some areas of the country still have projected yield losses of over 20 percent, most locations are projected to have losses of 10 to 20 percent, and about one-quarter of the areas in the country where maize is grown have projected losses of between 5 and 10 percent.

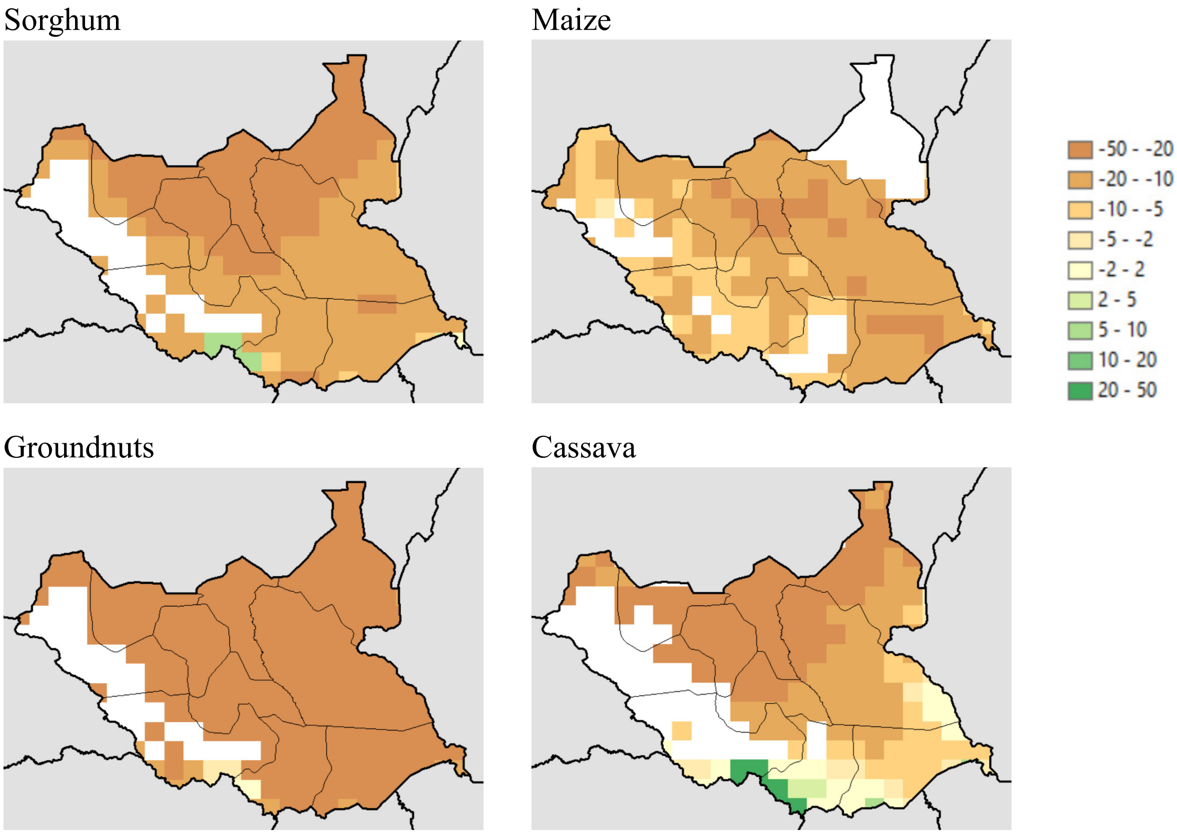
Groundnuts are projected to have large yield losses from climate change, with almost the entire country projected to have losses exceeding 20 percent, including some areas with losses of over 30 percent. Cassava, on the other hand, is much more geographically nuanced. Areas in the north

[8] See Annexes 4 and 5 for results of the climate (rainfall and temperature) projections to 2060.

are projected to have losses of over 20 percent. A small area along the border with the Democratic Republic of Congo is projected to have yield gains of more than 20 percent, and much of the south and southeast are projected to have up to a 10 percent loss.

These projections suggest several things about the climate impact on yields. First, the relationship between temperature and yields are generally inverse-U-shaped, but the optimal temperature varies by crop and by time during the growing season. For example, maize yields decline above 29 or 30 degrees in the silking phase. Secondly, crops generally prefer water up to a point, after which yields will not increase and will sometimes decrease. Furthermore, each crop's ability to go without water during certain periods of time differs. Drought-resistant crops and crop varieties have lower yield losses in dry weather than ones not drought-resistant.

Figure 18: Projected yield changes due to climate change for selected crops, South Sudan (% between 1960-1990 and 2050)



Source: Rosenzweig et al. (2014).
Note: Changes represent the median value at each pixel.

The projected yield changes for the selected counties are shown in Table 13. For sorghum, groundnuts and cassava, Yambio and Torit appear to be least adversely impacted; for maize, it is Yambio and Wau.

FSN typology of value chain interventions

Based on the efficiency classification and underlying constraints presented earlier, counties are identified as low, medium, and high priority areas for intervention depending on the level of nutritional status observed. The results are shown in Figure 19, with specific recommendations for each county in Table 14.

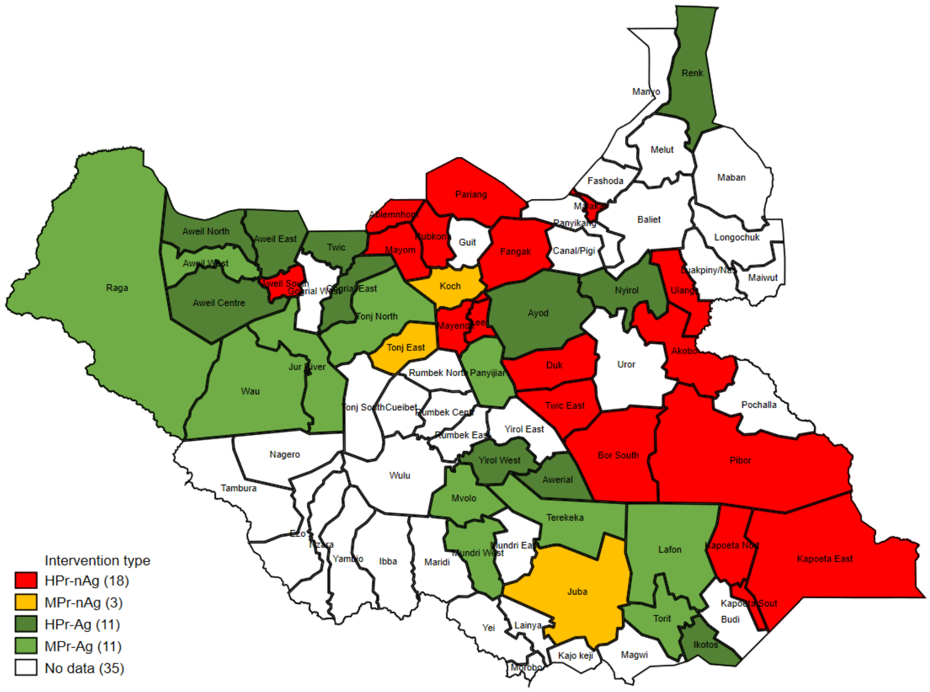
With respect to the prioritizing the different counties for intervention, we identified 29 high-priority counties, of which 18 are of low agricultural potential and 11 are of high agricultural potential. The counties with more agricultural potential are mostly found west of the diagonal that crosses the country from Twic in the north to Ikotos in the south, whereas those with less agricultural potential are mostly located to the east of the same diagonal. Exceptions to this overall trend are the high-priority counties of Ayod, Nyirol, Renk (with high agricultural potential) and Aweil South (with low agricultural potential).

Table 13: Projected yield changes due to climate change for selected crops and counties, South Sudan (% between 1960-1990 and 2050), year

County	Agricultural potential	Cities and towns with population of:			
		Sorghum	Maize	Groundnuts	Cassava
Aweil Centre	Moderate	-21	-13	-29	-23
Aweil North	Low-moderate	-22	-13	-30	-22
Awerial	Low-moderate	-17	-15	-27	-17
Bor South	Low-moderate	-17	-14	-28	-16
Duk	Low-moderate	-23	-18	-30	-22
Rumbek Centre	Moderate	-21	-18	-30	-22
Torit	Moderate-high	-12	-13	-22	-1
Twic East	Low-moderate	-19	-17	-29	-19
Wau	Moderate-high	-19	-9	-28	-24
Wulu	Moderate	-17	-12	-27	-18
Yambio	High	-12	-9	-19	-1
Yirol East	Moderate	-21	-12	-29	-20
Yirol West	Moderate	-19	-14	-28	-19

Source: Authors' calculation based on Rosenzweig et al. (2014).
Note: Yield change is average of pixel data on the counties. Agricultural potential is based on the rainfall-temperature measure.

Figure 19: Food security and nutrition intervention type by county, South Sudan (2014–2017)



Source: Authors' illustration based on results from the spatial typology of food security and nutrition.
Notes: LPr, MPr, HPr = low-, medium-, and high-priority intervention, respectively. Ag = high agricultural potential, and nAg = low agricultural potential. Agricultural potential is based on the area-kilocalorie conversion measure.

Although most of the thirteen target counties share the same urgency in terms of child wasting (with levels above the emergency threshold of 15 percent) and therefore are identified as high priority for intervention, the optimal intervention mix will depend on several factors, including the location of the county (in terms of agricultural potential and market access for example) and the most constraining segments of the production-to-nutrition pathway. Taking xx and xx of the selected counties from Table 14 as an example, …

Table 14: Interventions at relevant segments of the production-to-nutrition chain in different counties, South Sudan

County	Agricultural potential	Priority for intervention	Intervention area
Selected			
Aweil Centre	High	High	Build resilience to food safety system; promote processing of groundnuts, sesame, vegetables, and fish
Aweil North	High	High	Diversify household income sources, build strategic food stocks, intensify irrigation
Awerial	High	High	Create employment, improve transport infrastructure, reduce red tape, intensify irrigation; promote food processing
Bor South	Low	High	Intensify irrigation; promote processing of groundnuts, sesame, vegetables, fish, dairy and flour
Duk	Low	High	Improve access to land, credit systems, inputs markets, and extension services; Improve cooking habits, food safety, and quality of health care services.
Rumbek Centre	High	n.a.	Create employment, improve transport infrastructure, reduce red tape, intensify irrigation; promote food processing
Torit	High	Medium	Create employment, improve transport infrastructure, reduce red tape, intensify irrigation; promote processing of groundnuts, sesame, and cassava
Twic East	Low	High	Diversify household income sources, build strategic food stocks; promote food processing
Wau	High	Medium	Diversify household income sources, build strategic food stocks, intensify irrigation; promote processing of groundnuts, sesame, cassava, and honey
Wulu	High	n.a.	Create employment, improve transport infrastructure, reduce red tape, intensify irrigation; promote food processing
Yambio	High	n.a.	Create employment, improve transport infrastructure, reduce red tape; promote food processing
Yirol East	n.a.	n.a.	Create employment, improve transport infrastructure, reduce red tape, intensify irrigation; promote food processing
Yirol West	High	High	Create employment, improve transport infrastructure, reduce red tape, intensify irrigation
Other			
Akobo	Low	High	Build resilience to food safety system.
Baliet	n.a.	n.a.	Improve access to land, credit systems, inputs markets, and extension services.
Budi	n.a.	n.a.	Diversify household income sources, build strategic food stocks
Canal/Pigi	n.a.	n.a.	Improve access to land, credit systems, inputs markets, and extension services. Create employment, improve transport infrastructure, reduce red tape
Jur River	High	Medium	Diversify household income sources, build strategic food stocks
Kapoeta North	Low	High	Improve cooking habits, food safety, and quality of health care services.
Leer	Low	High	Build strategic reserves of agricultural inputs, stimulate community resilience in credit and extension services
Luakpiny/Nasir	n.a.	n.a.	Diversify household income sources, build strategic food stocks
Magwi	n.a.	n.a.	Create employment, improve transport infrastructure, reduce red tape
Mayendit	Low	High	Diversify household income sources, build strategic food stocks
Mayom	Low	High	Build resilience to food safety system.

County	Agricultural potential	Priority for intervention	Intervention area
Nyirol	High	High	Improve access to land, credit systems, inputs markets, and extension services; Build resilience to food safety system.
Nzara	n.a.	n.a.	Create employment, improve transport infrastructure, reduce red tape
Panyijiar	High	Medium	Improve access to land, credit systems, inputs markets, and extension services.
Rubkona	Low	High	Improve cooking habits, food safety, and quality of health care services.
Rumbek East	n.a.	n.a.	Create employment, improve transport infrastructure, reduce red tape
Tambura	n.a.	n.a.	Create employment, improve transport infrastructure, reduce red tape

Source: Authors' based on results from the spatial typology of food security and nutrition.
Motes: Agricultural potential is based on the area-kilocalorie conversion measure. N.a. = not applicable due to lack of data.

4.4. Household and local level determinants of resilience

As presented 2 and 3, resilience building in South Sudan is confronted with a complex mix of social, environmental, political, governance, and economic factors. Therefore, it should be approached through integrated actions that collectively address the complex set of shocks, stressors and challenges households and local communities face. As a result, the PfRR (2019) adopted an integrated framework comprising four pillars: i) re-establish access to basic services, ii) rebuild trust in people and institutions, iii) restore productive capacities, and iv) nurture effective partnerships. This helps ensure the resilience framework is a common framework that provides an inclusive goal and platform among all development partners with different agendas (growth and productivity, access to social services, vulnerability, institutional change, and capacity building, among others).

In this section, other factors affecting resilience of individuals, households, and communities in South Sudan are presented. The results are based on analysis of household and community surveys data on opinions and perceptions on demographics, nonfarm job opportunities and livelihoods, conflicts and their causes, and institutions for resolving conflict and promoting community coherence.

Demographics

Average size of the families surveyed is between 5 and 7. Those residing in Bor and Rumbek counties are ethnically homogenous, while those in Wau and Yei are ethnically heterogeneous. The others, Torit, Yambio, and Aweil contain small populations of ethnic minorities.[9] Most households identify as Christian of different denominations, but predominantly Catholic or Anglican. Children (under 10 years old) and boys and girls (ages 10-19 years) dominate the age grouping of the household, followed by young adults and men and women in their twenties and thirties, respectively. In all counties except Bor, adult women (ages 20-39) predominate their

[9] See Annex 8 for charts on demographics (ethnicity, religion, and household size) in the surveyed counties.

male counterparts. This is due to adult men being more likely to migrate or become involved in "bush" groups or conflict. Gender is more balanced in the younger group (up to 19 years of age) and older generations (age 40 and older), the balance of men and women within households is more balanced, suggesting that the gender imbalance onset occurs as boys become adolescents or young men and return as they become older.

Nonfarm opportunities and livelihoods

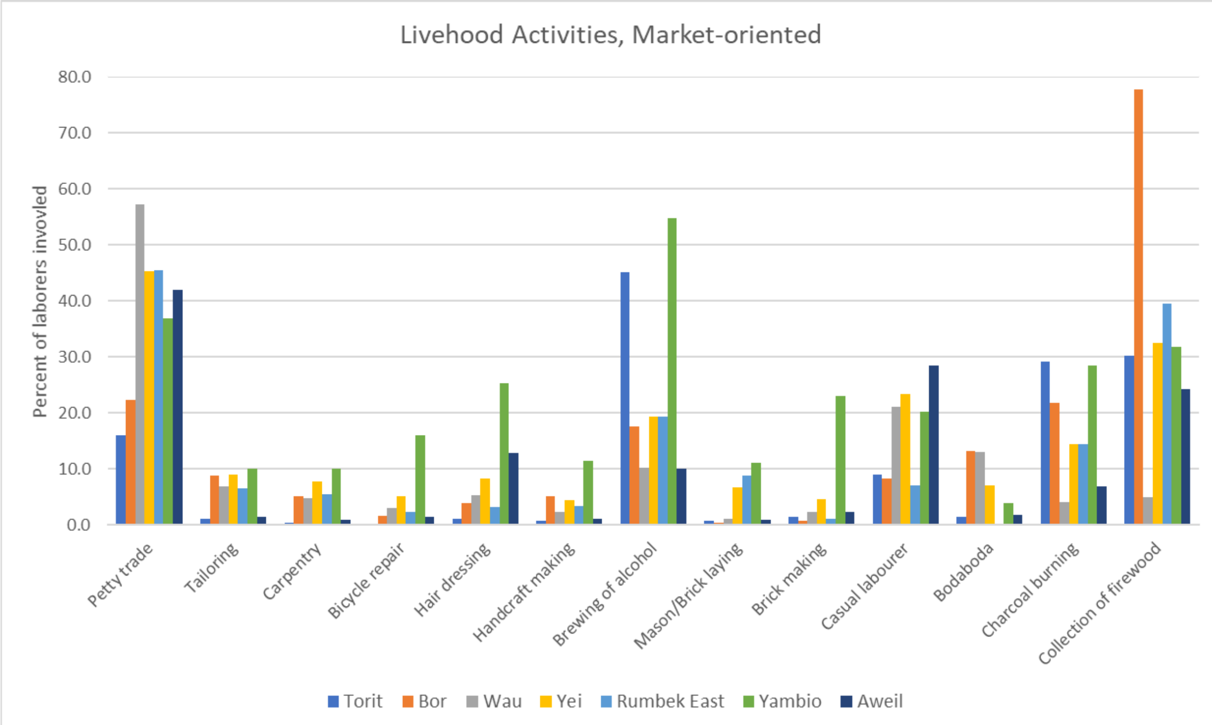
Households engaged in many market-oriented nonfarm activities. In general, petty trading, fuel (charcoal and firewood), alcohol brewing, and casual labor dominate the activities, which are differentiated by county (Figure 20). There are gender differences too. For example, women dominated work in food and dairy processing, baking, retail, and clothing, whereas men dominated work in construction, mechanics, and carpentry. Insecurity and lack of employment opportunities and capital were cited as the primary obstacles to livelihoods in the nonfarm sector across gender, but other obstacles cited were differentiated by gender and age (Figure 21). In general, youth opinions on the obstacles were more homogenous across the seven surveyed counties, compared to those by adults. Across the counties, female youth more consistently cited insecurity as the main obstacle. Women complained of gender discrimination more than men, while boys complained of gender discrimination more than girls, for example.

Nonfarm livelihoods are influenced by availability of natural resources and jobs offered by nonagricultural projects run by NGOs. With respect to available natural resources, Aweil centre, Duk, Twic East and Wau appear the least endowed (Table 15). Across all the counties, water and land are the most prevalent natural resources. Majority of key informants highlighted livestock and fisheries in Awerial, Bor, Yambio and Yirol. Less than 50 percent of key informants reported available natural resources, except in Duk and Wau. Potential for rivers transportation is reported as viable option by most respondents except in Aweil north, Torit and Wulu. With respect to nonagricultural projects, except for those with a focus on improving democracy (in Awerial, Duk, Wulu and Yirol East) and conflict mitigation (in Torit), most respondents indicated the presence of non-agricultural projects in the targeted counties (Table 16). It is worth noting that less than 50 percent of informants are aware of humanitarian activities in Aweil north, Rumbek central, Torit, and Yirol.

Figure 22 shows that communities face pervasive social risks and threats of violence, both domestically and outside the home.[10] The percentage of households affected by social risks is highest in the counties of Torit, Bor, Yei and Yambio. Reported risks were much lower in Rumbek East and Aweil. Of the risks deriving from outside of the home, burglaries/robberies (including livestock raids in three counties) was identified as the most common. Of the risks deriving from within the household, those associated with alcohol abuse, domestic violence, child abuse, and teen pregnancy are common, with particularly deleterious effects on women and children.

[10] See annex 9 for more on the risks in the surveyed counties.

Figure 20: Market-oriented nonfarm activities in selected counties of South Sudan, 2018



Source: Authors' calculation based on MESP (2018).

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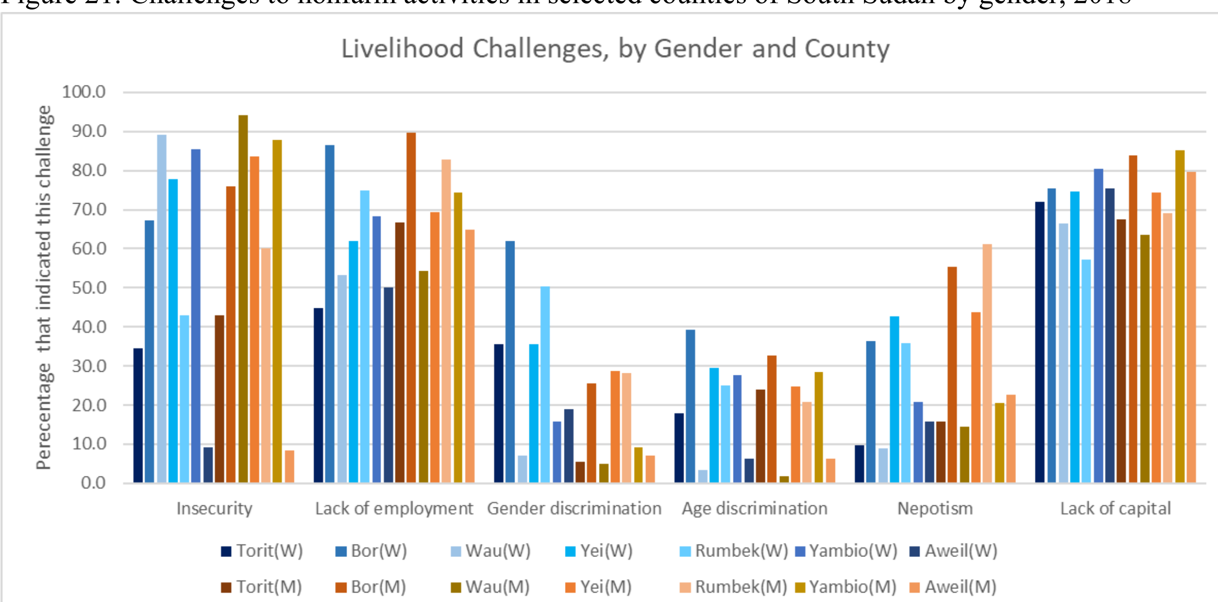
Figure 21: Challenges to nonfarm activities in selected counties of South Sudan by gender, 2018



Source: Authors' calculation based on MESP (2018).

Table 15: Availability of natural resources in selected counties of South Sudan, 2020 (% of key informants responding)

County	Land	Water	Oil and Gas	Forests	Fisheries	Rivers
Aweil North	45.5	9.1	0.0	18.2	18.2	18.2
Aweil centre	75.6	52.3	0.0	47.7	44.6	27.6
Awerial	66.7	100.0	0.0	66.7	83.3	83.3
Bor	89.3	76.6	7.1	76.6	89.3	74.6
Duk	50.0	50.0	50.0	50.0	50.0	50.0
Rumbek central	100.0	100.0	0.0	100.0	26.7	33.3
Rumbek East	100.0	100.0	25.0	75.0	75.0	50.0
Torit	92.9	78.6	0.0	25.0	0.0	0.0
Twic East	87.5	87.5	25.0	87.5	87.5	87.5
Wau	100.0	91.7	54.2	54.2	54.2	45.8
Wulu	100.0	83.3	25.0	91.7	41.7	25.0
Yambio	100.0	75.0	0.0	87.5	75.0	41.7
Yirol	100.0	87.5	0.0	87.5	75.0	75.0

Source: Authors' calculation based on key informant interviews.

Table 16: Availability of non-agricultural projects in selected counties of South Sudan, 2020 (% of key informants responding)

Counties	Health	Education	Humanitarian	Democracy	Conflict mitigation
Aweil North	45.5	36.4	9.1	18.2	36.4
Aweil centre	56.3	87.5	78.1	6.3	62.5
Awerial	100.0	77.8	72.2	22.2	66.7
Bor	64.3	60.7	57.1	14.3	64.3
Duk	50.0	50.0	50.0	0.0	50.0
Rumbek central	50.0	50.0	20.0	10.0	40.0
Rumbek East	75.0	50.0	75.0	0.0	100.0
Torit	72.3	65.2	43.8	25.0	43.8
Twic East	87.5	87.5	87.5	50.0	87.5
Wau	68.8	81.3	83.3	6.3	81.3
Wulu	100.0	83.3	66.7	58.3	100.0
Yambio	75.0	100.0	87.5	12.5	62.5
Yirol	37.5	25.0	25.0	0.0	50.0

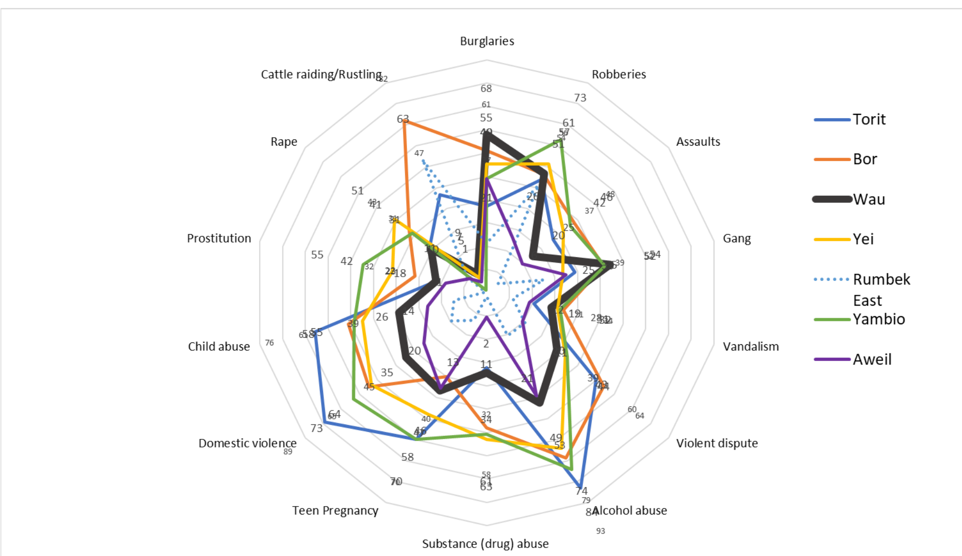
Source: Authors' calculation based on key informant interviews.

In five of the seven counties, at least 30 percent of the households there indicated rape was a prevalent social risk. Opinions and perceptions on the causes of local conflict was asked. Tribal affiliation, firearms availability, lack of rule of law, and revenge were the primary ones cited (Figure 23). Some of the respondents identified conflicts as being ethnically based, especially in Torit (12% of the respondents), Rumbek (18%), Yei (19%), and Bor (25%). Conflicts over natural resources, especially forestry and water, were also cited. Respondents in Aweil, Yambio, Bor, and Yei also blamed conflicts on oil disputes, whereas fishing was identified as a major source of conflict in Rumbek and Bor.

Conflict, resolution, and role of and trust in institutions

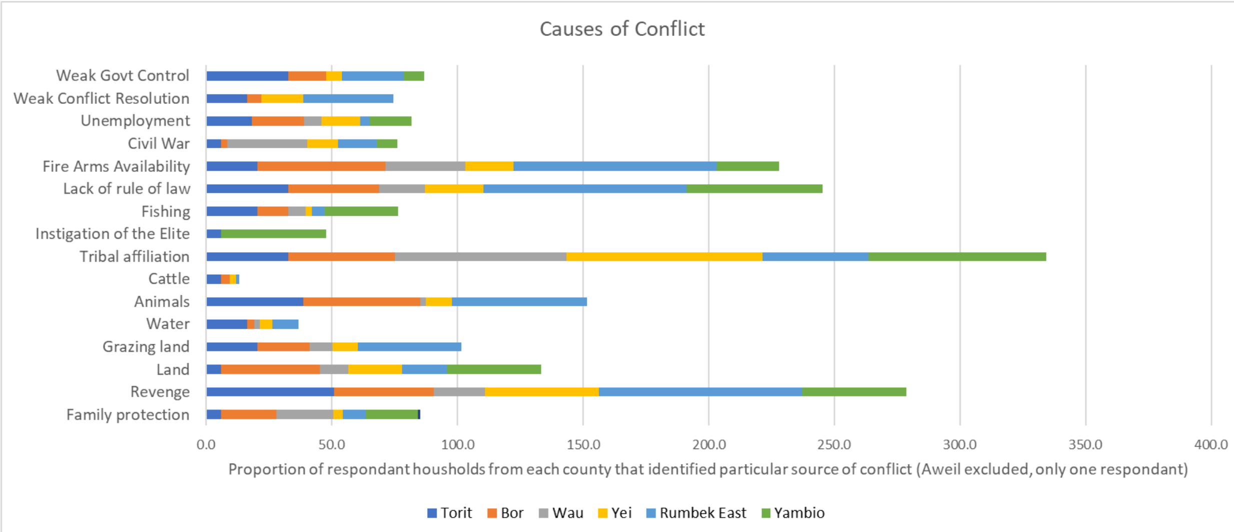
From focus group interviews, further insights were obtained on the nature of the conflicts, especially those related to domestic and gender-based violence, resource-based conflicts, tribalism, and firearms availability. One peace committee key informant indicated that "after the LRA, those boys didn't know what to do with their guns." Tribal communities are recruited by "beating the drum" after conflict events or theft, such that revenge spreads from singular victimized households to entire communities. Many comments were directed at political manipulation, particularly of youth as a lynchpin of sustaining violence. Using confusion and propaganda, "politicians made the arrow boys" and incited regional conflict to become tribal. "Conflicts are 'sold' to us," stated a local leader in Yambio. Political groups who feel they've been unfairly treated retreat to the bush and incite violence and chaos. Respondents noted resource conflicts over timber, oil ("fighting at oil locations") and suspicion about external oil interest and other countries using South Sudan. Comments connected land and water to competition from migrating livestock, which may destroy agricultural crops or contaminate drinking water. They stated that the government has banned grazing in select areas due to conflict violence. Land resource conflicts arise between tribes, sometimes leading to cycles of conflict/revenge, but also due to the land policy and community confusion about what it means to own land. Cattle conflicts relate to communal natural resources but also theft, especially cattle-raiding for cows to enable marriages.

Figure 22: Percent of population affected by risks in selected counties of South Sudan, 2018



Source: Authors' illustration based on MESP (2018).
Notes:

Figure 23: Causes of conflict in South Sudan, 2018 (% of respondents in selected counties)



Source: Authors' illustration based on MESP (2018).

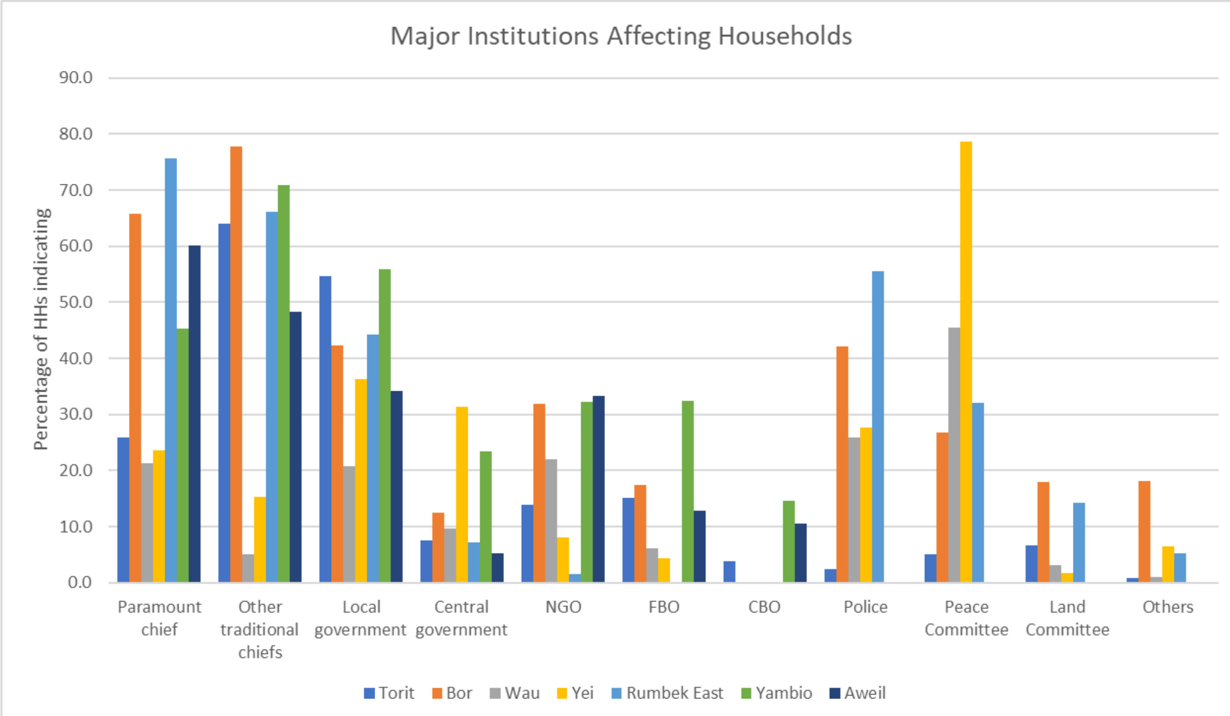
Conflict and violence profoundly affect domestic life in South Sudan. Women and children face tremendous domestic threats, such as violence, abandonment by husband/father, or girls forced into marriage for financial reasons. One male focus group identified conflict caused due to women as the "source of bride wealth." Beyond the economic and social strain, women may face trauma due to loss of their children or spouse from violence, or from political violence—even from children. As one woman stated, "your own child will rape you." Many women generally feared retribution for themselves and their communities from reporting rape. Commentary expressed that young people are "too traumatized" because of constant death.

Leadership and predominant Institutions in community development

Institutions and local leadership impact households and communities in many ways, which are heterogeneous across the surveyed counties. Traditional leaders (paramount and other traditional chiefs) play the largest leadership role in most of the counties, except in Wau and Yei where they play a smaller role (Figure 24). This followed by local government, police, and peace committees, especially in Tori, Wau, Yei and Rumbek where their roles are strong. NGOs and FBOs play a modest role in some of the counties. The functions of traditional leaders are several, with the dominant ones being settling of disputes and providing law and order (Figure 25).

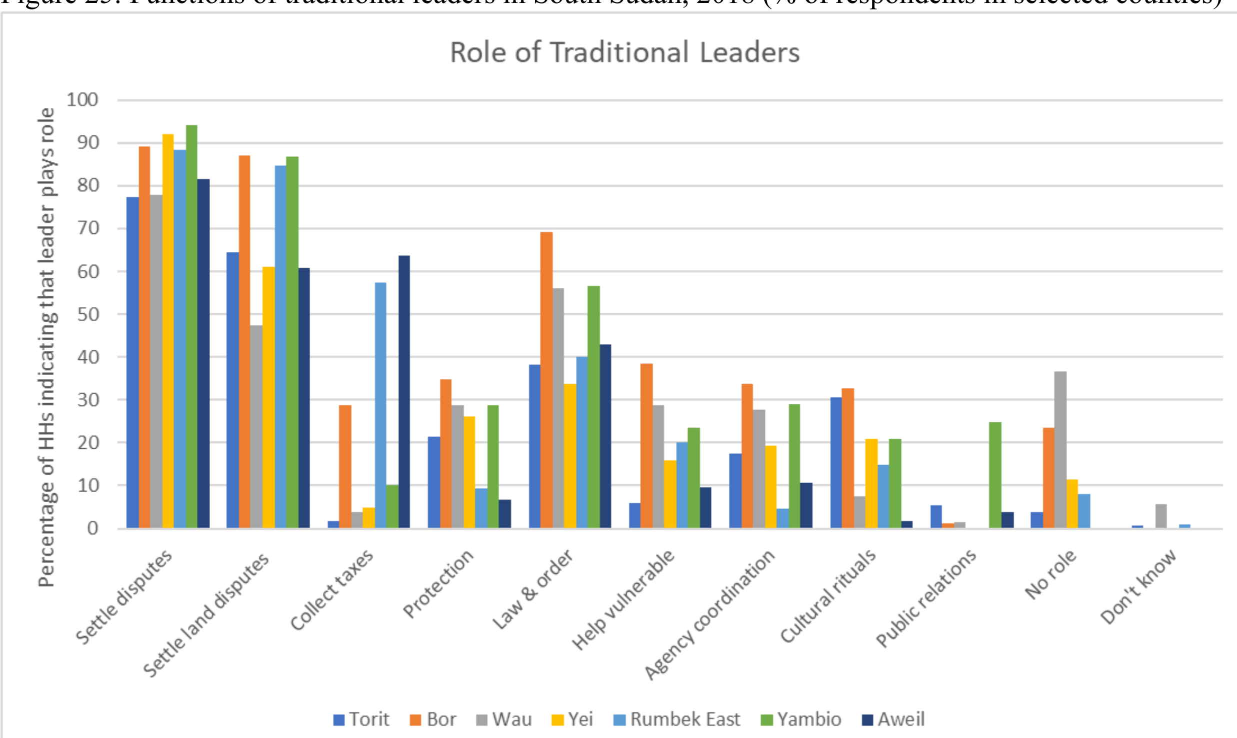
In general, respondents were critical of political leadership, but did not criticize traditional leaders, nor NGOs, FBOs, churches, or peace committees. Peace committees were identified as the most positive government action, although there was extreme lack of trust in political leadership. This distrust seems tied to the belief that politicians have demonstrated greed, lack of transparency and accountability, especially related to finances and natural resources. Comments indicated that politicians cling to power, appoint offices based on favoritism instead of qualification or education, and use money to buy weapons and protect themselves at the cost of others: "eat and get rid of others."

Figure 24: Institutions affecting households in South Sudan, 2018 (% of respondents in selected counties)



Source: Authors' calculation based on MESP (2018).

Figure 25: Functions of traditional leaders in South Sudan, 2018 (% of respondents in selected counties)

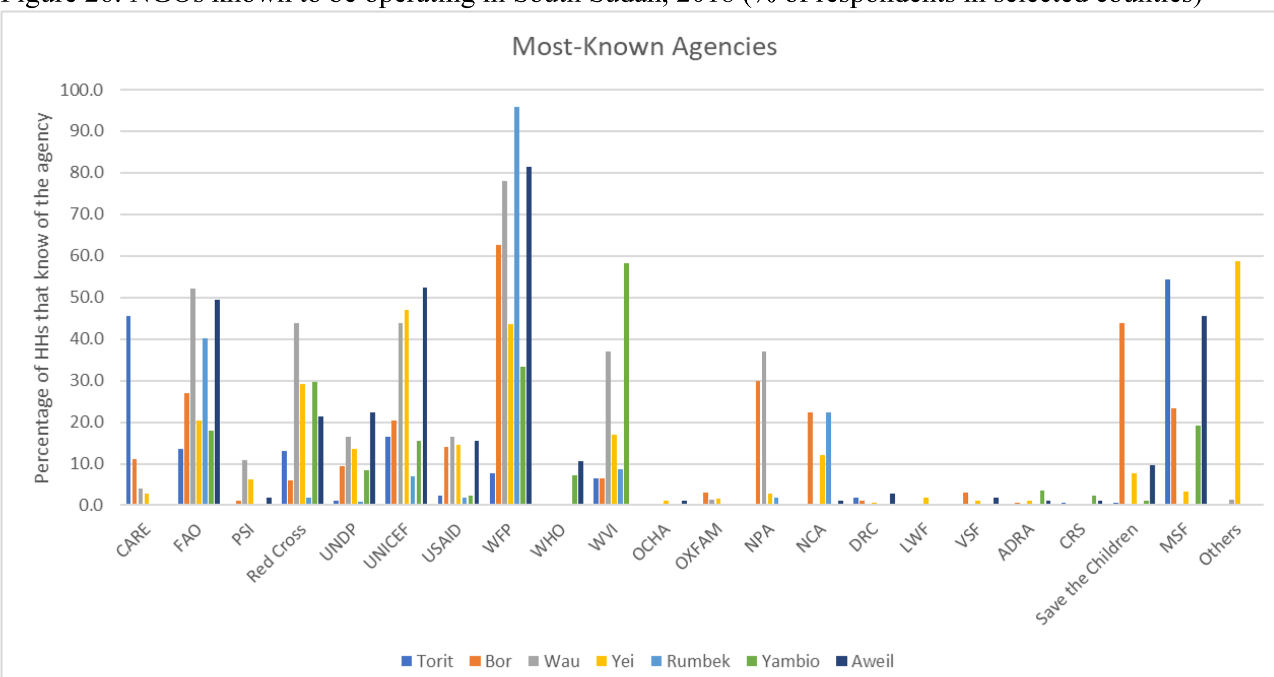


Source: Authors' calculation based on MESP (2018).

Some communities felt that disparate levels of education create conflict, since the educated become the elite and thus can manipulate others. Remarks also expressed anger over government silence about atrocities, lack of support for victims, government threatening civilians, the absence of law, order and constitution, and limited contact with communities—highlighting the difference between towns and "grassroots, where they apply traditional Laws of Wanth-Alel." However, peace committees in Yambio applauded the three-month holiday in which leaders could visit their communities and find out their needs, thus building trust. Others noted the lack of dissemination of peace: "the grassroots couldn't get any news about the peace and knew nothing about it.

With respect to NGOs or humanitarian and development agencies that were known to be operating in South Sudan, WFP seem to be the most widely known, followed by UNICEF, FAO, and the Red Cross (Figure 26). Awareness of different agencies is highest in Torit, where 51 percent of households indicated knowing such an agency—in particular *Médecins Sans Frontières (MSF)* and *CARE International*. Households in Wau (13% of respondents) and Yambio (17%) were least aware of any agencies. Moderate awareness of agencies was reported in Aweil (21%), Bor (26%), and Yei (31%). The awareness of WFP was particularly high in Bor, Yambio, Wau, and Aweil.

Figure 26: NGOs known to be operating in South Sudan, 2018 (% of respondents in selected counties)



Source: Authors' calculation based on MESP (2018).

5. CONCLUSIONS AND IMPLICATIONS

This paper analyzed the determinants of long-term individual and community resilience for food and nutrition security in South Sudan using data from multiple sources including key informant interviews, household and community surveys, and georeferenced secondary data on climate, agricultural production, irrigation, and market access. Analysis of stakeholder opinions and perceptions from different survey data is used to describe the major agricultural development constraints, access to services and ownership of productive assets, the incidence of and responses to shocks and conflict, and options for improving agriculture and broader development outcomes. Climate-crop modeling and simulation methods are used to evaluate the constraints and to identify suitable crops to invest in. Then, a spatial typology of food and nutrition security is used to evaluate the constraints along the production-to-nutrition pathway and to identify interventions that target different segments of the chain. These are used to classify counties by level of production, access, and utilization efficiencies, and whether the underlying constraints are structural (i.e., level of efficiency remains the same over time) or stochastic (i.e., level of efficiency changes over time). The analysis is focused on about a dozen selected counties.

The results show that the development challenges are compounded by climate change, with significant increase in the mean annual rainfall and daily maximum temperature for the warmest month. Between 1975 and 2016 for example, the mean annual rainfall in the selected counties increased by 40-111 mm/year, with a rise in the intensity of 0.2-1.3 mm per event. The daily maximum temperature for the warmest month increased by 2.0-3.2°C. If these trends (especially for temperature) continue to 2050, crop yields are projected to decline in the selected counties on average by 12-23% for sorghum, 9-18% for maize, 19-30% for groundnuts, and 16-24% for cassava. In general, there is an inverse-U-shaped the relationship between temperature and yields, although it varies by crop and time of the growing season, among other factors.

Results of spatial typology show that majority (78%) of the selected counties are classified as having medium production efficiency and 22% as low production efficiency, without any as high production efficiency. With respect to access, 55%, 29%, and 17% are classified as low, medium, and high access efficiency, respectively. And for utilization, 37%, 26%, and 37% are classified as low, medium, and high utilization efficiency, respectively. Whereas production efficiency is mostly structural, (76% of the counties), access and utilization efficiency seem balanced (48% structural and 52% stochastic). These suggest that the access segment of the production-to-nutrition value chain is the most constraining, followed by the utilization segment.

Most of the selected counties were demarcated as having similar urgency to reduce child wasting and, therefore, were identified as high priority for intervention. The optimal intervention mix however, depends on several factors such as the location of the county (in terms of for example agricultural potential and market access) and the most constraining segments of the production-to-nutrition chain. Specific interventions to consider at each segment of the chain were provided for the different counties. In the design, implementation, and monitoring and evaluation of any intervention however, it will be important to involve the communities to be impacted (including their traditional leaders and other local institutions) at all stages. Top-down approaches or solely government-management interventions will likely fail because of lack of trust in political leadership as the survey results indicated.

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ANNEXES

Annex 1: Instrument used for key informant survey

Agricultural Assessment of South Sudan

Field Level Checklist: Implementing Partners & Agriculture Extension Workers

Introduction

Management System International (MSI) in partnership with International Food Policy and Research Institute (IFPRI) is commissioned by United State of Agency for International Development (USAID) to conduct an assessment of Agriculture sector of South Sudan. The assessment aims at informing future investment options for the agricultural sector in South Sudan as well as assisting USAID/South Sudan to identify immediate humanitarian and agricultural sector development needs necessary to increase long-term individual and community resilience.

Any information that you provide will be kept strictly confidential and will not be shared with other people. Your voluntary participation in this interview is *NOT IN ANY WAY* linked to your personal or community's chance of receiving food or other assistance. This is voluntary and you can choose not to answer any or all of the questions if you want. However, we hope that you will participate since your views are important to us. Do you have any questions for me?

Do you agree to participate in this interview? Yes [ ] No [ ]

Interviewer/ Enumerator		Telephone		Date:	

Profile

State	
County	
Institution/Organization	
Respondent Name	
Respondents Name	
Respondent's Designation	
Respondent's Phone Number	
Respondent's email	

1. What is the role of your institution in the development of the agricultural sector in South Sudan?

Formulate policies and regulations	[ ]	Extension services	[ ]
Capacity building	[ ]	Advisory services	[ ]
Inputs support	[ ]	Water, Sanitation & Hygiene	[ ]

Research	[ ]	Infrastructure development	[ ]
Funding	[ ]	All the above	[ ]
Guidance and coordination	[ ]	Others (Specify)	
Putting in place Coronavirus (COVID-19) pandemic mitigation measures	[ ]		

2. Which of your support to agricultural development affected by the coronavirus (COVID-19) pandemic.

Formulate policies and regulations	[ ]	Extension services	[ ]
Capacity building	[ ]	Advisory services	[ ]
Inputs support	[ ]	Water, Sanitation & Hygiene	[ ]
Research	[ ]	Infrastructure development	[ ]
Funding	[ ]	All the above	[ ]
Guidance and coordination	[ ]	Others (Specify)	

3. What is the source of funding for your activities?

USAID	[ ]	Denmark	[ ]	Sweden,	[ ]
EU	[ ]	Germany	[ ]	Switzerland	[ ]
United Kingdom (UK)	[ ]	Ireland	[ ]	World Bank	[ ]
Norway	[ ]	Republic of Korea	[ ]	African Development Bank	[ ]
Australia,	[ ]	Luxembourg	[ ]	Foundations (Bill and Melinda Gates, etc.)	[ ]
Belgium	[ ]	Netherlands	[ ]	Self	[ ]
Canada	[ ]	Norway	[ ]	Others (Specify)	

4. What are the organizations and other entities in the target area that could be useful partners in future agricultural development and resilience activities?

- UN Agencies
- INGOs
- NNGOs
- Faith-based organizations
- Traditional community systems/leaders
- Youth and Women Groups
- Cooperatives
- Community networking

5. Do farmers in this area have access to the following agricultural inputs throughout the year? If yes, how?

Seed	[ ]	Tools and implements	[ ]
Fertilizer	[ ]	Veterinary medicines	[ ]
Pesticides	[ ]	Other (Specify)	

6. Which of the agricultural inputs access affected by Coronavirus (COVID-19) pandemic mitigation measures

Seed	[ ]	Tools and implements	[ ]
Fertilizer	[ ]	Veterinary medicines	[ ]
Pesticides	[ ]	Other (Specify)	

7.
8. Do farmers in this area have access to agricultural extension services? If yes, how?

- Formulation of policies that encourage extension services
- Availability of extension workers because of more training.
- Frequent public extension visits
- Frequent private extension visits

9. What are the assets in this area that can be mobilized to support agriculture and food security?

Land	[ ]	Fisheries	[ ]	Roads	[ ]
Water	[ ]	Livestock	[ ]	Markets	[ ]
Irrigation	[ ]	Gold or other mineral resources	[ ]	Peace and Security	[ ]
Oil and Gas	[ ]	Wild animals	[ ]	Storage facilities	[ ]
Forests	[ ]	Sand and Grave	[ ]	Others (Specify)	
Rivers	[ ]				

10. What are non-farming development activities currently being implemented in your area?

Health	[ ]	Democracy and governance	[ ]
Education	[ ]	Conflict mitigation	[ ]
Humanitarian relief	[ ]	Others (Specify):	

11. What are the main constraints to agricultural development in this area?

Insecurity and conflict	[ ]	Lack of skilled labor	[ ]
Bad roads	[ ]	Lack of land security	[ ]
Limited access to markets	[ ]	Lack of storage facilities	[ ]
High taxes	[ ]	Flooding	[ ]
Lack of inputs	[ ]	Drought	[ ]
pests & diseases	[ ]	Others (Specify):	

12. What agricultural value chain opportunities exist in this area?

- Groundnut and sesame paste
- Cassava chips
- Fodder production
- Vegetables processing/ drying
- Fish processin/drying
- Meat processing
- Dairy processing
- Honey processing
- Hides and skins processing
- Flour milling
- Marketing support

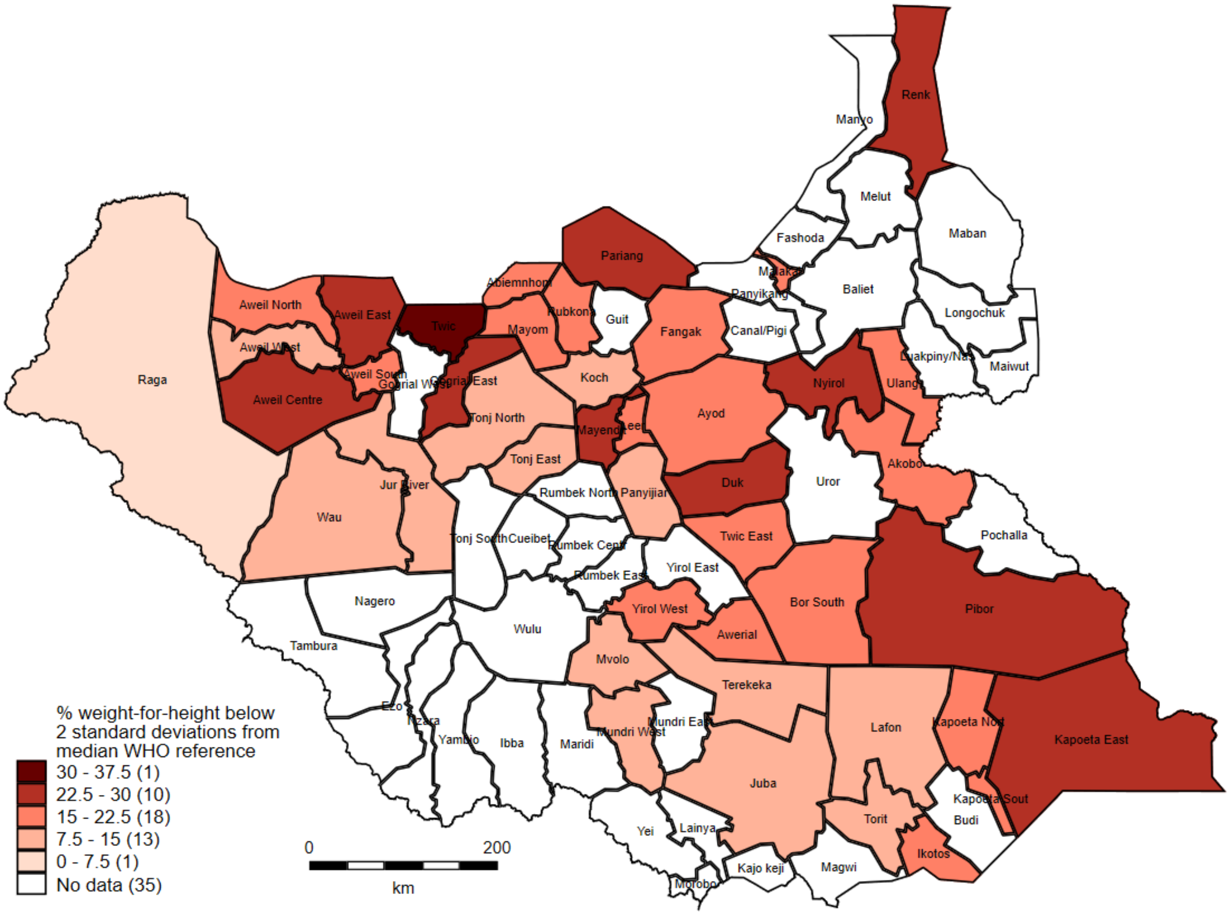
13. What opportunities are available to strengthen the existing value chains in your area?

- Produce /raw products availability
- Consumer demand/markets availability
- Skilled labor
- Humanitarian support

14. Did COVID-19 Change your activities?
    - Yes
    - No
15. What are the effects of COVID-19 on your activities?
    - Activities stopped/slowed because of funding
    - Activities stopped/slowed due to no available/sufficient personnel
    - Activities stopped/slowed because cannot reach farmers
16. How will COVID-19 impact your programming for the rest of the year?
    - No impact
    - Reduce activities
    - Increase activities

THANK YOU!

Annex 2: Spatial distribution of global acute malnutrition (GAM) among children below the age of five years in South Sudan, 2017



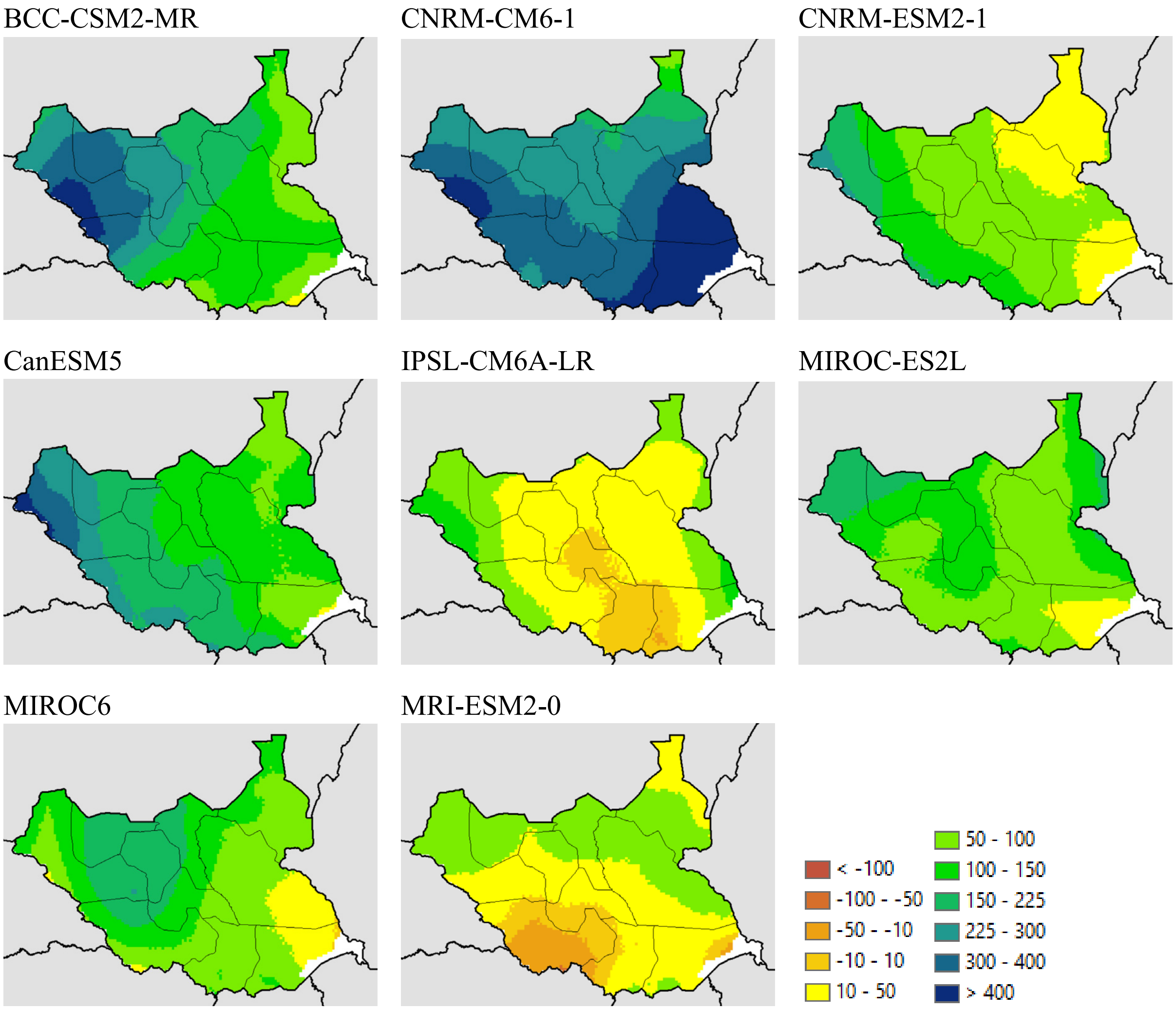
Source: Authors' based on data from the Standardized Monitoring and Assessment of Relief and Transitions survey (2017).

Annex 3: Summary of value chain efficiencies by county, South Sudan (2014-2017)

County	Agricultural potential	Efficiency		
		Availability	Access	Utilization
Akobo	Low	stochastically medium	structurally medium	stochastically low
Aweil Centre	High	structurally medium	stochastically medium	stochastically low
Aweil North	High	structurally medium	stochastically low	stochastically medium
Awerial	High	structurally medium	structurally low	structurally high
Baliet	n.a.	structurally low	stochastically medium	n.a.
Bor South	Low	stochastically medium	stochastically medium	stochastically medium
Budi	n.a.	structurally medium	stochastically low	n.a.
Canal/Pigi	n.a.	structurally low	structurally low	n.a.
Duk	Low	structurally low	structurally high	structurally low
Guit	n.a.	stochastically medium	stochastically high	n.a.
Jur River	High	structurally medium	stochastically low	stochastically high
Kapoeta North	Low	structurally medium	stochastically high	structurally low
Leer	Low	stochastically low	stochastically medium	structurally high
Luakpiny/Nasir	n.a.	stochastically medium	stochastically low	n.a.
Magwi	n.a.	structurally medium	structurally low	n.a.
Mayendit	Low	structurally medium	stochastically low	stochastically high
Mayom	Low	structurally medium	stochastically high	stochastically low
Nyirol	High	structurally low	stochastically high	stochastically low
Nzara	n.a.	structurally medium	structurally low	n.a.
Panyijiar	High	structurally low	stochastically medium	stochastically medium
Rubkona	Low	stochastically medium	structurally high	structurally low
Rumbek Centre	n.a.	structurally medium	structurally low	n.a.
Rumbek East	n.a.	structurally medium	structurally low	n.a.
Tambura	n.a.	structurally medium	structurally low	n.a.
Torit	High	structurally medium	structurally low	stochastically medium
Twic East	Low	stochastically medium	stochastically low	stochastically medium
Ulang	Low	stochastically medium	structurally medium	structurally medium
Wau	High	structurally medium	stochastically low	stochastically high
Wulu	n.a.	structurally medium	structurally low	n.a.
Yambio	n.a.	structurally medium	structurally low	n.a.
Yirol East	n.a.	structurally medium	structurally low	n.a.
Yirol West	High	structurally medium	structurally low	structurally high

Source: Authors' illustration based on results from the spatial typology of food security and nutrition.
Notes: Agricultural potential is based on area-kilocalorie conversion measure. n.a. = not analyzed due to lack of data. Structural means underlying constraints associated with the level of efficiency are stable between 2014 and 2017, and stochastic means the underlying constraints are variable over that same period.

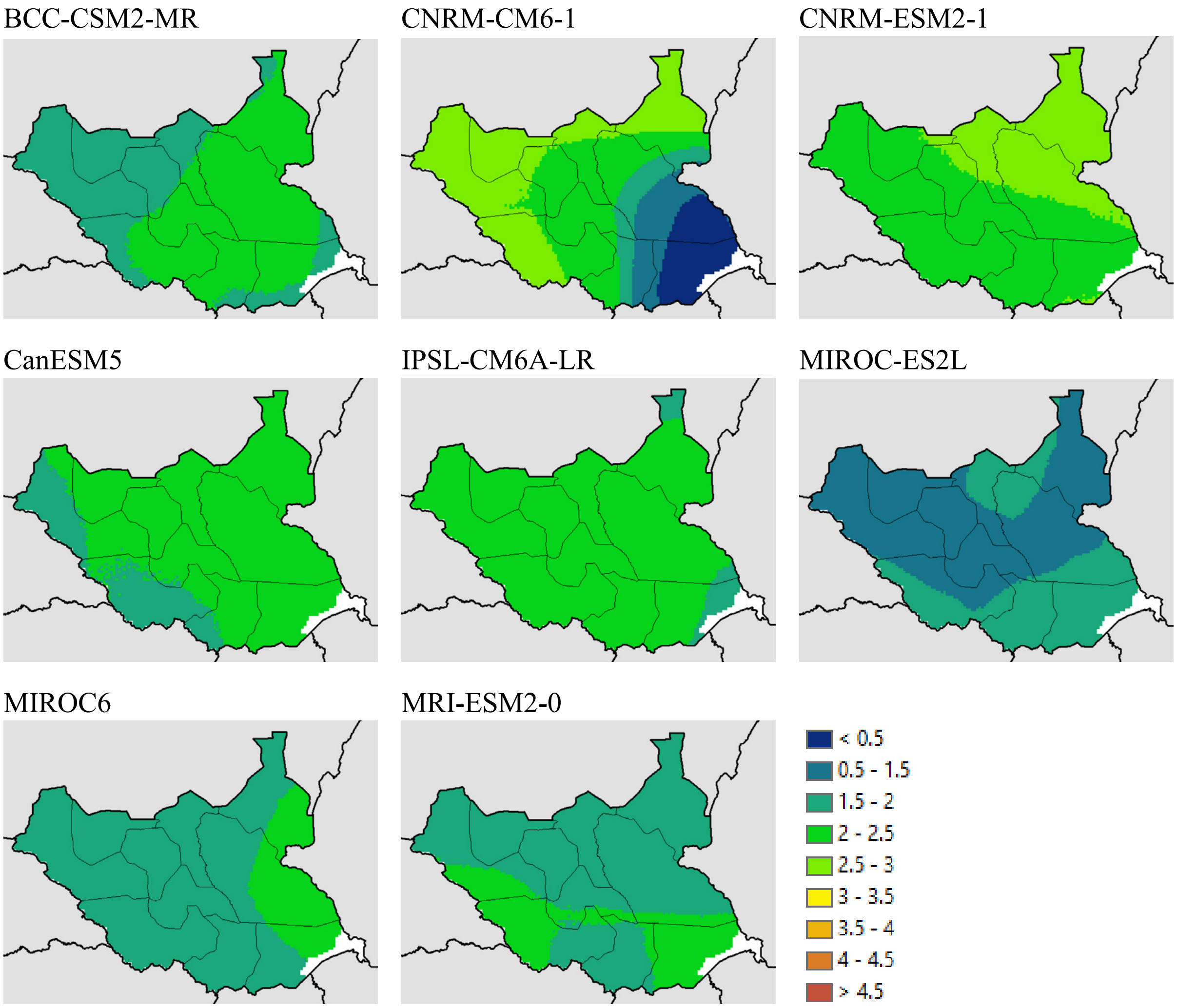
Annex 4: Change in mean annual precipitation in millimeters, South Sudan (between 1970–2000 and 2040–2060 for different models)[11]



Source: WorldClim 2.1 (Hijmans et al. 2005).
Notes on models: BCC-CSM2-MR = Beijing Climate Center, Beijing 100081, China. CNRM-CM6-1 = Centre National de Recherches Météorologiques, Toulouse 31057, France. CNRM-ESM2-1 = Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique, Toulouse 31057, France. CanESM5 = Canadian Centre for Climate Modelling and Analysis, Environment and Climate Change Canada, Victoria, BC V8P 5C2, Canada. IPSL-CM6A-LR = Institut Pierre Simon Laplace, Paris 75252, France. MIROC-ES2L and MIROC6 = Japan Agency for Marine-Earth Science and Technology, Kanagawa 236-0001, Japan); Atmosphere and Ocean Research Institute, The University of Tokyo, Chiba 277-8564, Japan; National Institute for Environmental Studies, Ibaraki 305-8506, Japan; and RIKEN Center for Computational Science, Hyogo 650-0047, Japan. MRI-ESM2-0 = Meteorological Research Institute, Tsukuba, Ibaraki 305-0052, Japan. See Table 2 in the main text for details.

[11] Five of the models (BCC-CSM2-MR, CNRM-CM6-1, CNRM-ESM2-1, CanESM5, and MIROC-ES2L) show increases in rainfall everywhere, MIROC6 has a very small area with essentially no change, IPSL-CM6A-LR shows a very small area with a decrease, and MRI-ESM2-0 shows a small to moderate area with decreases in rainfall. The largest increase in rainfall (more than 400 mm/year observed in the southeast) is obtained from CNRM-CM6-1, whereas the smallest increase in rainfall (observed in the west) is from BCC-CSM2-MR.

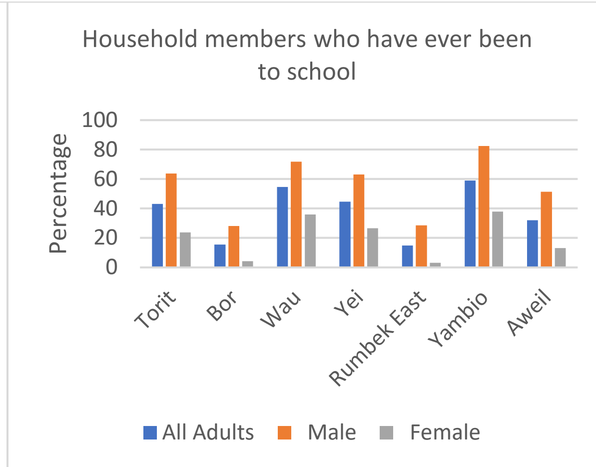
Annex 5: Change in mean daily maximum temperature in degrees Celsius, South (between 1970–2000 and 2040–2060)

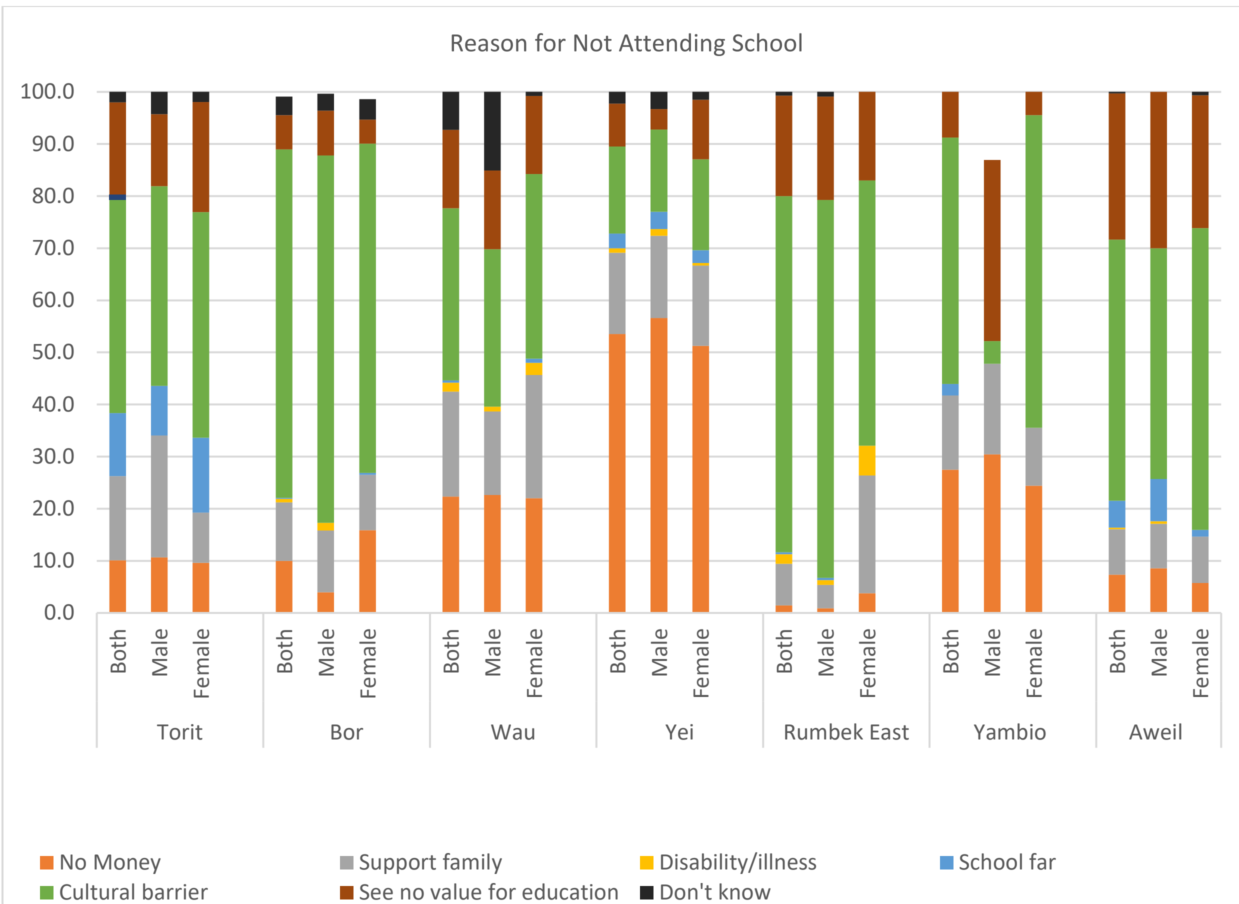


Source: WorldClim 2.1 (Hijmans et al. 2005).

Notes on models: BCC-CSM2-MR = Beijing Climate Center, Beijing 100081, China. CNRM-CM6-1 = Centre National de Recherches Météorologiques, Toulouse 31057, France. CNRM-ESM2-1 = Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique, Toulouse 31057, France. CanESM5 = Canadian Centre for Climate Modelling and Analysis, Environment and Climate Change Canada, Victoria, BC V8P 5C2, Canada. IPSL-CM6A-LR = Institut Pierre Simon Laplace, Paris 75252, France. MIROC-ES2L and MIROC6 = Japan Agency for Marine-Earth Science and Technology, Kanagawa 236-0001, Japan); Atmosphere and Ocean Research Institute, The University of Tokyo, Chiba 277-8564, Japan; National Institute for Environmental Studies, Ibaraki 305-8506, Japan; and RIKEN Center for Computational Science, Hyogo 650-0047, Japan. MRI-ESM2-0 = Meteorological Research Institute, Tsukuba, Ibaraki 305-0052, Japan. See Table 2 in the main text for details.

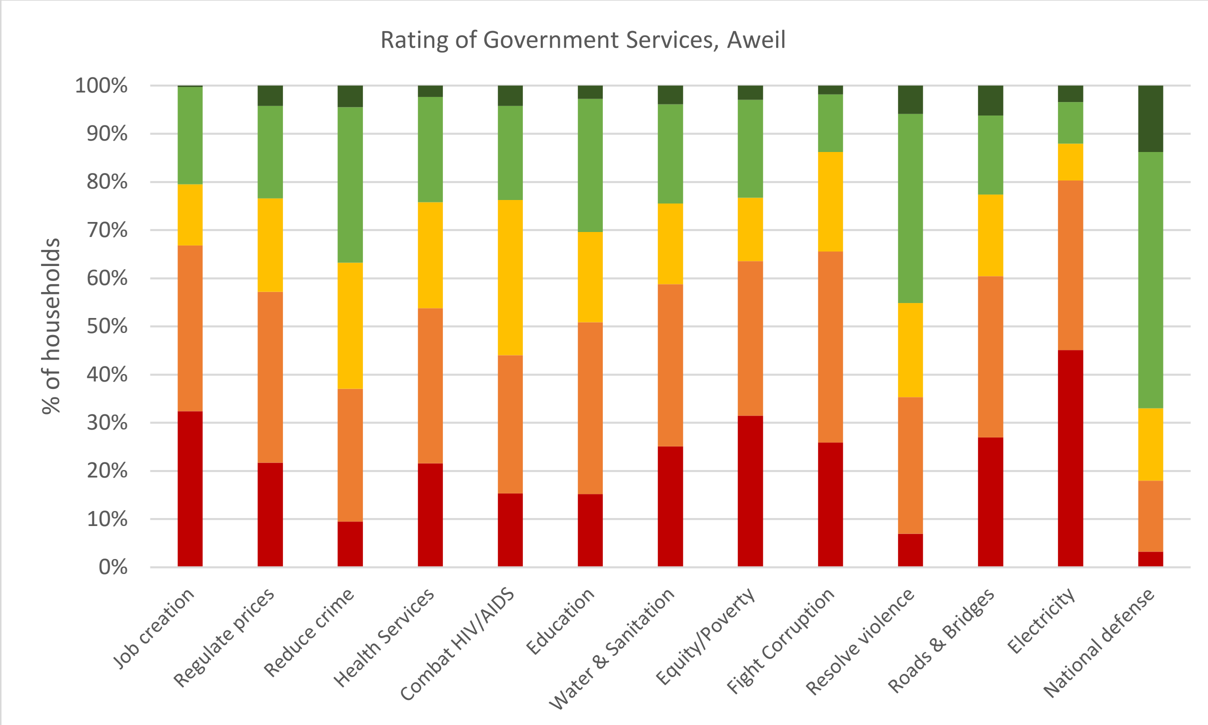
Annex 6: Indicators on education in selected counties of South Sudan, 2017

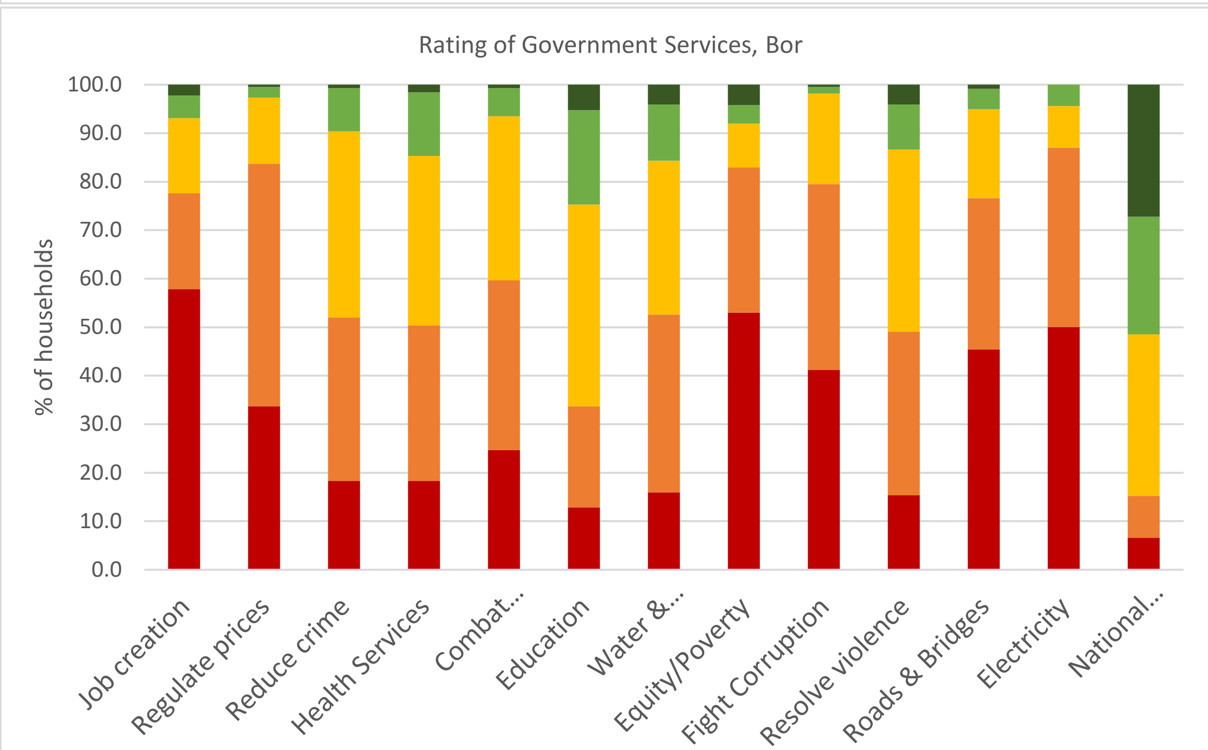




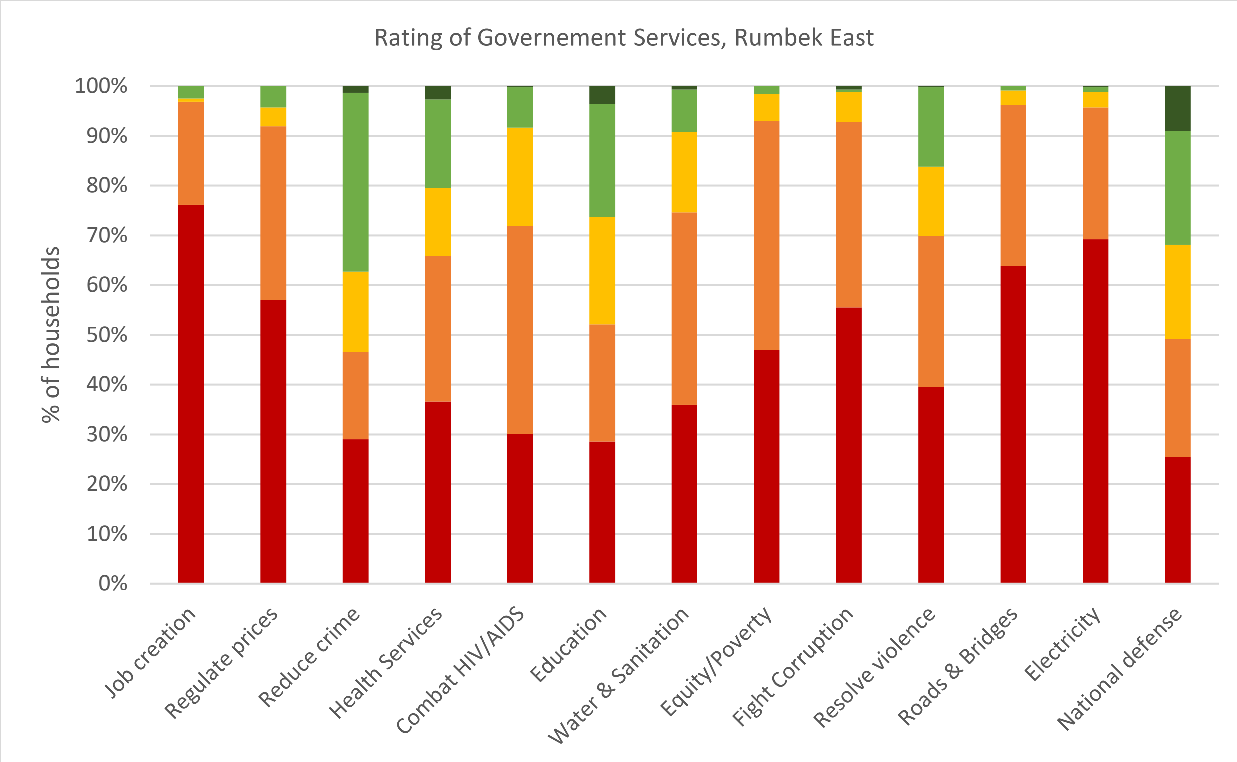
Source: Authors' calculation based on MESP (2017).

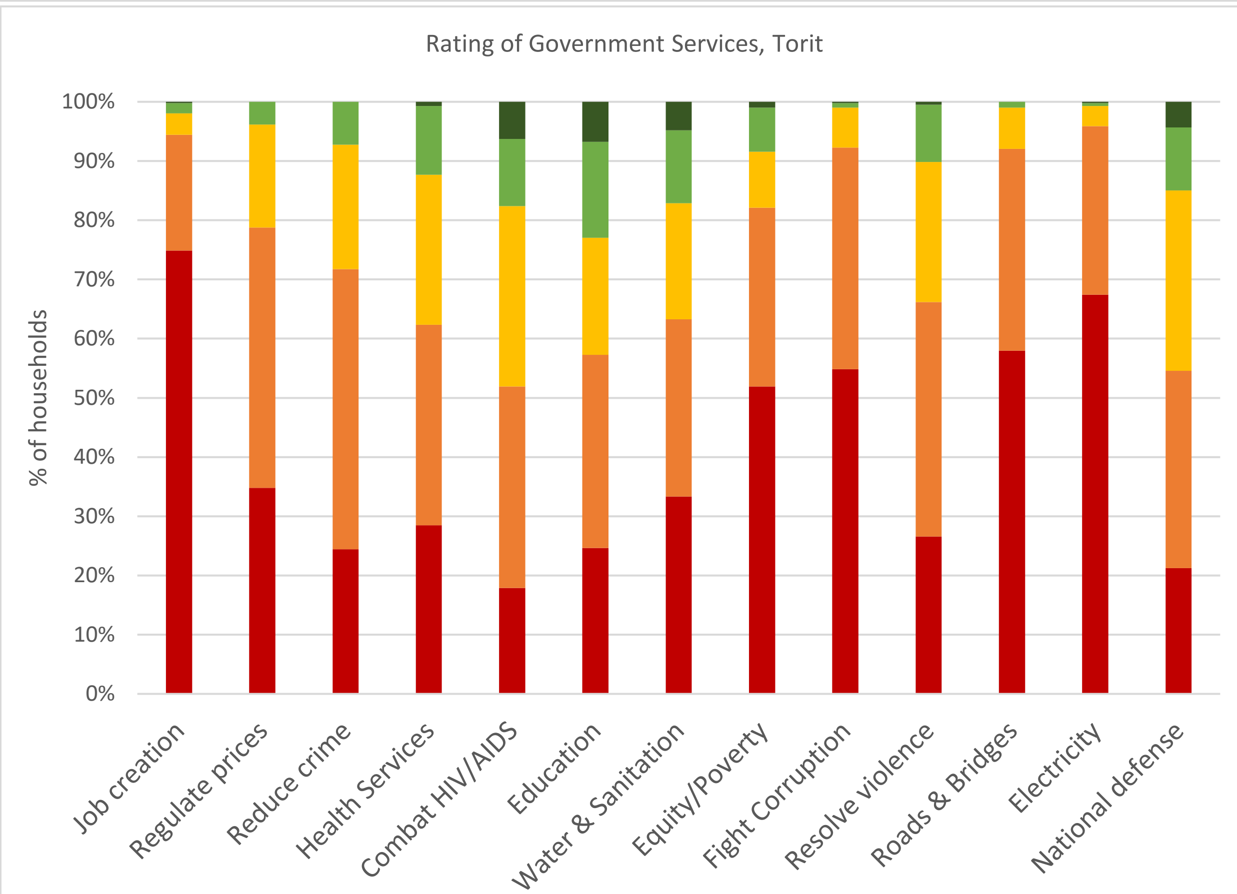
Annex 7: Rating of government services in selected counties of South Sudan, 2017[12]

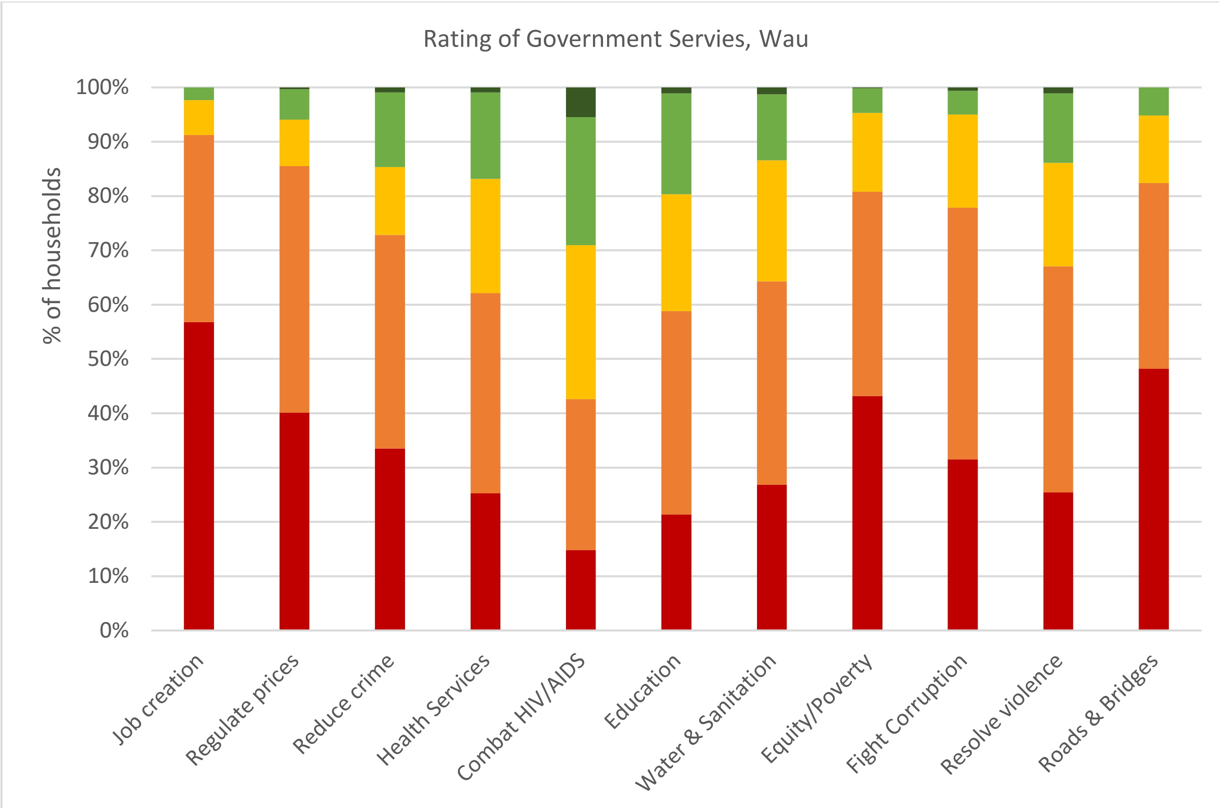


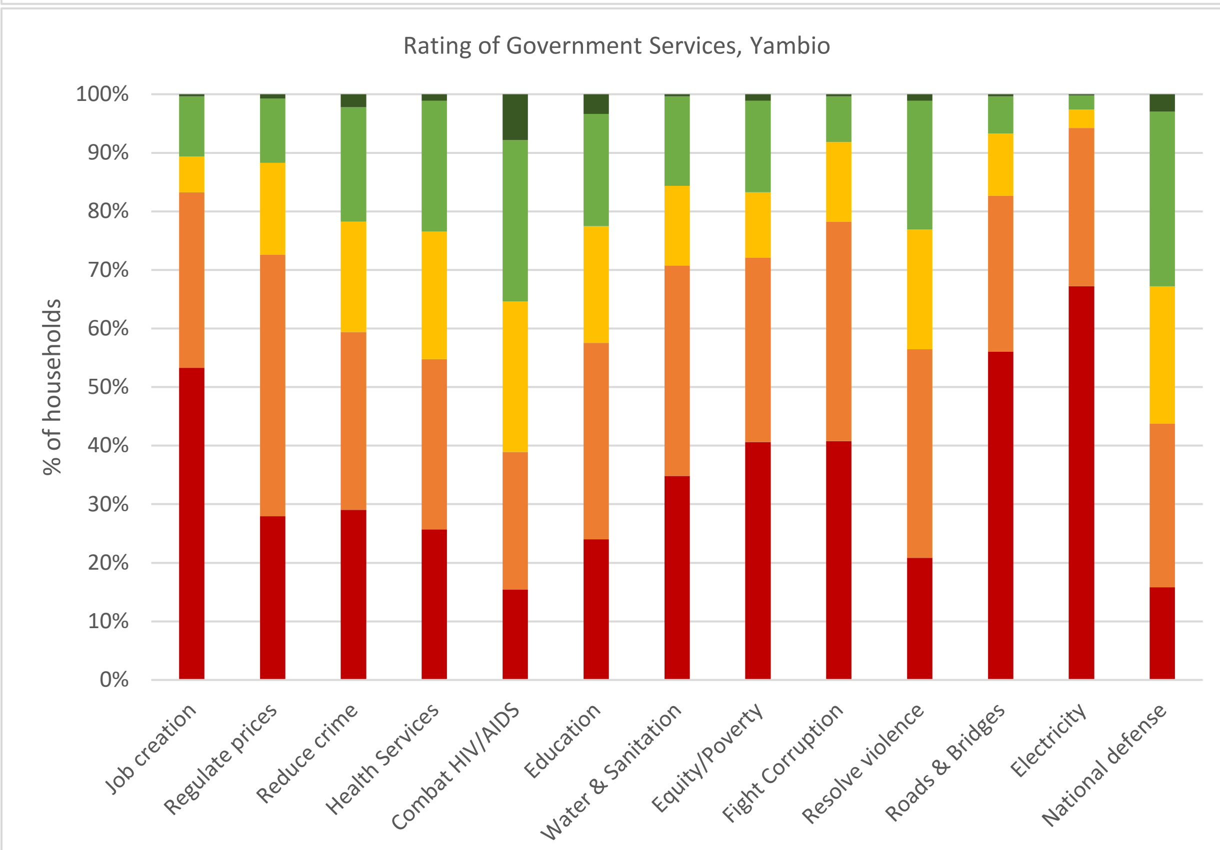


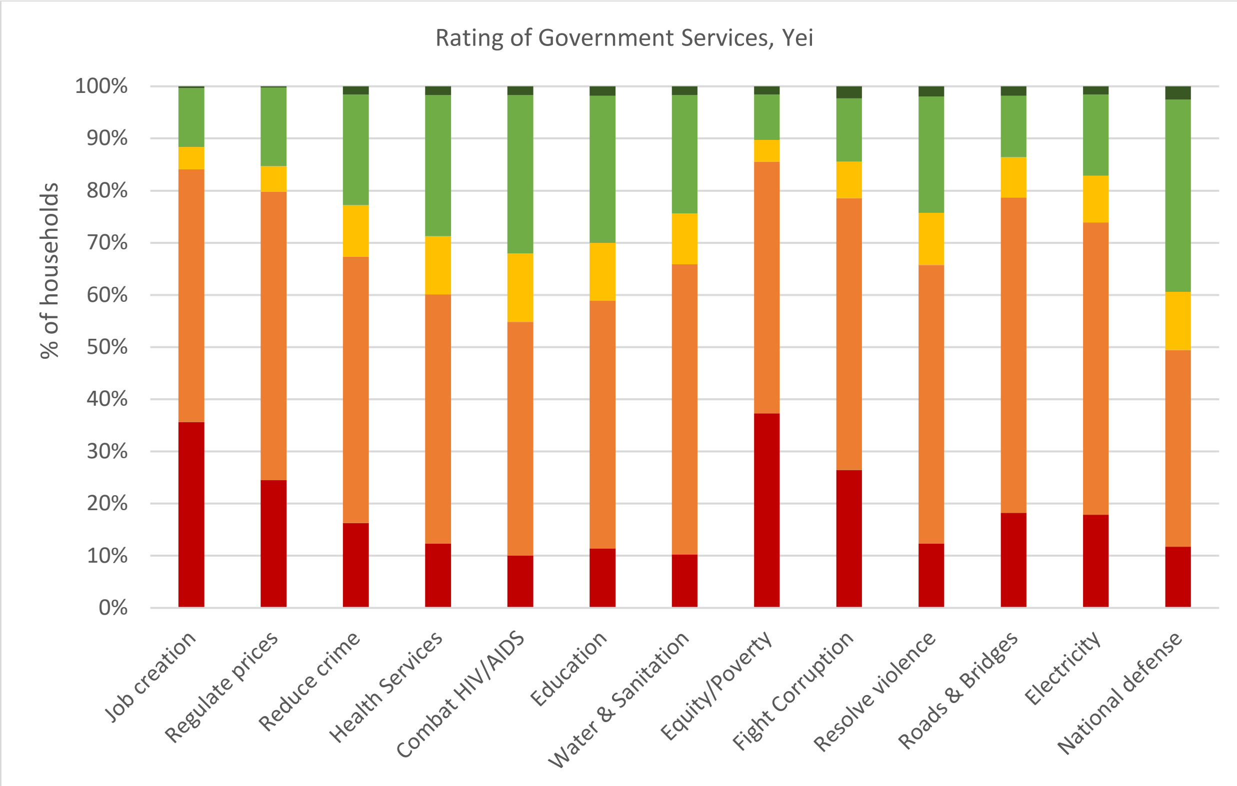
[12] Note: Very poor (RED), Poor (ORANGE), Somewhat (YELLOW), Good (GREEN), Very good (BLUE)


Rating of Governement Services, Rumbek East
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% of households
Job creation
Regulate prices
Reduce crime
Health Services
Combat HIV/AIDS
Education
Water & Sanitation
Equity/Poverty
Fight Corruption
Resolve violence
Roads & Bridges
Electricity
National defense


Rating of Government Services, Torit
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% of households
Job creation
Regulate prices
Reduce crime
Health Services
Combat HIV/AIDS
Education
Water & Sanitation
Equity/Poverty
Fight Corruption
Resolve violence
Roads & Bridges
Electricity
National defense

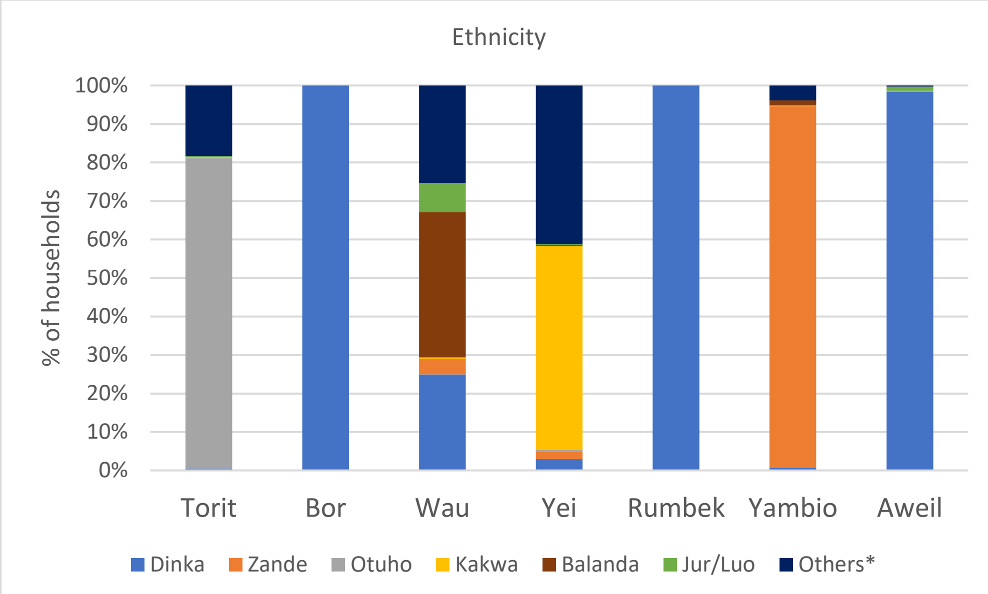

Rating of Government Servies, Wau
% of households
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Job creation
Regulate prices
Reduce crime
Health Services
Combat HIV/AIDS
Education
Water & Sanitation
Equity/Poverty
Fight Corruption
Resolve violence
Roads & Bridges

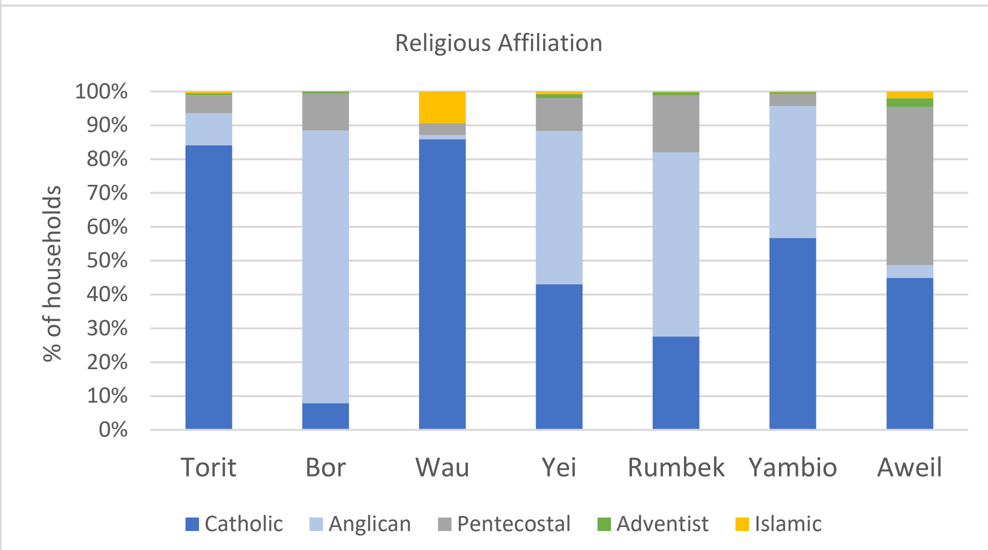

Rating of Government Services, Yambio
% of households
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Job creation
Regulate prices
Reduce crime
Health Services
Combat HIV/AIDS
Education
Water & Sanitation
Equity/Poverty
Fight Corruption
Resolve violence
Roads & Bridges
Electricity
National defense

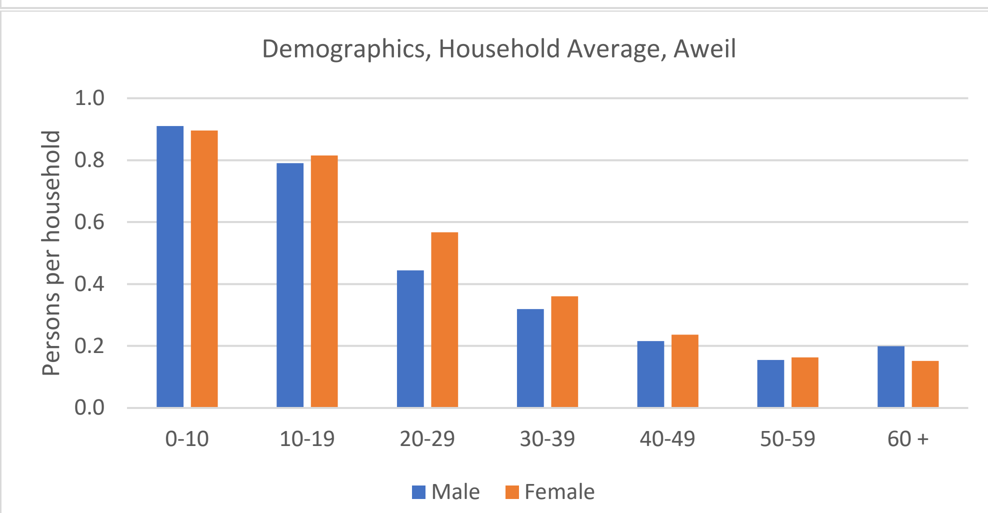


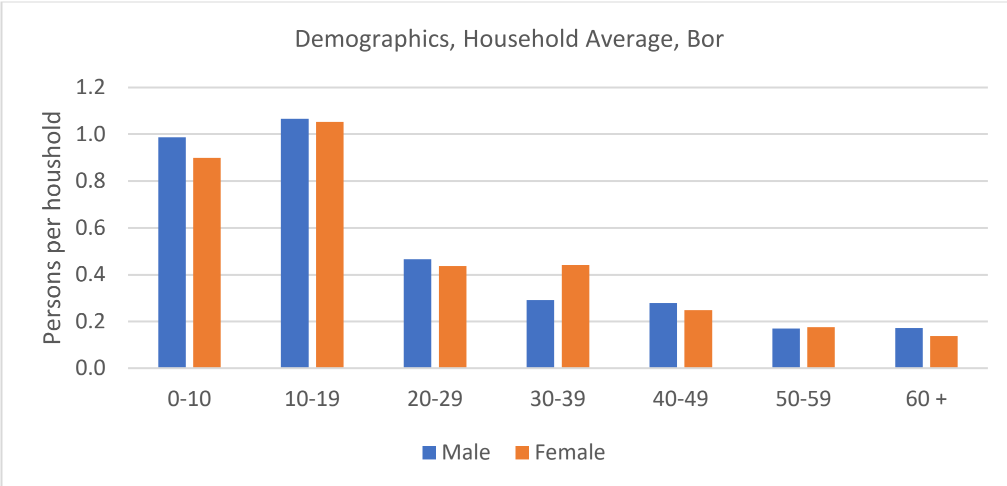
Source: Authors' calculation based on MESP (2017).

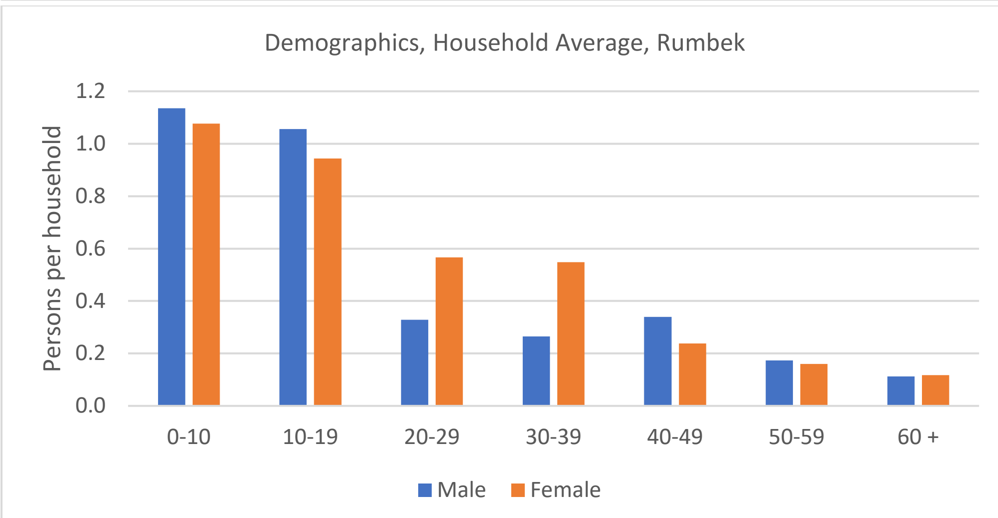
Annex 8: Household characteristic in selected counties of South Sudan, 2017

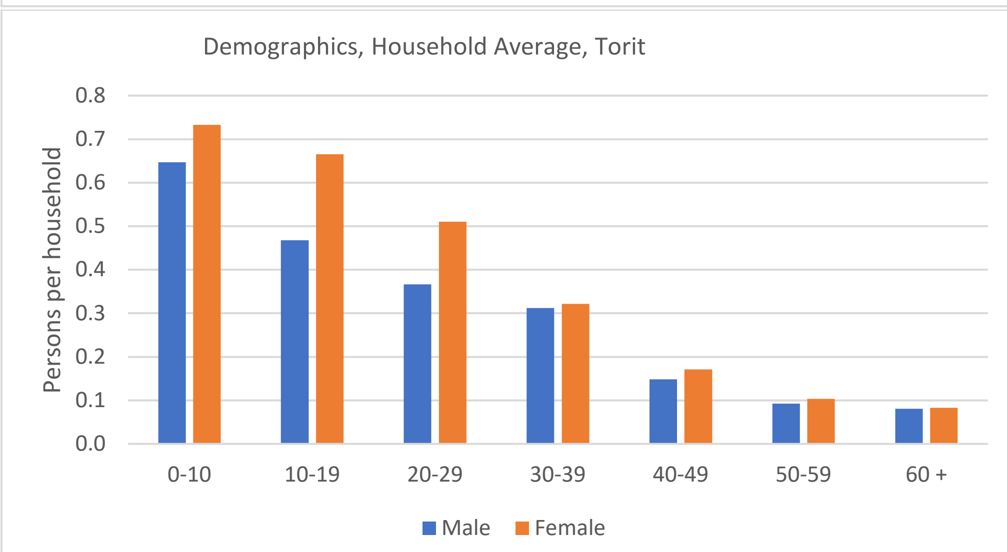


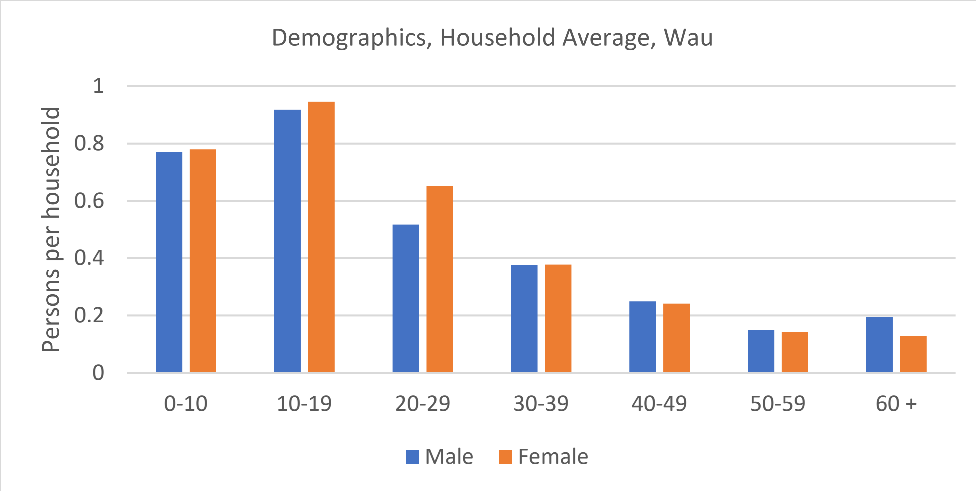


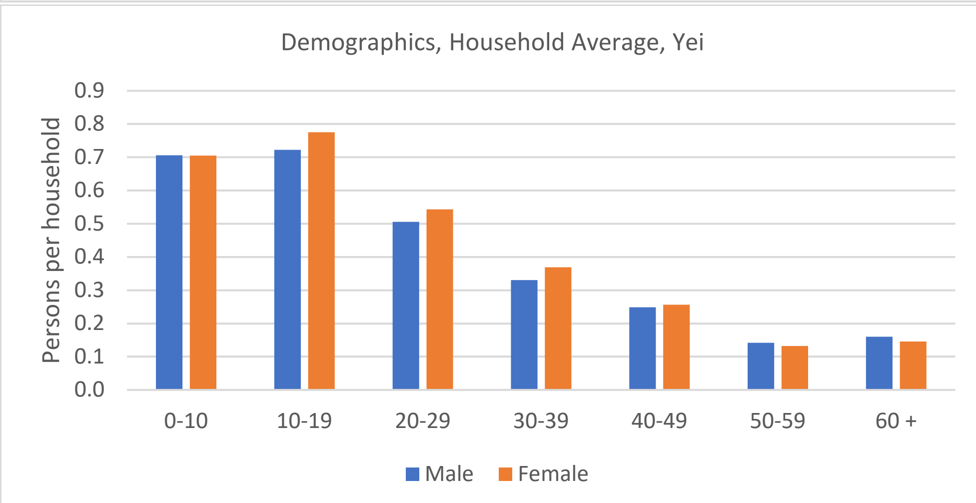


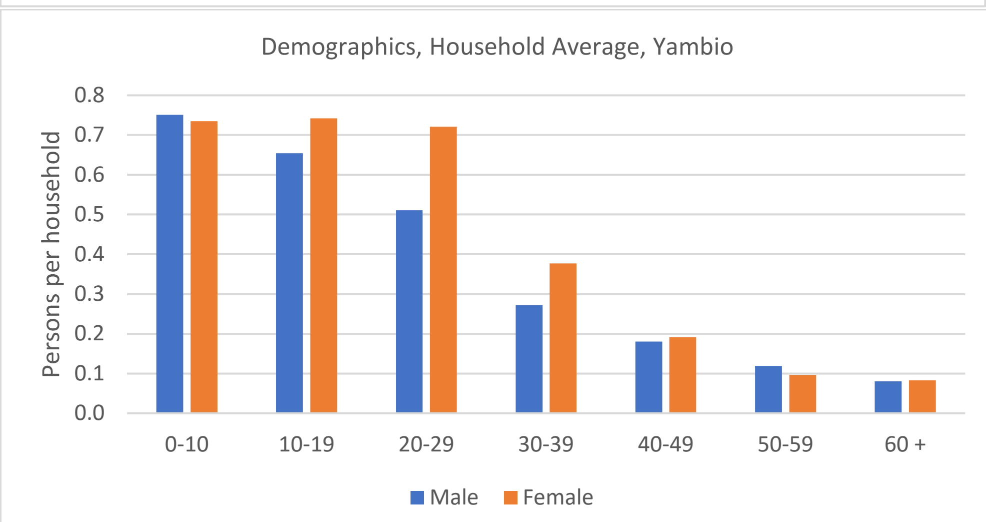

Demographics, Household Average, Bor
Persons per houshold
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0-10
10-19
20-29
30-39
40-49
50-59
60 +
Male
Female


Demographics, Household Average, Rumbek
Persons per household
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0-10
10-19
20-29
30-39
40-49
50-59
60 +
Male
Female


Demographics, Household Average, Torit
Persons per household
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0-10
10-19
20-29
30-39
40-49
50-59
60 +
Male
Female







Source: Authors' calculation based on MESP (2017).

Annex 9: Percentage of population affected by social risk in selected counties of South Sudan, 2017

	Torit	Bor	Wau	Yei	Rumbek East	Yambio	Aweil
Burglaries	37	61	68	55	21	49	49
Robberies	54	56	57	61	51	73	26
Assaults	37	48	25	42	6	46	20
Gang	39	52	54	33	25	52	35
Vandalism	21	34	28	31	12	32	19
Violent dispute	60	64	39	43	21	44	20
Alcohol abuse	93	79	53	74	21	84	49
Substance (drug) abuse	32	58	34	63	2	61	11
Teen Pregnancy	70	40	47	58	13	70	46
Domestic violence	89	65	45	64	20	73	35
Child abuse	76	61	39	55	14	58	26
Prostitution	22	32	23	42	1	55	18
Rape	31	43	31	51	11	41	10
Cattle raiding/Rustling	47	82	9	7	63	1	5

Source: Authors' calculation based on MESP (2017).

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