

# Sorghum production in selected states of Sudan during the 2024/25 growing season

Sustainable Agrifood Systems Approach for Sudan (SASAS)

CIMMYT  
April 3, 2025





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## Executive Summary

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The crop assessment work presented in this report focuses on monitoring the area, yield, and production of sorghum planted during the 2024/25 growing season. Our analysis covers the states of Gedaref, White Nile, Blue Nile and the New Halfa irrigation scheme in Kassala, which are Sudan's main surplus sorghum producers. Sorghum is Sudan's staple crop and has been referred to as a banking alternative because it can be safely stored for more than a year in underground pits called Matmuras. For the analysis, we first used satellite data to identify areas (pixels in the satellite images) grown with sorghum. Next, we related the peak normalized difference vegetation index (Peak-NDVI) with yield data obtained from crop cuts. In the last step, we applied the resulting regression curve to all sorghum areas.

The major insights from the report are:

- ◆ Crop conditions were better than expected despite the many challenges farmers faced in 2024/25;
- ◆ Sorghum planted area in Gedaref was slightly higher than in 2023/24. It was also higher than the long-term average in White Nile and Kassala, while it was below average in Blue Nile;
- ◆ For Kassala, we could only generate an area estimate, which was 734,000 ha;
- ◆ The 2024/25 state level average productivity of rainfed sorghum was around 0.9 t/ha;
- ◆ The 2024/25 estimated total sorghum production was 2.65 million t (by state: Gedaref, 1.57; White Nile, 0.70; Blue Nile, 0.31 and New Halfa irrigation scheme in Kassala 0.07 million t).

# 1. Introduction

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For farmers, the current Sudan conflict has caused a shortage of inputs (diesel, fertilizer, seed, pesticide), a lack of credit (FAO, 2024), and uncertainty regarding the timing and prices for grain sales. Foreign governments and international relief organizations are concerned about food security in Sudan, especially for millions of internally displaced people. Procuring domestically produced sorghum for food aid would create income and an incentive for farmers to continue growing sorghum, besides costing less than imported food.

CIMMYT was asked to estimate Sudan crop production, as part of the USAID-funded “Sustainable Agrifood Systems for Sudan” (SASAS) project. This report follows a similar report that was published for 2023 (Osman et al., 2024). Our study focuses on the sorghum producing states of Gedaref, White Nile, Blue Nile, and the New Halfa irrigation scheme in Kassala. New Halfa was selected because

farmers in that irrigation scheme received support in the form of a package that included improved and certified seeds, fertilizer, herbicides, and regular crop management advice. The support package covered about 15,000 ha. In 2024, these four states were mostly only indirectly affected by the conflict. However, Sennar, which we monitored in 2023, was not secure anymore in 2024. Instead, we added White Nile, which has not only irrigated but also a considerable area of rainfed sorghum production by smallholder farmers, to the monitoring area.

We had a team on the ground making yield measurements (crop cuts) and interviewing farmers about their crop management practices. Hence, this report relies on measured data from sorghum fields and satellite images to generate an assessment of the 2024 sorghum production in key surplus states of Sudan.

## 2. Methodology

### 2.1. Crop cut survey

In the crop cut survey, conducted during November to December, 2024, enumerators measured grain yield from 4 x 4 m plots in poor, average, and high-yielding sorghum fields. They also took geo-tagged photos of the sampling locations and interviewed the respective farmers regarding crop

management practices and input availability. Security concerns limited enumerators' travel within the four states. The enumerators also completed a short questionnaire with each participating farmer. They were asked to compare the 2024 conditions to 2023 and to provide information on land management, sowing, fertilizer application, weeding and their assessment of the 2024 growing season.



**GPS tagged photo of sampling location for crop-cut: sorghum heads from an area of 4 by 4 m were harvested to estimate yield.**

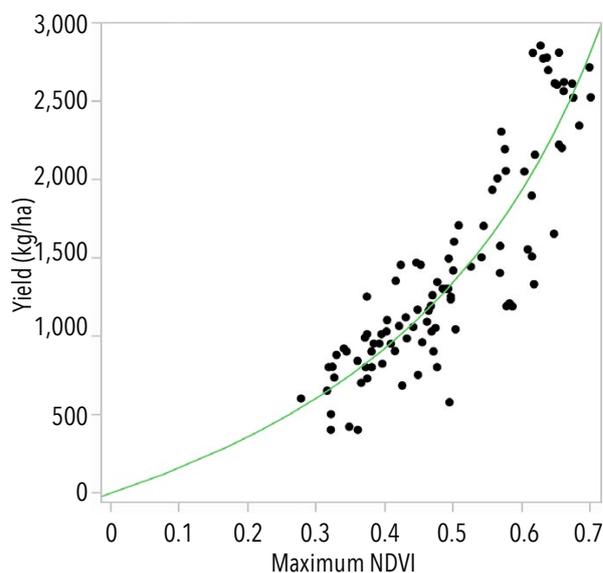
## 2.2. Remote sensing analysis

We used atmospherically-corrected (L2A) Sentinel-2 satellite data to identify areas (pixels) grown with sorghum and then estimated the yield of each sorghum pixel. The Sentinel-2 data have a resolution of 10 m and are acquired at 5-day intervals.

To identify crops (including sorghum) and non-cropland, we relied on geo-tagged photos acquired in a survey and the locations of the crop cuts. Based on photo locations and visual interpretation of segmented satellite images, we created training data for a random forest classifier using Google Earth Engine (GEE). For classification, we used blue, green, red, and NIR bands, as well as NDVI from cloud-free images acquired between September 15 and November 30, 2024. We created separate training data for each of the four states. The overall accuracies (OA) varied among the states. It was highest for Gedaref, with an OA of 0.91, followed by White Nile (0.77), Kassala (0.71) and Blue Nile (0.70). Producer accuracies, which indicate the percentage of actual sorghum pixels on the ground that are identified correctly, ranged from Blue Nile (74.7%), White Nile (59.6%), Gedaref (59.4%) to Kassala (59%). For the user accuracies, which indicate that a pixel shown on the map indeed is sorghum, the percentages were: Blue Nile (79.6%), Gedaref (78.6%), Kassala (71.3%) and White Nile (70.7%). Taking Gedaref as an example, with a producer accuracy of 59.4% and a user accuracy of 78.6%, the numbers indicate that the probability that a sorghum pixel was not recognized as such was 41.6%, while the chance of a false positive was 21.4%. The largest source of errors was the confusion of sorghum with millet.

To estimate yield, we first created a map with the peak NDVI value (Peak-NDVI) of each pixel between September 15 and November 30, 2024. We used that map for quality control of the crop cut data, comparing the reported yield to the photo from the crop cut location and Peak-NDVI. We then extracted the peak-NDVI for each sampling point from the satellite images and used a Michaelis-Menten equation to estimate yield for each pixel. The resulting line of fit between Peak-NDVI and measured yield had an  $R^2$  value of 0.80 and a root mean square error of 306 kg/ha (Figure 1). We then applied the regression

equation to the Peak-NDVI of each sorghum pixel to estimate its yield. Total production was estimated by adding up the yield of all sorghum pixels within each state.



**Figure 1: Relationship between the maximum normalized difference vegetation index (NDVI) obtained from satellite images acquired between September 15 and November 30, 2024 and yield measurements from crop cuts of sorghum. The green line represents fitted values of a Michaelis-Menten curve ( $R^2=0.80$ ).**

Some sorghum fields—presumably weed-infested, low-yielding ones—are sold to pastoralists for grazing. In the FAO reports, the fraction of harvested fields is reported to vary among states and years. We can assume that, during uncertainty caused by the conflict, farmers are more inclined to harvest their fields. Moreover, more labor is available due to internal displacement into regions less affected by the conflict. Farmers typically hand-harvest the heads of sorghum plants, making it impossible to determine with remote sensing whether a field is harvested. We assumed that 20% of the fields were not harvested and further reduced yield estimates by 20%, to account for an inherent sampling bias in crop cuts (Kosmowski et al., 2021; people tend to skip areas with no plants, thereby overestimating yield).

### Analysis of rainfall and regional NDVI

We used the CHIRPS rainfall and MODIS derived NDVI data provided by the World Food Program (WFP, 2024) to assess overall conditions during the 2024 production season.

### 3. Results

Based on WFP rainfall and NDVI data, production conditions were favorable in the four states during the 2024 sorghum growing season. Please see Appendix 1 for an in-depth analysis of rainfall and NDVI patterns over cropland.

The area, yield, and production estimates are summarized in Table 1. We are using the average of the last five years of the most recent available FAO report (FAO, 2024) as a reference and also compare our estimates for 2024 to our 2023 estimates, where applicable. Since we could not operate in Sennar in 2024, the total production numbers cannot be compared 1:1. For Gedaref, the most important state in terms of total production, a slight increase of 7% in the area planted was observed. In Blue Nile, the area of sorghum decreased by one third. This can be attributed to excessive rainfall. Moreover, some large farms reportedly moved their operations to

South Sudan. For White Nile, we estimated 899,000 ha, which is higher than the average. A noticeable portion of fields in the irrigated areas were not or irregularly planted. However, in the rainfed region, conditions were favorable due to above average rainfall, enabling farmers in those areas to increase the acreage, which more than offset area losses in the irrigated lands. For the New Halfa irrigation scheme, we estimated a sorghum area of 48,000 ha.

The average estimated yield for Gedaref was slightly lower than in 2023. However, it was still almost double of the long-term average reported by FAO. Lower yields than in 2023 were also observed for Blue Nile. Flooding impacted crop growth in that state. This is also visible in the NDVI development graph shown in Figure 5. Average yield levels were also higher than the long-term average for White Nile. In New Halfa, the average yield was

**Table 1: Summary of production estimates according to the 5-year average reported by FAO (FAO, 2024), compared to CIMMYT’s estimate for 2023 and 2024. Area planted and production are in millions. Please note that the total production estimates cover different states each year.**

		FAO estimates					CIMMYT				CIMMYT			
		5-yr average 2018/19-2022/23					2023				2024			
State	Sector	Area planted	Area harvested	Fract harv	Yield (t/ha)	Production million (t)	Area planted	Fract harv	Yield (t/ha)	Production million (t)	Area planted	Fract harv	Yield (t/ha)	Production million (t)
Gedaref	Semi-mechanized	1.951	1.531	0.78	0.48	<b>0.735</b>	2.144	0.8	0.99	<b>1.698</b>	2.293	0.8	0.86	<b>1.570</b>
Sennar	Semi-mechanized	0.664	0.533	0.80	0.47	0.251								
	Rainfed	0.234	0.171	0.73	0.41	0.070								
	Total (Sennar)	0.898	0.704	0.78		<b>0.321</b>	1.196	0.8	1.03	<b>0.986</b>				<b>No data</b>
Kassala	Semi-mechanized	0.522	0.399	0.76	0.52	0.207								
	Rainfed	0.142	0.113	0.80	0.43	0.049								
	Irrigated (New Halfa)	0.023	0.021	0.91	1.89	<b>0.040</b>					0.048	0.8	1.90	<b>0.073</b>
	Total (Kassala)	0.664	0.512	0.77		<b>0.256</b>				<b>No data</b>	0.734			<b>No data</b>
White Nile	Semi-mechanized	0.461	0.358	0.78	0.56	0.200								
	Rainfed	0.21	0.147	0.70	0.51	0.075								
	Total (White Nile)	0.671	0.505	0.75		<b>0.275</b>				<b>No data</b>	0.899	0.8	0.97	<b>0.696</b>
Blue Nile	Semi-mechanized	0.516	0.427	0.83	0.61	0.260								
	Rainfed	0.149	0.113	0.76	0.66	0.075								
	Total (Blue Nile)	0.665	0.54	0.81		<b>0.335</b>	0.711	0.8	1.11	0.631	0.459	0.8	0.86	<b>0.314</b>
<b>Total</b>		<b>3.951</b>	<b>3.109</b>	<b>0.79</b>		<b>1.641</b>	<b>4.051</b>			<b>3.315</b>	<b>4.385</b>			<b>2.654</b>

similar to the long-term average for irrigated sorghum. It is noteworthy that yields in the northern part of New Halfa exceeded over 3 t/ha for most fields. That region benefitted most

from the package that was provided as part of the SASAS initiative. The spatial distribution of the yield levels, as well as the locations of the crop cuts, are shown in Figure 2.

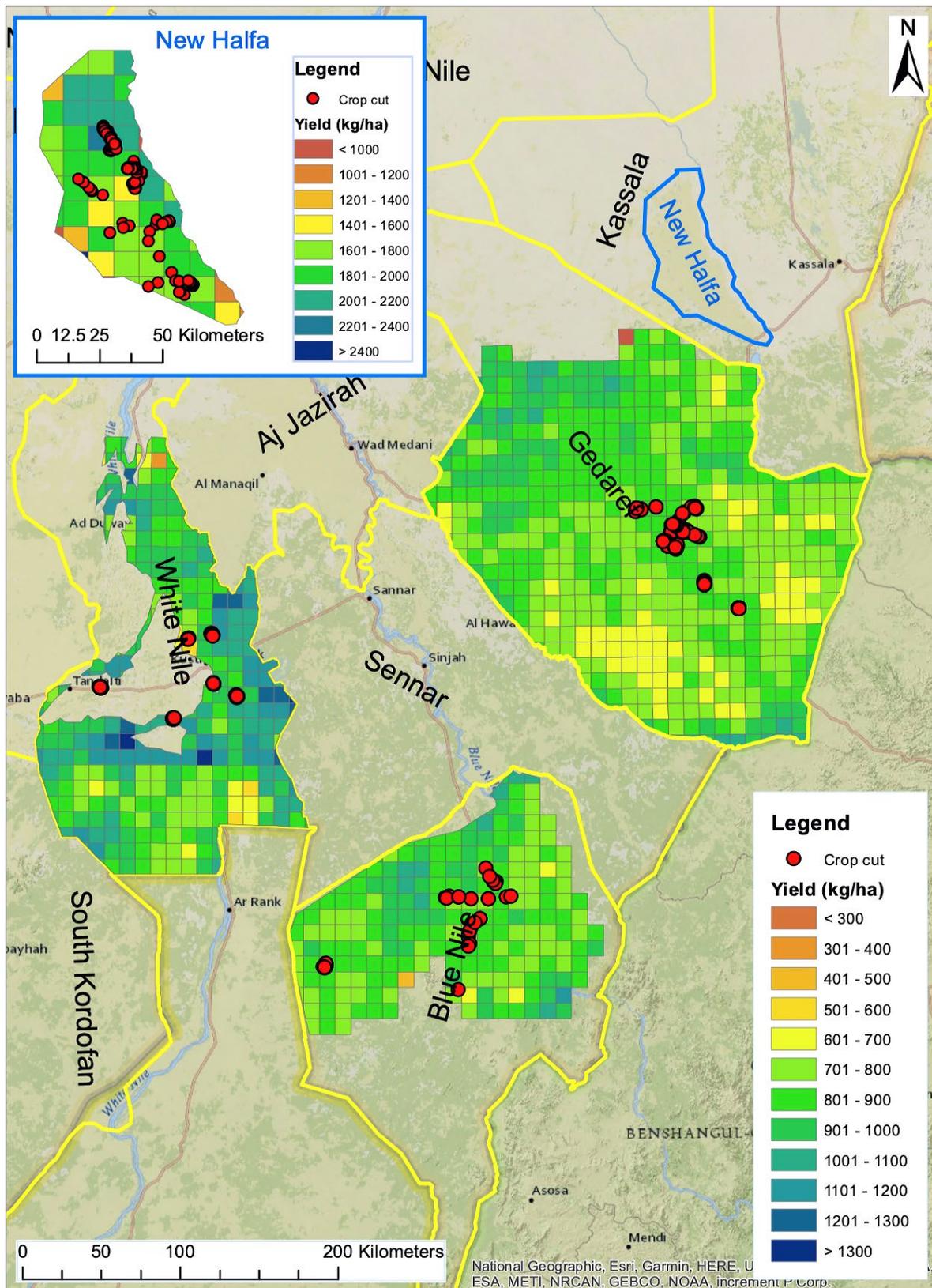


Figure 2: Average predicted yield for sorghum shown for grid cells measuring 10 x 10 km and locations of crop cuts in the states of Blue Nile, White Nile, Gedaref, and New Halfa irrigation scheme in Kassala, during the 2024-25 growing season.

### Feedback from the farmers

The answers from the farmer’s survey corroborated the area and yield estimates generated from the crop cuts and remote sensing. In all four states, the majority of farmers reported they planted the same area as in 2023 (Table 2). White Nile had the highest percentage of respondents who reported a reduced area (45.3%) followed by Blue Nile (35.9). It was reported that many large-scale farmers had moved their operations out of these two states. In Gedaref and New Halfa, the majority of farmers reported higher yields than in 2023. For Blue Nile, two-thirds of the farmers indicated lower yields, mainly due to temporary flooding.

Farmers gave a variety of reasons for adjusting the area planted. Availability of excess seeds

from 2023 and financial support from relatives or the production packages provided by CIMMYT were cited. Lack of finance was the main reason to reduce the area or limit weeding, which in turn reduced yields. Good rainfall was the most frequently mentioned reason for expecting higher yields.

**Table 2: Farmers’ responses to questions about how the area planted and yields changed in 2024 compared to 2023.**

	Area			Yield		
	Higher	Same	Lower	Higher	Same	Lower
<b>Gedaref</b>	19.4	76.7	3.9	56.3		43.7
<b>Blue Nile</b>	16.7	47.4	35.9	26.3	6.2	67.5
<b>White Nile</b>		54.7	45.3	40.3	22.8	36.8
<b>New Halfa (Kassala)</b>	25.7	73.3	1	73.3	18.8	7.9

## Discussion

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Total sorghum production is estimated based on area, fraction of area harvested, and yield per unit area. The following sections discuss the assumptions made by CIMMYT for each factor and compare them to the 5-year averages reported by FAO (2024).

Sorghum production in 2024, as in 2023, benefitted from above-average and regularly distributed rainfall. Abnormal rainfall caused a yield reduction in Blue Nile only, where excess rainfall caused waterlogging and yield losses. Because of a good supply of fuel and early rains, land preparation was generally conducted in a timely manner. However, farmers stagger the sowing date. Sorghum was sown between early July and late August, which has several advantages. Labor for farm operations from sowing to weeding and harvesting can be spread over a longer period, late sowing also decreases the negative effect Striga has on yield, and the risk of total loss of production due to intermittent dry spells is reduced. Fortunately, no such dry spell was observed in 2024.

Rainfed sorghum is usually produced without fertilizer and pesticides, so the lack of inputs had little effect on the production levels:

- ◆ The CIMMYT estimate for total sorghum area for the states of Gedaref, Kassala, White Nile and Blue Nile was 4.385 million ha. The FAO 5-year average area for the four states is 3.951 million ha. While the area planted was negatively impacted by the large farmers reducing the area planted in White Nile and Blue Nile, it was more than offset by an increase in area by small-holder farmers. Kassala experienced an increase in area planted.
- ◆ Our production estimates are in line with those from 2023. A slight decline for Gedaref, the most important state, was estimated. The decline was larger for Blue Nile, but yield levels were still above the 5-year average. Rainfed production in White Nile experienced favorable conditions, more than offsetting the decline in production under irrigation.
- ◆ The farmers perceptions reflected the remote sensing based results: a similar area planted as in 2023 and mixed observations for yield.

## Conclusions

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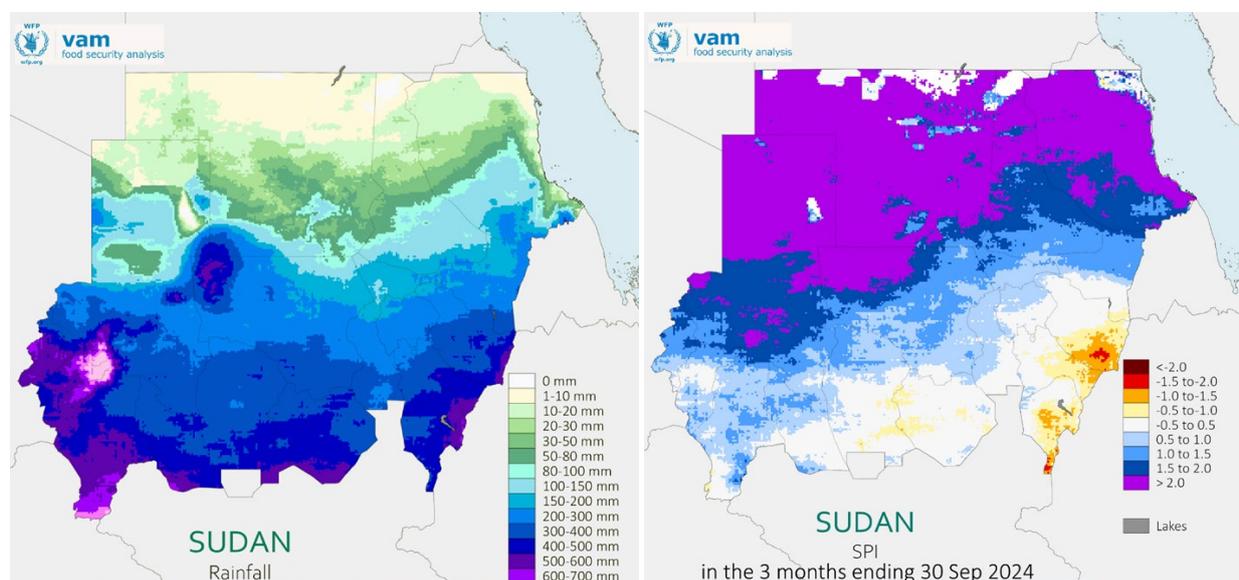
Conditions for sorghum production in the surplus states of Gedaref, White Nile, and Blue Nile were generally favorable in 2024. Semi-mechanized farmers in Sudan are very dynamic, and they respond quickly to opportunities, such as in Kassala, and avoid regions that are perceived as risky, such as White Nile and Blue Nile. Small-holder farmers are more bound to their land holdings. They took advantage of the favorable rainfall

and made a significant contribution to domestic sorghum production in Sudan in 2024. The in-situ and satellite data we collected indicate above-average sorghum production, resulting in grain for locally-procured food aid for other regions of Sudan. A strong demand for sorghum grain will entice farmers to continue to invest in sorghum production in the coming rainy season.

## Appendix 1. Weather conditions and regional NDVI during the 2024/25 growing season

Rainfall conditions were favorable (Figure 3; WFP, 2024). Total rainfall was above average in the northern, drier regions. In contrast, in the high-rainfall (typically more than 400 mm per year) southeast region of Gedaref, rainfall was slightly below average. Neither prolonged dry spells nor flooding were observed in southeast Sudan, as shown by the standard precipitation index (SPI) used to characterize droughts (Guimarães Nobre et al., 2023). It measures how far rainfall is from a reference

value, usually a long-term mean or median measured over several months. SPI values are centered around 0 and usually range within  $-4$  to  $+4$ . A zero value indicates average conditions for a given time and location, whereas negative SPI values represent a rainfall deficit. Sorghum production predominantly takes place on clay soils, which have a high plant available water holding capacity and can buffer dry spells.

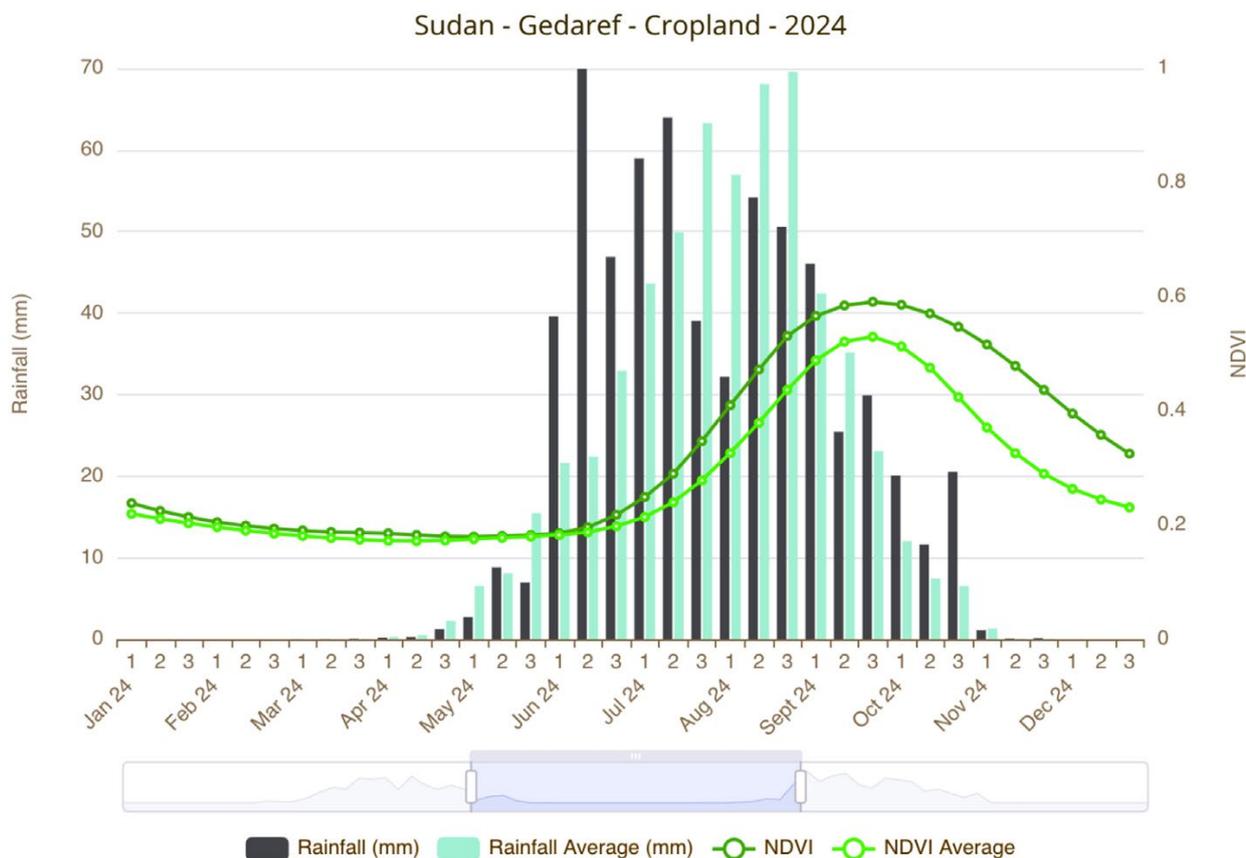


**Figure 3: Spatial distribution of a) rainfall and b) departure from the 20-year average as shown by the SPI (1994-2013) during the period from July 1 to September 30, 2024. (Source WFP).**

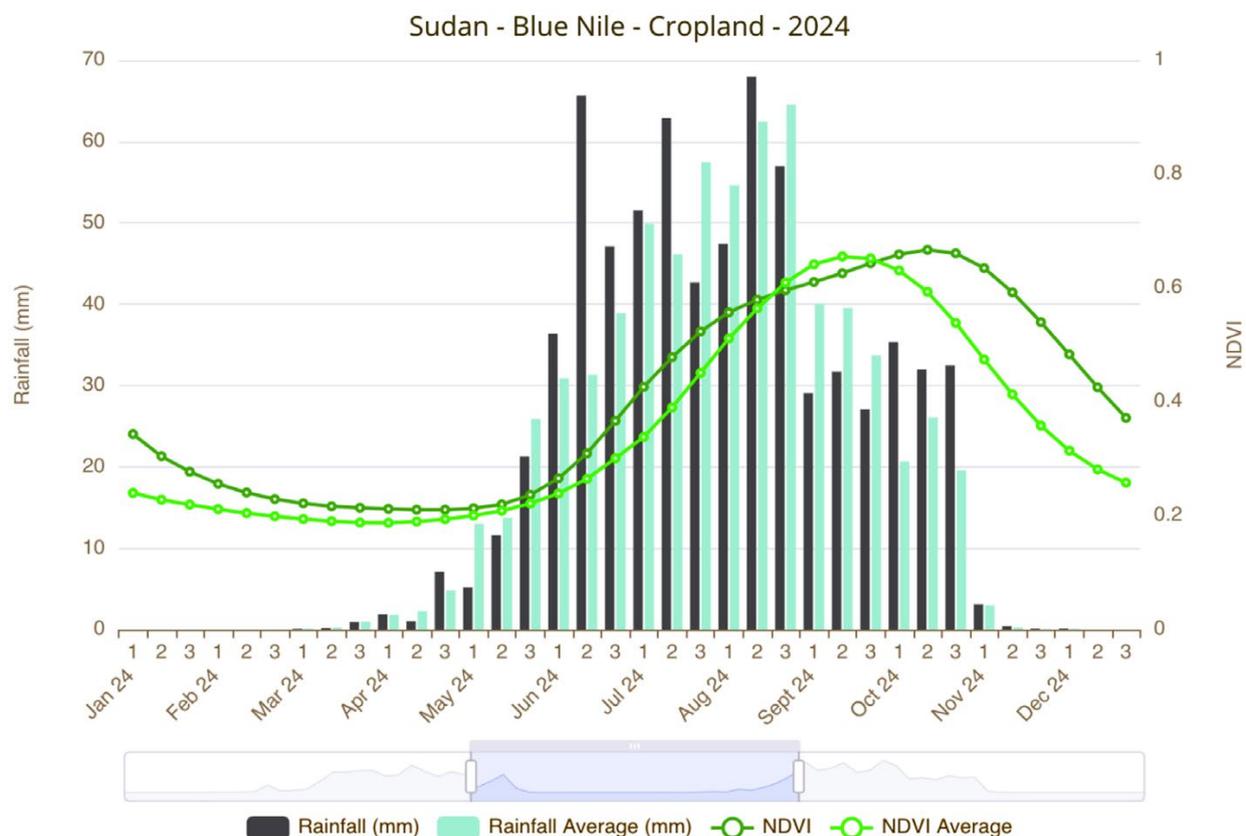
Figures 4 to 7 show the temporal distribution of rainfall in Gedaref, White Nile, Blue Nile and Kassala. There was substantial rainfall in all 10-day periods during the rainy season in all four states. The resulting NDVI trends, which express the cumulative effect of the environmental conditions on crop growth, were as follows:

- ◆ **Gedaref:** Above average.
- ◆ **White Nile:** Above average
- ◆ **Blue Nile:** Above average until the end of August. Slightly below average until late October, presumably due to some excess rainfall. Above average in November and December
- ◆ **Kassala:** Above average

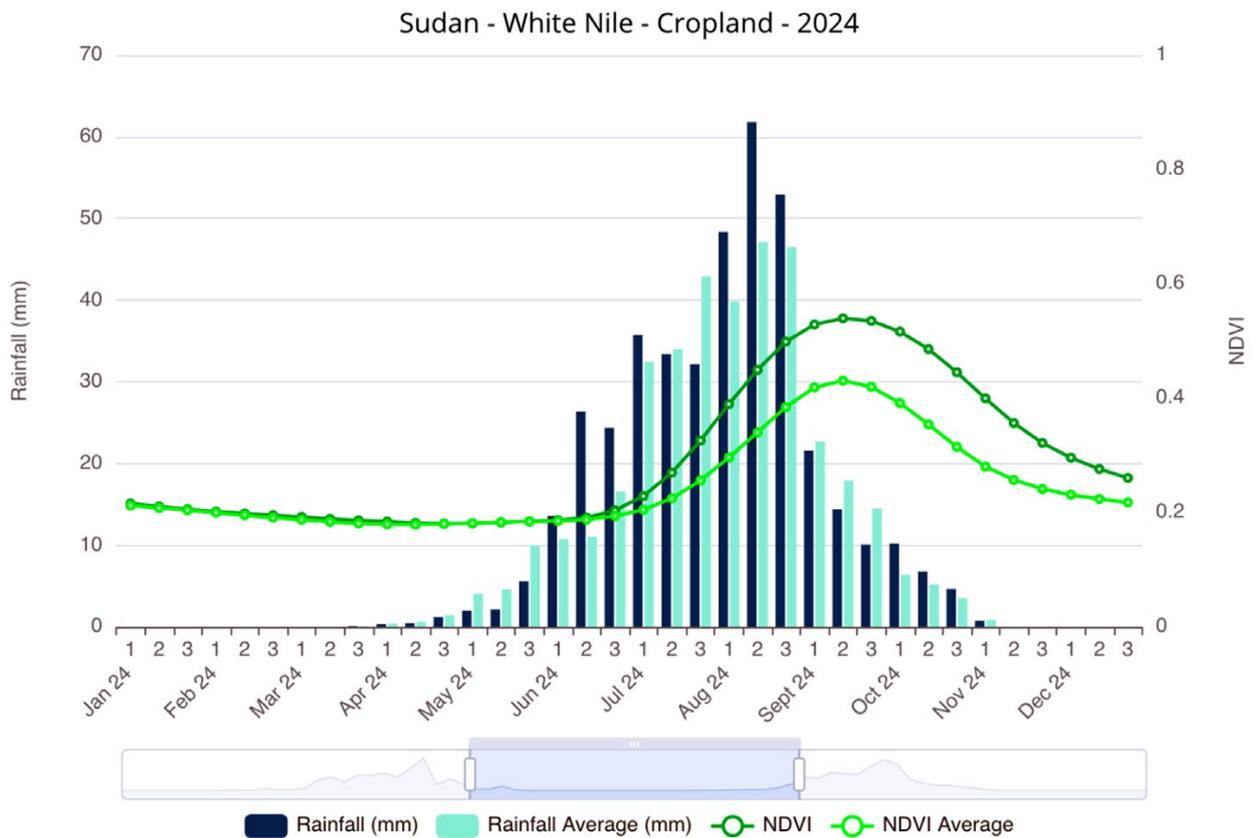
Farmers planted sorghum over a relatively long period, with the last fields planted in early September. For the majority of the fields, grain filling starts in October, and the plants reach maturity in December. The peak of NDVI is a good measure of yield in cereals (Schulthess et al., 2013), which set grain number shortly after flowering when the canopy reaches its peak. Cereals also store a high amount of carbohydrates in the stems at that time, for later translocation to the grain. The NDVI peaks surpassed the 20-year average in all four states. This, in combination with far above average NDVI values in October and November, indicates favorable conditions for above average yields.



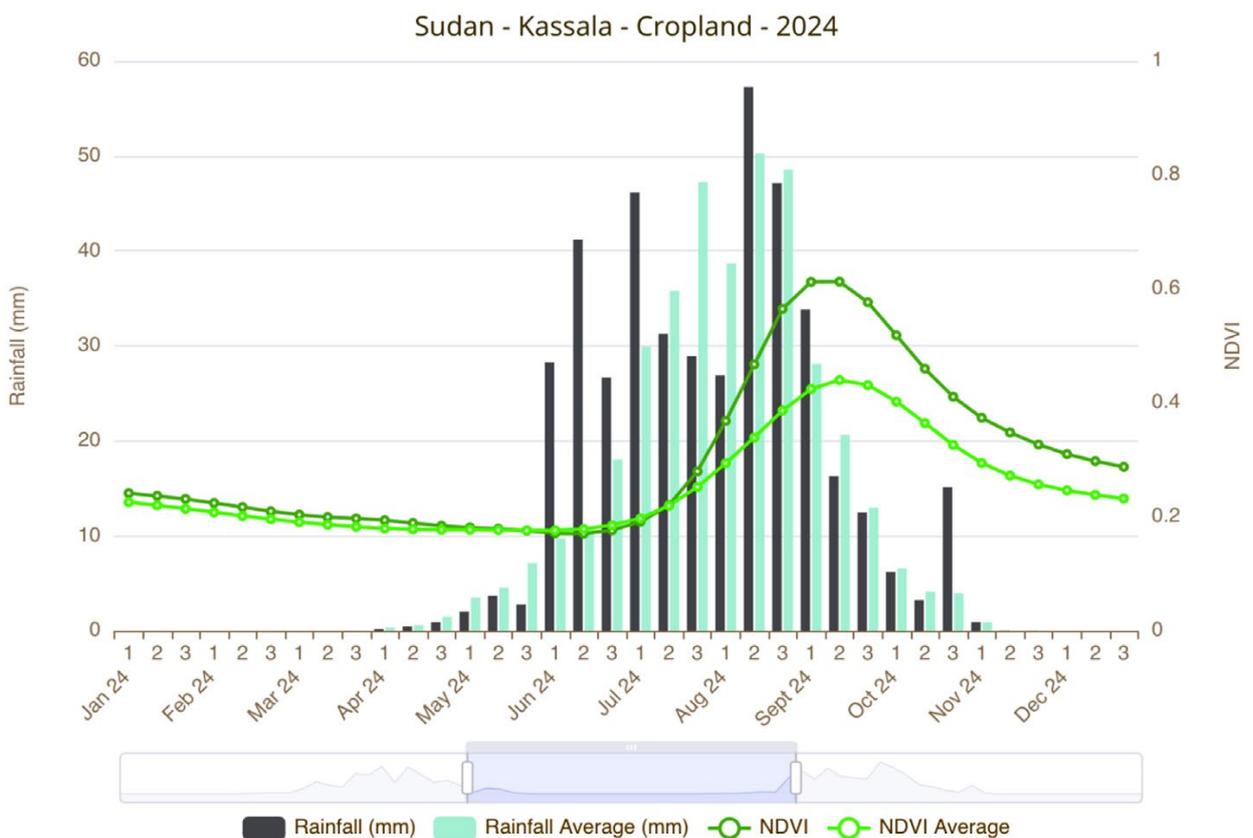
**Figure 4: Temporal rainfall distribution and NDVI trend for Gedaref over cropland in 2024. The reference periods are 1994-2013 for the rainfall average and 2002-2013 for NDVI. (Source: WFP).**



**Figure 5: Temporal rainfall distribution and NDVI trend for Blue Nile over cropland in 2024. The reference periods are 1994-2013 for the rainfall average and 2002-2013 for NDVI. (Source: WFP).**



**Figure 6: Temporal distribution of rainfall and NDVI trend for White Nile over cropland in 2024. The reference periods are 1994-2013 for the rainfall average and 2002-2013 for NDVI. (Source: WFP).**



**Figure 7: Temporal distribution of rainfall and NDVI trend for Kassala over cropland in 2024. The reference periods are 1994-2013 for the rainfall average and 2002-2013 for NDVI. (Source: WFP).**

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