SUDAN CRISIS ANALYSIS

Remote Sensing to Anticipate Agriculture Conditions: Gedaref State

MARCH 2024

This paper is an update to satellite imagery analysis conducted in <u>August</u> and <u>September 2023</u> across Sudan, measuring vegetation levels in agricultural areas to better understand the impact of conflict on agriculture. This further analysis assesses the impact of weather conditions (rainfall, soil moisture, temperature) on vegetation health, and tentatively predicts vegetation health in agricultural areas for the 2024 early planting season, as a proxy for agricultural productivity. This paper focuses on the outlook for Gedaref State. Papers covering Kassala, Blue Nile, and South Kordofan States, and an overall briefing paper for all four states, were also produced as part of this analysis.¹

Key Findings

- The main soil type in Gedaref is *versitols* this is clay-rich soil, which is generally chemically fertile but has a relatively poor capacity to absorb water.² In previous years, Gedaref has been particularly susceptible to erratic rainfall causing both flash flooding and dry spells, with soil moisture a dominant factor affecting vegetation health.
- Rainfall and soil moisture projections suggest that from March to July 2024, weather conditions will be particularly favourable for cultivation in the centre Gedaref State, while conditions are projected to be unfavourable in small areas in the central-south and south-east borders.
- Despite favourable weather conditions, long-term maintenance challenges, and armed clashes, suggest that cultivation in the Rahad Irrigation Scheme may be severely disrupted in early 2024.
- Secondary data indicates that agricultural production in Gedaref will likely be impacted by desert locust invasions, lack of agricultural inputs and agricultural assistance, and market disruptions caused by conflict. Other factors which may impact production are poor irrigation infrastructure, displacement, and disruption to the labour market.

Introduction

Conflict in Sudan has had a profound impact on food security across the country. Since April 2023 the number of people classified as acutely food insecure (in IPC phase 3 or above) has risen steadily, reaching 17.7 million people (37% of the population) for the period October-December 2023³. Domestic agricultural production is critical as it supports both livelihoods and food availability – in particular since the outbreak of conflict in April 2023, which has disrupted national and international food trade flows⁴.

With the planting season upcoming, this report aims to inform agricultural assistance planning, by providing an indication of the opportunities and risks to agricultural production in different areas of Gedaref State.



¹ These will be published on the Mercy Corps <u>resources website</u>.

² D. Smiles, P.A.C. Raats (2005): <u>Encyclopedia of Soils in the Environment</u>.

³ IPC (2024): <u>Sudan: Acute Food Insecurity Projection Update for October 2023</u>.

⁴ FAO (2023): <u>The Sudan Summer Season Rapid Assessment</u>.

Context: Agriculture in Gedaref State

Gedaref is part of the "breadbasket" of Sudan and a key production area for sorghum and sesame. Gedaref contains 6% of arable land in Sudan,⁵ and combined with Al Jazirah State contributes 50% of Sudanese sorghum production. In 2023, sorghum occupied the largest planted area in Gedaref State, followed by sesame and millet. Relatively small areas are planted with sunflower, cotton, groundnuts and other crops.⁶ The majority of agricultural land in Gedaref is semi-mechanized rainfed agriculture, and there is large-scale irrigation at Rahad.⁷

Agriculture types in Sudan⁸

Irrigated: Large schemes use river flows from the Nile and its tributaries, spate irrigation uses seasonal flooding. Main crops are sorghum, sugarcane, cotton, wheat and alfalfa. Main reported causes of poor yields: floods and waterlogging, plant invasions, poor maintenance of irrigation channels and equipment.

Semi-mechanized Rainfed: Mostly large entrepreneurial farms: average size 420 hectares. Mechanisation is limited to land preparation, sowing and sometimes harvesting.Main crops are sorghum and millet; others are sesame, sunflowers, millet and cotton. Main reported causes of poor yields: lack of agricultural finance, poor rainfall, poor supply or price of inputs.

Traditional Rainfed: Mainly family-owned farms (2-50 hectares), using mainly traditional methods and minimal chemical inputs. Cultivation is largely for subsistence: main crops are millet and sorghum. Main reported causes of poor yields: unfavourable rainfall, lack of seed distributions, poor access to land.





Rahad irrigation scheme: As of 2022, the Rahad scheme was producing far below average yields due to adverse weather conditions and poor irrigation infrastructure. Only 4 out of 11 irrigation pumps are functional, 2 of which are used primarily for drinking water. Irrigation channels have been insufficiently cleaned, impeding the flow of water. This irrigation scheme relies on rainwater for 40% of its water needs.¹⁰

Winter wheat cultivation began in the Rahad scheme in 2023, but is expected to be constrained by limited agricultural finance, shortage and high cost of agricultural inputs, including fertilisers, seeds, and fuel, and hotter-than-typical weather conditions.¹¹

While Gedaref has in general been calm compared to conflict hotspot areas in Khartoum, Greater Darfur and Greater Kordofan, the sorghum and millet harvest (November - January) was reportedly disrupted by conflict which prevented farmers from accessing their fields. In particular, clashes between the RSF and SAF have

⁵ IFPRI (2003): <u>The Architecture of the Sudanese Agricultural Sector and Its Contribution to the Economy between 1990 and 2021</u>.

⁶ FAO (March 2023): <u>The Sudan, 2022 Crop and Food Supply Assessment Mission</u>.

⁷ UNOCHA (March 2023): <u>State Profile: Gedaref</u>.

⁸ FAO (March 2023): <u>The Sudan, 2022 Crop and Food Supply Assessment Mission</u>; UNEP (2020): <u>Sudan- First State Environment Outlook</u> <u>Report</u>; FAO (2023): <u>The Sudan Summer Season Rapid Assessment</u>.

⁹ FAO (2023): <u>The Sudan Summer Season Rapid Assessment</u>.

¹⁰ FAO (March 2023): <u>The Sudan, 2022 Crop and Food Supply Assessment Mission</u>.

¹¹ FEWSNET (December 2023): <u>Food Security Outlook Update</u>.

been reported in Al Fao, close to the border with Al Jazirah State, and the location of the Rahad irrigation scheme.¹² This was expected to reduce the size of the 2023 harvest.¹³





ACLED incidents included in the map are: battles,riots, violence against civilians, and explosions/remote violence.

Food security in Gedaref:

- 16% of the population of Gedaref were projected to be acutely food insecure before the outbreak of conflict,¹⁴ compared to 19% in the current projection period (October 2023 February 2024).¹⁵
- In AI Fao Locality, food was the number one need reported by IDPs in December 2023: reports suggested that food was available on markets in AI Fao, but that IDPs lacked financial resources to purchase food.¹⁶

¹² ACLED Conflict database, accessed 26.02.24.

¹³ FEWSNET (December 2023): <u>Food Security Outlook Update</u>.

¹⁴ UNOCHA (March 2023): <u>State Profile: Gedaref</u>.

¹⁵ IPC (2024): <u>Sudan: Acute Food Insecurity Projection Update for October 2023</u>.

¹⁶ NRC (December 2023): <u>Rapid Needs Assessment, Al Fao Locality, Gedaref.</u>

Impact of Rainfall and Soil Moisture on Cropland Vegetation since 2015

Rainfall and soil moisture

This analysis serves as an extension to the Mercy Corps study that assessed changes in vegetation in agricultural areas prior to the harvest season last year. It integrates environmental factors like soil moisture and precipitation, assessing the impacts of these factors on vegetation health (see Annex 1 for methodology).¹⁷

- Effect of soil moisture: The analysis shows that soil moisture is the dominant factor impacting vegetation health.
- Effect of rainfall: Precipitation, although less impactful than soil moisture, is still a significant predictor for vegetation health. This suggests that

Cropland vegetation health is measured using the **Normalized Difference Vegetation Index (NDVI)**. By measuring the density and colour of foliage, NDVI can be used to remotely assess vegetation health. **NDVI is often used as a proxy for agriculture productivity**, however it is not a direct indicator of this; for example NDVI does not distinguish between crops and weeds. This analysis used existing geospatial data on **monthly total precipitation, median soil moisture, median soil temperature and maximum NDVI, from 2015-2023.** It analyses the relationship between these drivers to make projections for NDVI until July 2024. For more information see the technical report for this analysis.

while immediate soil moisture is paramount for vegetation health, the cumulative rainfall over the preceding four months cannot be overlooked.

• Soil moisture retention and rainfall infiltration: The analysis shows that there is a closer link between soil moisture levels and vegetation health compared to rainfall volume alone.





Gedarif State Precipitation, Soil Moisture, and NDVI - 04/15 - 11/23 w/ IPC Classification

¹⁸ IPC level data is **indicative only:** locality-level classifications were established using the FEWSNET methodology, where the highest classification represented by more than 20% of the population is shown..Time series plots represent monthly values for NDVI, soil moisture and precipitation.

¹⁷ Full analysis and methodology are available in a Technical Report; contact <u>crisisanalysis@mercycorps.org</u> for further information.

Contextualising drivers of agricultural productivity and food security

2023/24: Figure 2 reflects the low precipitation reported in the south-east of Sudan in 2023, coinciding with a decrease in peak vegetation health. This adds to reports which together suggest that, while the planted area in Gedaref was initially slightly higher than previous years, low and erratic rainfall, lack of access to agricultural inputs, and pest destruction led to poor harvests. In addition, the disruption of harvests following the deterioration of the security situation in the south-east of Sudan between December 2023 and January 2024 has likely contributed to a 42-27% decrease in sorghum supply in the AI Gadarif market in these months, compared to previous years.¹⁹

2022/23: While peak vegetation health was high in 2022, precipitation and soil moisture were below previous years. This may reflect reports that Gedaref experienced late onset of rains, followed by downpours and waterlogging in the Rahad irrigation scheme, which also suffered from dysfunctional equipment. Farmers also reported low effectiveness of herbicides compared to previous years, which contributed to low yields. Together, these factors led to a 13-14% decrease in production in Gedaref state, while the rest of the country saw above-average harvests.²⁰

2021/22: Agricultural production was reportedly low across Sudan in 2021, due to below average and erratic rainfall. In Gedaref this reportedly translated to dry spells and flash flooding, which was further exacerbated by pest damage. The Rahad irrigation scheme reportedly suffered from waterlogging, due to flash flooding and poor maintenance of irrigation channels.²¹ This poor distribution of rainfall appears to be represented by the high but short-term precipitation peak in Figure 2, which is followed significantly later by a rise in soil moisture.

Projected Cropland Vegetation Quality in Gedaref in 2024

Figures 3 and 4 below represent projections of cropland vegetation health in Gedaref State in the next four months based on projected weather conditions (rainfall, soil moisture and soil temperature). Figure 3 represents the projected cropland health, while Figure 4 represents the projected difference from average vegetation health. Key findings are:

- The majority of the state, which is dominated by semi-mechanized rainfed agriculture, is expected to see average levels of cropland vegetation health at the beginning of the planting season in June, with some small areas seeing above average vegetation health. This suggests a favourable beginning to the planting season based on weather conditions, though previous analysis shows that favourable conditions can easily change throughout the season.²²
- In July, cropland vegetation health in the centre of the state (around Mid Gedarif, El Gedarif, Al Fao and Al Mafaza localities) is projected to be above average. Favourable conditions in these areas of high density cropland (see Map 1) which traditionally supply much of the country with staple crops, may indicate that these areas show high potential for large-scale domestic food production.
- In July, parts of the central south, and south-eastern borders of the state, are projected to see below average vegetation health compared to previous years. This may point to a late arrival of the rains which could delay planting, or a season-long reduction in vegetation cover which could reduce

¹⁹ FEWSNET (December 2023): <u>Food Security Outlook Update</u>; FAO (2023): <u>The Sudan Summer Season Rapid Assessment</u>; Mercy Corps (September 2023): <u>Remote Sensing to Monitor Impact of Conflict on Agriculture: Round 2</u>; WFP (January 2024): <u>Market Monitor, Sudan</u>.

²⁰ FAO (March 2023): <u>The Sudan, 2022 Crop and Food Supply Assessment Mission</u>.

²¹ FAO (March 2022): <u>The Sudan, 2021 Crop and Food Supply Assessment Mission</u>.

²² Mercy Corps (September 2023): <u>Remote Sensing to Monitor Impact of Conflict on Agriculture: Round 2</u>.

agricultural production in this area over the season. It may also increase the likelihood of flash flooding later in the rainy season, as has been reported in Gedaref in previous years (see Contextualising Drivers of Agricultural Production and Food Security, page 4).

 The area surrounding the Rahad irrigation scheme is expected to see average cropland vegetation health. Despite relatively good weather projections, the reported decline of infrastructure in the Rahad irrigation scheme, and reports of armed clashes in the area, are likely to negatively impact agricultural production in the irrigation scheme.^{23 24}



Figure 3: Projected cropland vegetation quality in Gedaref State

²³ FAO (March 2023): <u>The Sudan, 2022 Crop and Food Supply Assessment Mission</u>.

²⁴ <u>ACLED Conflict database, accessed 26.02.24.</u>





Contextualising results: other drivers of agricultural production

The remote sensing results above give an indication of agricultural production considering weather projections, *all else equal.* As in previous years, socio-economic factors are likely to influence agricultural production and therefore food insecurity: particularly given the ongoing conflict since April 2023.²⁵

Expected drivers of agricultural production in Gedaref in 2024:

Conflict: While the conflict since 15 April has been chaotic and difficult to predict, conflict is projected to spread further East in 2024, beginning with White Nile and Sennar and reaching Gedaref and Kassala in the medium term.²⁶ Self-defence groups across the Eastern states are reportedly mobilising in preparation for an RSF advance on the region, increasing the risk of high casualties and mass displacement.²⁷ In January 2024, clashes between the RSF and SAF were reported in Al Fao locality.²⁸ Conflict in Gedaref would likely lead to the same impacts as have been seen in other states: disruption

²⁵ FEWSNET (December 2023): <u>Food Security Outlook Update</u>.

²⁶ ACLED Watchlist 2024 (January 2024): <u>Sudan, Setting the Stage for a Long War</u>.

²⁷ FEWSNET (December 2023): Food Security Outlook Update; Crisis Group (January 2024): Sudan's Calamitous War.

²⁸ <u>ACLED Conflict database, accessed 26.02.24.</u>

to cultivation activities, destruction and looting of cropland, grain stores and infrastructure, closure of markets and interruption of humanitarian assistance.²⁹

- **Displacement:** As of February 2024, there are estimated to be over 400,000 IDPs in Gedaref State, many of whom arrived following the clashes in AI Jazirah state in December 2023.³⁰ Tensions between IDP and host communities due to shortages of basic goods, including food, and saturation of the labour market leading to lower wages, are reportedly particularly severe in Gedaref.³¹
- **Irrigation infrastructure:** Irrigation infrastructure in Gedaref was in poor condition before the outbreak of conflict in 2023.³² Conflict is projected to continue to hamper maintenance of irrigation channels, reducing yields, and the recent clashes in AI Fao may lead to destruction and the total interruption of irrigation activities if they continue.³³
- Agricultural inputs: The prices of agricultural inputs in Gedaref, including tractors, machinery, fertilisers and herbicides, and seeds, had increased in price by at least 14.3% and at most 430.3% between 2021 and 2022.³⁴ Since the outbreak of conflict, price rises have continued to rise while supply has diminished, with many producers using stocks held over from previous years.³⁵ Considering the dominance of semi-mechanized agriculture in Gedaref, which relies heavily on inputs compared to traditional rainfed agriculture,³⁶ these shortages may particularly impact production in the state.
- Agricultural assistance: Farmers in the east of Sudan (Gedaref, Kassala, Red Sea) received a relatively large proportion of agricultural finance in previous years,³⁷ and in 2023 lack of agricultural finance was cited as a reason for poor agricultural production across the country.³⁸ Lack of government assistance is expected to continue into 2024 as conflict persists, constraining the capacity of the Sudanese government. This is likely to exacerbate the impact of price rises for agricultural inputs, cited above. The relatively good humanitarian access to the state ³⁹ may compensate for this, however the spread of conflict may severely limit humanitarian activity as it did in Al Jazirah State.⁴⁰
- **Grain stores:** Gedaref contains some of the largest grain storage silos in Sudan; these are vital for storing surplus grain production.⁴¹ Prior to the conflict, the Sudanese government was struggling to maintain its system of buying up surplus wheat to store in strategic reserves; this dysfunction can be expected to be exacerbated by the conflict since April 2023. Following the looting of grain stores during the conflict in AI Jazirah in December 2023, there were reports of stocks in Gedaref being moved to rural locations or panic-sold in advance of an expected invasion.⁴² Reduction in grain stores, through looting, sale, or inability of the Strategic Reserves Company to purchase surplus, will likely have serious implications for future food security.
- **Market functionality:** The ability of producers to export surplus production from Gedaref to other States in Sudan has been hampered by conflict in Khartoum and disruption to transport routes across

²⁹ FEWSNET (December 2023): <u>Food Security Outlook Update</u>.

³⁰ IOM DTM (February 2024): <u>Sudan Weekly Displacement Snapshot</u>; FEWSNET (December 2023): <u>Food Security Outlook Update</u>.

³¹ FAO: <u>The Sudan Summer Season Rapid Assessment, 2023</u>

³² FAO (March 2023): <u>The Sudan, 2022 Crop and Food Supply Assessment Mission</u>.

³³ IPC (2024): <u>Sudan: Acute Food Insecurity Projection Update for October 2023</u>; FEWSNET (December 2023): <u>Food Security Outlook Update</u>.

³⁴ FAO (March 2023): <u>The Sudan, 2022 Crop and Food Supply Assessment Mission</u>.

³⁵ FEWSNET (December 2023): <u>Food Security Outlook Update</u>.

³⁶ FAO (March 2023): <u>The Sudan, 2022 Crop and Food Supply Assessment Mission</u>.

³⁷ FAO (March 2023): <u>The Sudan, 2022 Crop and Food Supply Assessment Mission</u>.

³⁸ FAO: <u>The Sudan Summer Season Rapid Assessment, 2023</u>.

³⁹ UNOCHA (January 2024): <u>3W Matrix of Operational Presence in Sudan</u>.

⁴⁰ WFP (February 2024): <u>Urgent Call for Safe Access to Feed Millions</u>.

⁴¹ FEWSNET (December 2023): <u>Food Security Outlook Update</u>.

⁴² FEWSNET (December 2023): <u>Food Security Outlook Update</u>.

the country.⁴³ Furthermore, the central market in Al Gadarif town reportedly closed during the clashes in Al Jazirah State in December 2023. Without the possibility to sell produce from 2023, the capacity of the agricultural sector to continue producing in 2024 may be reduced.

- **Pests and diseases:** As of February 2024, FAO warns that the desert locust situation has reached threat level, with Eastern States particularly at risk. This is reportedly due to constraints on the Sudanese government's ability to implement control measures, and a shortage of pesticides across the country, which are expected to continue as the conflict continues.⁴⁴
- Flooding: While the impact of flooding varies year-on-year, flooding has impacted Gedaref repeatedly in recent years.⁴⁵ Gedaref was reportedly the second most flood-affected state in March 2023.⁴⁶ Flash flooding can directly affect agriculture through replanting or total crop failure and waterlogging of irrigated areas, and indirectly through disruption to transport, which is vital for sales of surplus grains from Gedaref State to the rest of the country.^{47 48} While it is difficult to assess flood risk in the scope of this paper, cataloguing MODIC NRT flood extent data may help to better inform regions where flooding could cause larger problems.

Recommendations

- Support semi-mechanized agriculture in central and eastern Gedaref to increase domestic food production. Weather conditions are projected to be particularly favourable for agriculture around Mid Gedarif, El Gedarif, Al Fao and Al Mafaza localities, presenting an opportunity for high . However without support producers are unlikely to have the resources to capitalise on these good conditions. Based on past reports, cash or credit-based assistance, or the provision of machinery and chemical inputs may be high priority for producers in Gedaref, however this should be checked against market studies and other ground data.
- Support areas in central south and south-eastern Gedaref to avoid under-performance: considering Gedaref is usually a net exporter of agricultural produce, below-average harvests may contribute to worsening food supply across the country, while having little impact on food availability in Gedaref itself. In these areas, agricultural assistance might be able to mitigate the impact of poor weather conditions to improve agricultural production and thus food supply to other areas of Sudan. However, this should be checked against ground data, as other factors are expected to constrain food access in Gedaref, necessitating food and/or cash assistance to improve food security.
- **Rehabilitate irrigation infrastructure in Rahad:** Infrastructure in the Rahad scheme appears to be in a particularly poor condition, due to several years of under-maintenance. Without intervention, yields in the Rahad scheme are likely to be very low, despite the favourable weather conditions projected for 2024.
- **Support transport infrastructure and market functionality:** While weather conditions are projected to be favourable for large harvests, barriers to selling and transporting products will have implications for the agricultural sector in Gedaref, and for food security across the country. Methods

⁴³ Mercy Corps (September 2023): <u>Remote Sensing to Monitor Impact of Conflict on Agriculture: Round 2</u>.

⁴⁴ IPC (2024): <u>Sudan: Acute Food Insecurity Projection Update for October 2023</u>; UN Geneva (2024): <u>Press Briefing, 6 February 2024</u>.

⁴⁵ FAO (March 2023): <u>The Sudan, 2022 Crop and Food Supply Assessment Mission</u>; FAO (March 2022): <u>The Sudan, 2021 Crop and Food</u> <u>Supply Assessment Mission</u>; Mercy Corps (September 2023): <u>Remote Sensing to Monitor Impact of Conflict on Agriculture: Round 2</u>.

⁴⁶ UNOCHA (March 2023): <u>State Profile: Gedaref</u>.

⁴⁷ FAO (March 2023): <u>The Sudan, 2022 Crop and Food Supply Assessment Mission</u>.

⁴⁸ UNEP (2020): <u>Sudan- First State Environment Outlook Report</u>.

of ensuring that producers can reliably store, sell and transport their produce, including **parallel cash assistance**, could be explored. This <u>recent analysis</u> of agri-food and payment systems in Sudan might provide guidance on balancing supply and demand.

- Deliver timely assistance for the planting season: Weather conditions in June are projected to be relatively more stable than in July, where deviations from average conditions suggests a risk of dry spells or flooding. Assistance to farmers should therefore be delivered in time to allow farmers to begin planting in May and June, and capitalise on these favourable conditions.
- **Continue to monitor soil moisture and rainfall:** The projections in this analysis only cover until July 2024, after which weather conditions may change. Changes to precipitation and soil moisture, monitored remotely, can help to predict and prevent the effects of adverse weather conditions. Further, vegetation health in many areas was shown to be affected by conflict and related economic and sociopolitical factors throughout 2023, so analysis should be updated regularly to monitor such impact in 2024.⁴⁹

⁴⁹ Mercy Corps (September 2023): <u>Remote Sensing to Monitor Impact of Conflict on Agriculture: Round 2</u>.

Annex 1: Methodology and Limitations

This assessment uses publicly available data on Google Earth Engine (GEE) to collect soil moisture, precipitation, and NDVI data from April 1, 2015, to January 31, 2024 in Gedaref State. Following data cleaning, machine learning was used to determine the impact of soil moisture and precipitation on NDVI. Finally, a pixelby-pixel model was developed to spatially predict NDVI in the coming months. More detailed description of the remote sensing methodology can be found in the technical paper.⁵⁰

Remote sensing data is triangulated with secondary data in order to understand the interaction of soil moisture and precipitation with other drivers of agricultural productivity in Gedaref State. Publicly available data was collected through online searches and communication with humanitarian actors in Sudan. Qualitative information was manually coded by theme and geographical area, and cross-checked between sources.

Limitations:

- While the relation between soil moisture and NDVI has been found to be relatively robust, NDVI is an imperfect proxy for agricultural productivity and thus predicted NDVI should not be equated to predicted agricultural productivity.
- Forecasts are based only on historical performance-long-term changes to 'normal' patterns or shocks are not accounted for in the model. This may impact the accuracy of the projections.
- Due to time constraints, the secondary data review is not comprehensive; qualitative data cited in this report should be considered as reliable but incomplete information about drivers of agricultural productivity in Gedaref.
- Due to ongoing conflict and institutional constraints to humanitarian access, it has not been possible to collect qualitative information directly for this assessment. Results should be combined with ground-level information and discussed with local practitioners before being applied to programme planning.

⁵⁰ Please contact <u>crisisanalysis@mercycorps.org</u> to access the document.

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