SUDAN CRISIS ANALYSIS

Remote Sensing to Anticipate Agriculture Conditions: Kassala State

MARCH 2024

This paper is an update to satellite imagery analysis conducted in August and September 2023 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 Kassala State. Papers covering Gedaref, 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

- Even prior to the conflict, food insecurity and malnutrition indicators were more severe in Kassala compared to the national average, reflecting weather conditions such as erratic rainfall, but also lack of grain stores, localised conflicts and illicit border trade.
- A prominent soil type in Kassala is favourable for moisture retention: this may increase resilience of vegetation to dry spells but increase vulnerability to waterlogging.[2] In previous years, soil moisture has been the dominant factor affecting vegetation health, followed by recent rainfall.
- Rainfall, soil moisture and soil temperature projections indicate that conditions will be generally favourable for the planting season. Conditions are projected to be particularly favourable in Rifi Halfa locality, and relatively unfavourable in Rifi Wed Hilaio locality.
- While remote sensing results give an indication of agricultural productivity *all else equal,* secondary data indicates that agricultural productivity in Kassala is likely to be negatively impacted by displacement, lack of maintenance to irrigation infrastructure, and lack of access to agricultural inputs and agricultural finance. Agriculture in the state might also be impacted by direct conflict, flooding and waterlogging, or pests and diseases.

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 2023[3]. 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 flows[4]. **With the planting season upcoming, this report aims to inform agricultural assistance planning, by providing an indication of the opportunities and risks to agricultural productivity in different areas of Kassala State.**

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[1] These will be published on the Mercy Corps resources website.

[2] "Flash flooding" is rapid flooding, usually as a result of heavy rainfall following prolonged dry periods, whereas "waterlogging" describes the rise of the water table into the root zone of the soil profile, such that plant growth is adversely affected by deficiency of oxygen (FAO).

[3] IPC (2024): Sudan: Acute Food Insecurity Projection Update for October 2023.

[4] FAO (2023): The Sudan Summer Season Rapid Assessment.

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Context: Agriculture in Kassala State

Kassala is part of the "breadbasket" of Sudan due to its abundant water resources, arable land and livestock: the total cultivable area is 1.7 million hectares.[6] In 2023, sorghum occupied the majority of cultivated area, with relatively small areas planted with millet, sesame, groundnuts and very small areas planted with sunflower and cotton.[7] The majority of agricultural land in Kassala State is classified as semi-mechanized rainfed, with some traditional rainfed agriculture and two irrigation areas:

Halfa Al-Jadeeda irrigation scheme: producing sorghum, wheat, groundnut, sunflower, sugar and cotton as of 2022/23. The Halfa al-Jadeeda scheme saw significantly below average harvests in 2022/23 harvest, due to flooding and waterlogging, hyacinth invasion and poor maintenance.[8] While there are no reports of conflict events in the area since April 2023,[9] Halfa al-Jadeeda likely saw a decrease in planted area in 2023 compared to previous years [10][11][12] due to secondary impacts of the conflict, particularly displacement to the area[13] and lack of access to inputs.[14] Winter wheat cultivation in Halfa al-Jadeeda began in December 2023, but was reportedly limited by agricultural finance, shortage and high cost of agricultural inputs, including fertilisers, seeds, and fuel, and hotter-than-typical weather conditions.[15]

Spate irrigation on the Gash river: producing mainly sorghum as of 2022/23. [16] The Gash river is also a source of drinking water for the area. Since 2014 concerns have been raised about increasing population leading to environmental degradation of the river.[17] The reduced planted area in irrigated cropland, reported across Kassala, is likely to have impacted the Gash river area.[18]

Agriculture types in Sudan[5]

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.

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[5] FAO (2023): The Sudan, 2022 Crop and Food Supply Assessment Mission; UNEP (2020): Sudan- First State Environment Outlook Report; FAO (2023): The Sudan Summer Season Rapid Assessment.

[6] CMI (July 2020), Agricultural development and food Security in Sudan as seen from Kassala State.

[7] FAO (2023): The Sudan Summer Season Rapid Assessment.

[8] FAO (2023): The Sudan, 2022 Crop and Food Supply Assessment Mission.

[9] ACLED Conflict database, accessed 26.02.24.

[10] FAO (2023): The Sudan, 2022 Crop and Food Supply Assessment Mission.

[11] FAO (2023): The Sudan Summer Season Rapid Assessment.

[12] Mercy Corps (September 2023): Remote Sensing to Monitor Impact of Conflict on Agriculture: Round 2.

[13] IOM DTM (2023): DTM April 2023 - December 2023.

[14] FAO (2023): The Sudan Summer Season Rapid Assessment.

[15] FEWSNET (December 2023): Food Security Outlook Update.

[16] FAO (2023): The Sudan, 2022 Crop and Food Supply Assessment Mission.

[17] The Niles (2014): Press Release: The Gash suffers, Kassala locals at risk of disease, Jan 2014.

[18] FAO (2023): The Sudan, 2022 Crop and Food Supply Assessment Mission; FAO (2023): The Sudan Summer Season Rapid Assessment.

This area has no reported conflict events since April 2023,[19] but has seen the arrival of IDPs since April 2023, although in lower numbers than Halfa Al-Jadeeda.[20]

**Figure 1: Estimated planted area in Kassala: 5-year average[21]**

● Irrigated (~129,110 ha)
● Traditional Rainfed (~135,970 ha)
○ Semi-mechanized (~692,440 ha)
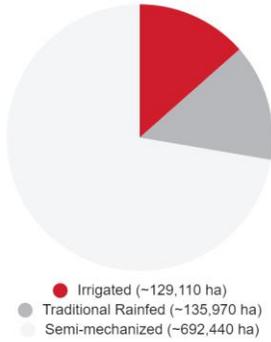
Figure 2: Estimated planted area in Kassala 2023[22]

● Irrigated (~58,570 ha)
● Traditional Rainfed (~147,010 ha)
○ Semi-mechanized (~427,230 ha)
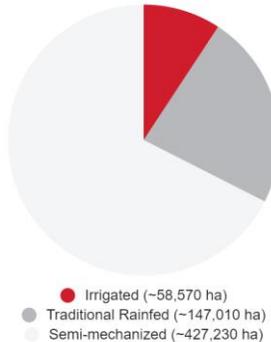
Figure 3: Estimated Sorghum production in Kassala: 5-year average[23]

● Irrigated (36.1%)
● Traditional Rainfed (11.5%)
○ Semi-mechanized (52.5%)
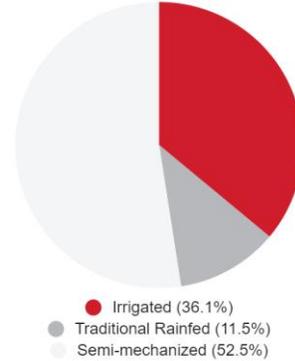
Map 1: Cultivated area in Kassala and conflict incidents recorded by ACLED since 15 April 2023
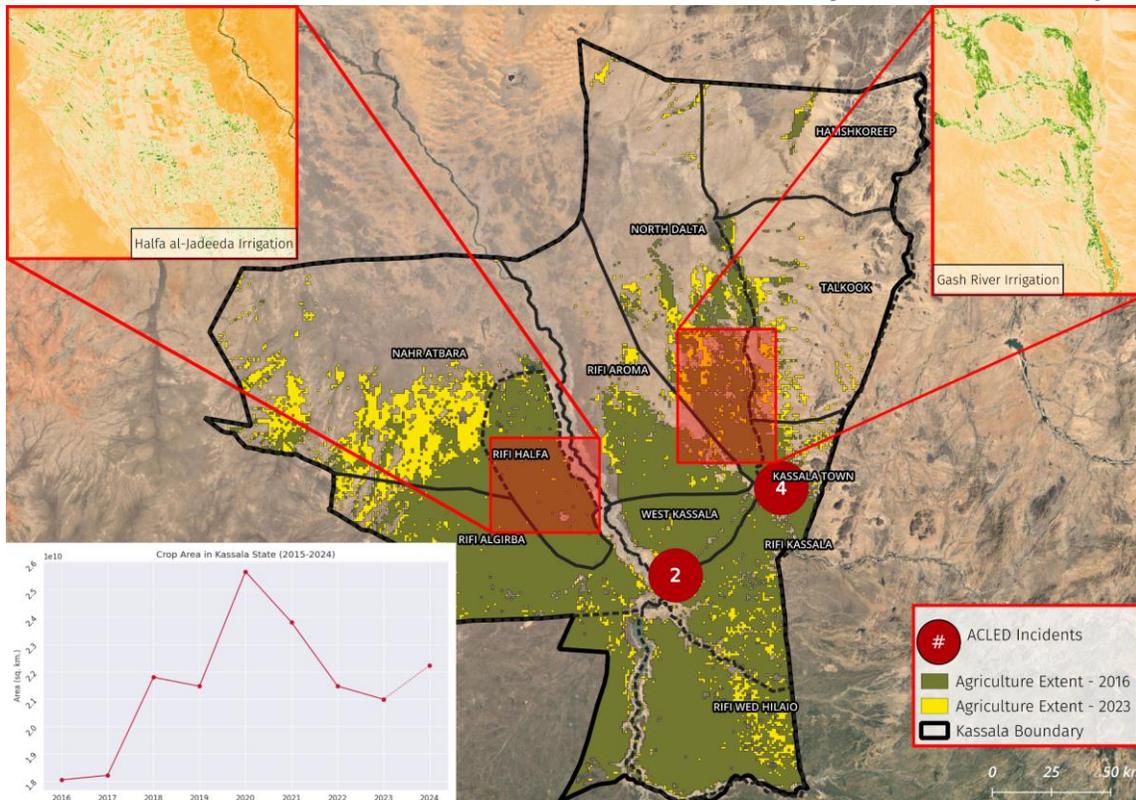
ACLED incidents included in the map are: battles, riots, violence against civilians, and explosions/remote violence.

[19] ACLED Conflict database, accessed 26.02.24.

[20] IOM DTM (February 2024): Sudan: Weekly Displacement Snapshot 20 Feb 2024.

[21] Analysis from secondary data- **indicative only**. Sums of five-year average from 2017/18 to 2021/22 for sorghum, millet, wheat, sesame, groundnut, sunflower, cotton. Does not include sugar. Source: FAO (2023): The Sudan, 2022 Crop and Food Supply Assessment Mission.

[22] As reported by: FAO (2023): The Sudan Summer Season Rapid Assessment.

[23] Five-year average from 2017/18 to 2021/22, as reported by: FAO (2023): The Sudan, 2022 Crop and Food Supply Assessment Mission.

Food security in Kassala

- As of 2020, the main food consumed in Kassala is sorghum, and despite the large mechanised sector, household production is an important part of food consumption.[24]
- Food insecurity and malnutrition indicators for Kassala were more severe than the national average prior to the outbreak of conflict. This was reportedly due to drought and flash flooding, lack of grain stores, and illicit trade across the Ethiopian border.[25]
- While Kassala State has been generally calm compared to other areas of the country,[26] food security has worsened since the outbreak of conflict in April 2023: 43% of the population are projected to be in IPC Phase 3 or above between October 2023 and February 2024, compared to 19% at the same time last year.[27] Reports suggest that this is due to economic impacts of conflict on food prices, incomes and agricultural production.[28]
- From October 2023 - February 2024, Hamshkoreep locality is projected to be in IPC Phase 4, while the rest of Kassala State is projected to be in IPC Phase 3. As 2024 continues, IDP populations, and populations of areas with below average agricultural production, are expected to be in IPC Phase 4.[29]

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).[30]

> 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.

- **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 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.

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[24] CMI (July 2020): Agricultural development and food Security in Sudan as seen from Kassala State.

[25] UNOCHA (March 2023): Kassala State Profile.

[26] ACLED Conflict database, accessed 26.02.24.

[27] IPC (2024): Sudan: Acute Food Insecurity Projection Update for October 2023; UNOCHA (March 2023): Kassala State Profile.

[28] FAO: The Sudan Summer Season Rapid Assessment, 2023; IPC (2024): Sudan: Acute Food Insecurity Projection Update for October 2023.

[29] IPC (2024): Sudan: Acute Food Insecurity Projection Update for October 2023.

[30] Full analysis and methodology are available in a Technical Report; contact crisisanalysis@mercycorps.org for further information.

Figure 4: Precipitation, soil moisture, vegetation quality (NDVI) and food insecurity in Kassala State in the last 10 years
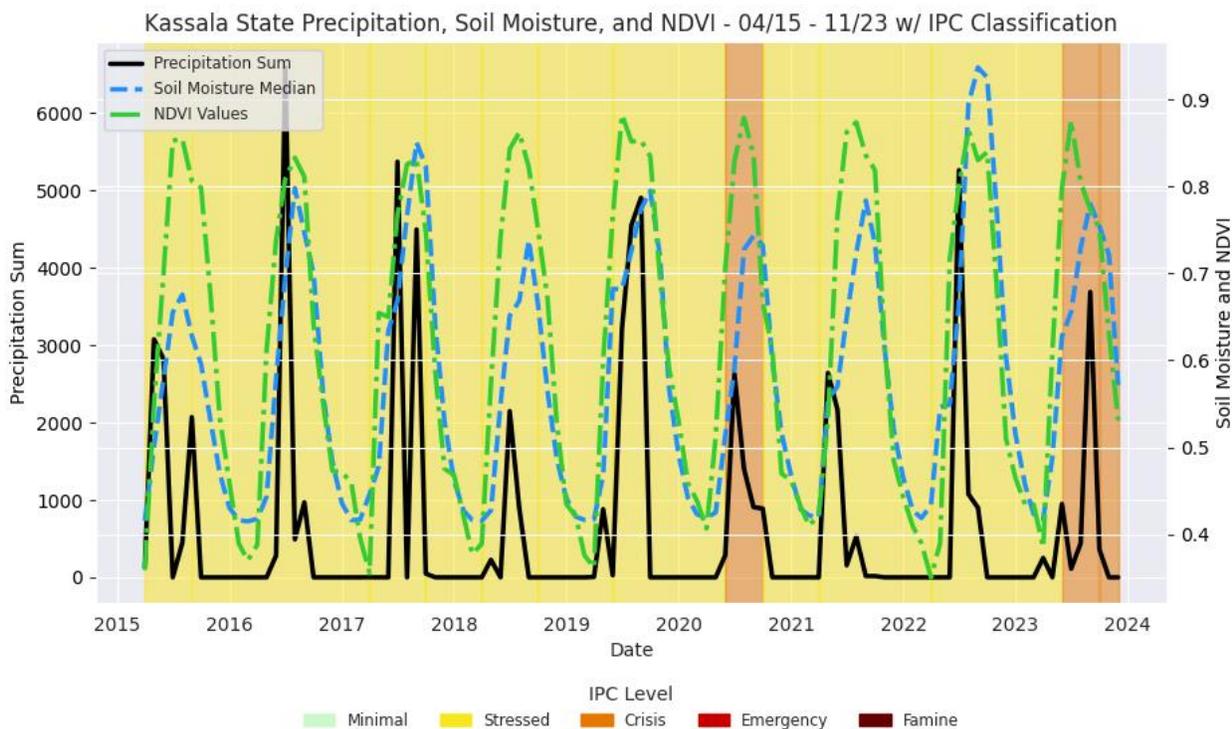
*IPC level data is **indicative only:** locality-level classifications were established using the FEWSNET methodology, where the highest classification represented by more than 20% of the population is shown. Time series plots represent monthly values for NDVI, soil moisture and precipitation.*

Contextualising drivers of agricultural productivity and food security

2023/24: Figure 4 shows that the peak vegetation health and median soil moisture for the last season was below that of the previous year. This is coherent with projections that the 23/24 harvest in Kassala will be significantly below average: while the planted area of millet increased compared to the previous year, crop quality was reportedly low, and sorghum planted area and production are projected to be below average. This is reportedly due to poor rainfall distribution, poor supply and high price of agricultural inputs, lack of usual government assistance for farmers, currency devaluation, widespread pest and disease, and conflict.[31]

2022/23: Results show a high peak vegetation health, which may reflect reports of an above-average harvest in this year. Reported drivers of good agricultural production in the year were: promising initial rainfall which encouraged large planted areas in the rainfed sector, lack of widespread pest and disease, and generally even distribution of rains which allowed for good recovery after initial flooding. The exception to this in Kassala was reportedly the Halfa-al-Jadeeda irrigation scheme, which lost 12% of cultivated area to waterlogging and poor canal maintenance. The Halfa al-Jadeeda scheme saw significantly below average harvests in 2022/23 harvest, due to flooding and waterlogging as well as hyacinth invasion and poor maintenance in irrigation

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[31] FAO: The Sudan Summer Season Rapid Assessment, 2023.

channels. However the previous harvest had been above average for cereals. While farmers reported issues related to high input prices and general economic decline, these inputs were available on most markets.[32]

2021/22: Despite high median soil moisture, 2021/22 saw a low peak vegetation health and high acute food insecurity. This year appears to exemplify the importance of rainfall distribution, as the FAO reported that "In Kassala State, the performance of the rainy season was particularly poor, with severe dryness prevailing during most of the rainy season, followed by above-average rains in September, of which the cumulative monthly amount was, however, well below that received in the previous year".[33] This harvest was also likely to have been impacted by socioeconomic factors in that year, including the national-level macroeconomic crisis in 2021, as well as state-level influx of refugees from Tigray, localised conflicts, flooding, labour shortages due to Covid-19.[34]

Projected Cropland Vegetation Quality in Kassala in 2024

Figures 5 and 6 below represent projections of cropland vegetation quality in Kassala state in the next six months (February - July 2024) based on projected weather conditions (rainfall, soil moisture and soil temperature). Figure 5 represents the projected cropland vegetation health, while Figure 6 represents the projected difference from average vegetation health since 2015. Key results are:

- Vegetation health in irrigated areas is expected to remain high from February through July. This suggests that environmental conditions will be favourable for planting and early season growth of crops in irrigated areas.[35]
- The vegetation health around Halfa Al-Jadeeda irrigation scheme is projected to be above average through July, while the Gash area may fall slightly below average vegetation health in July.
- In the rainfed sector, most areas in Kassala State are projected to have approximately normal cropland vegetation health, suggesting favourable environmental conditions for the planting season in rainfed sectors (June and July).
- Areas in the south of the State, in Rifi Wed Hilaio locality, are projected to have relatively low levels of vegetation health by July. This suggests that environmental conditions in Rifi Wed Hilaio will be less favourable for the beginning of the summer season. 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 agricultural productivity in this area over the season.

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[32] FAO (March 2023): The Sudan, 2022 Crop and Food Supply Assessment Mission.

[33] FAO (March 2022): The Sudan, 2021 Crop and Food Supply Assessment Mission.

[34] Sudan: Acute Food Insecurity Situation April - May 2021 and Projections for June - September 2021 and October 2021 - February 2022

[35] Irrigated areas rely on rainfall in June and July, to establish crops, before irrigation is used to supply water in September and October. FAO (March 2023): The Sudan, 2022 Crop and Food Supply Assessment Mission.

*Figure 5: Projected cropland vegetation quality in Kassala State*

Monthly NDVI Projections in 2024
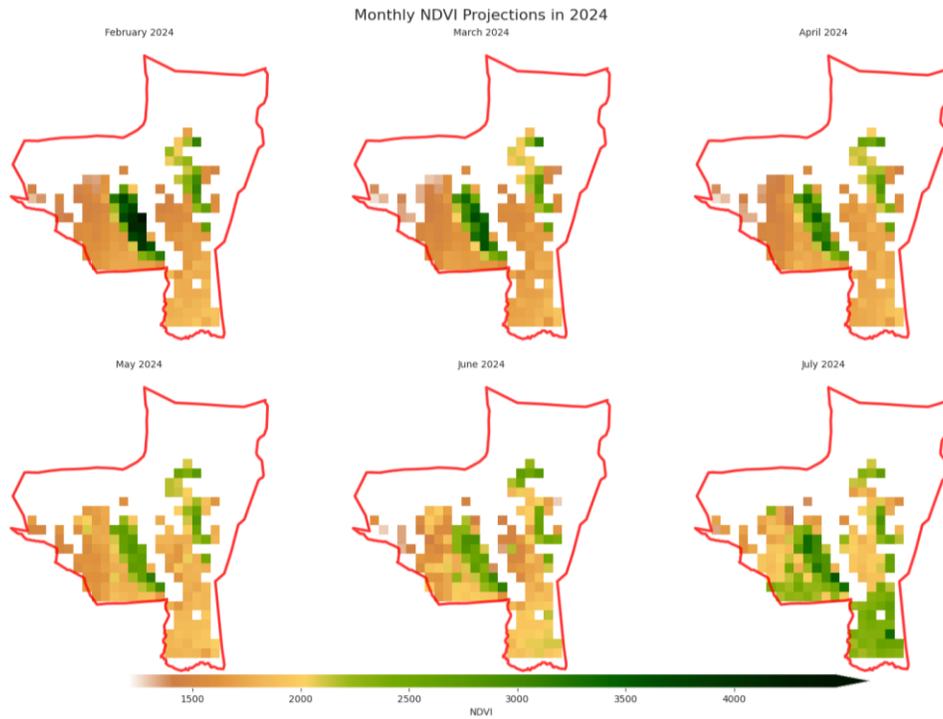
Figure 6: Projected cropland vegetation quality in Kassala State, compared to 2015-2023 average

Monthly NDVI Anomalies in 2024
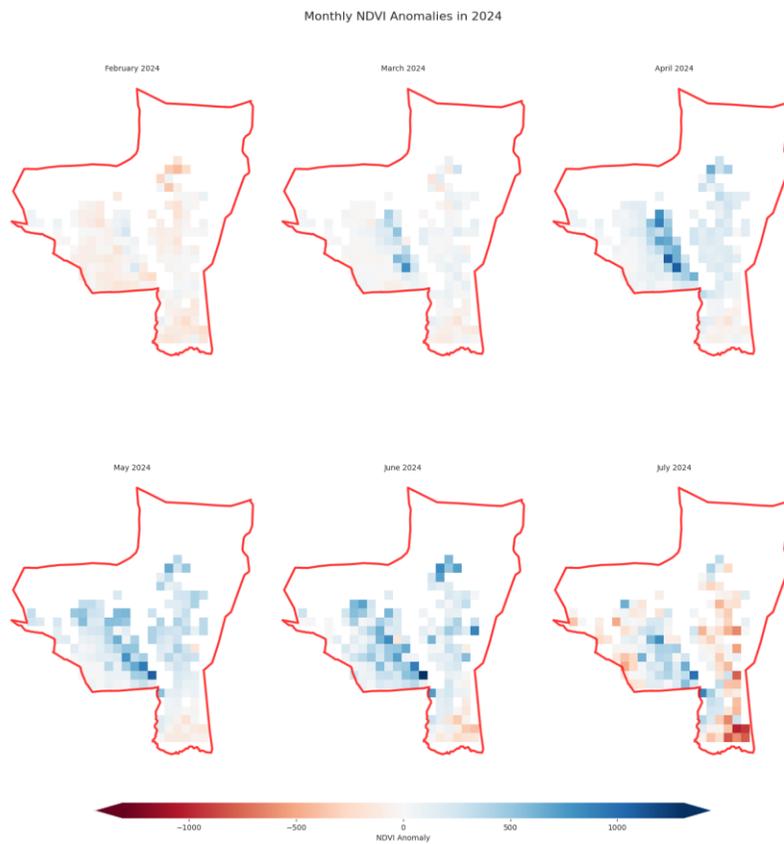
Contextualising results: other drivers of agricultural productivity

The remote sensing results above give an indication of agricultural productivity considering weather projections, *all else equal.* As in previous years, socio-economic factors are likely to influence agricultural productivity and therefore food insecurity: particularly given the ongoing conflict since April 2023.[36]

Expected drivers of agricultural productivity in Kassala in 2024:

- **Conflict:** Conflict is projected to spread further East in 2024, beginning with White Nile and Sennar and reaching Gedaref and Kassala in the medium term.[37] While clashes have so far been limited mainly to Kassala City and the surrounding area,[38] self-defence groups across the Eastern states are reportedly mobilising in preparation for an RSF advance on the region. In this context, fighting in Kassala risks high casualties and mass displacement.[39] However, developments in the conflict since April 2023 have been highly unpredictable. Should it occur, conflict in Kassala would likely lead to the same impacts as have been seen in other states: disruption to cultivation activities, destruction and looting of cropland, food stores and infrastructure, closure of markets and interruption of humanitarian assistance. The threat of conflict has also reportedly led to short-term price drops for agricultural produce, and movement of stores to rural locations, as producers anticipate looting.
- **Agricultural inputs:** High prices and low availability of seeds, fuel, machinery, fertilisers and pesticides which were reported in Kassala in 2023[40] are expected to continue into 2024. Any stocks held over from previous years are expected to be further depleted.[41]
- **Irrigation infrastructure:** Conflict is projected to continue to restrict maintenance of irrigation channels, reducing yields.[42] In the likelihood that conflict spreads from Jazirah into Eastern states, irrigation infrastructure may be actively destroyed in the conflict.[43]
- **Agricultural assistance:** Kassala historically benefitted from a large proportion of Sudanese government assistance, in the form of agricultural extension services, direct development spending, pest and disease control, credit provided by the Agricultural Bank of Sudan, subsidies on wheat, and seed and fertiliser distributions.[44] Lack of government assistance is expected to continue into 2024 as conflict persists, constraining the capacity of the Sudanese government. The relatively good humanitarian access to the state[45] may compensate for this, however the spread of conflict may severely limit humanitarian activity as it did in Al Jazirah State.[46]
- **Displacement:** As of February 2024, there are estimated to be over 175,000 IDPs in Kassala State. Several IDP gathering sites are clustered around Kassala city and Halfa al-Jadeeda.[47] Conflict is expected to spread eastward in early 2024 causing increasing displacement, which may disrupt labour supply for agriculture, and lead to increased pressure on local food supplies.[48]

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[36] FEWSNET (December 2023): Food Security Outlook Update.

[37] ACLED Watchlist 2024 (January 2024): Sudan, Setting the Stage for a Long War.

[38] ACLED Conflict database, accessed 26.02.24.

[39] Crisis Group (January 2024): Sudan's Calamitous War.

[40] UNOCHA (December 2023): Intersectoral Rapid Needs Assessment, Kassala State.

[41] FEWSNET (December 2023): Food Security Outlook Update.

[42] IPC (2024): Sudan: Acute Food Insecurity Projection Update for October 2023.

[43] FEWSNET (December 2023): Food Security Outlook Update.

[44] FAO (March 2023): The Sudan, 2022 Crop and Food Supply Assessment Mission.

[45] UNOCHA (January 2024): 3W Matrix of Operational Presence in Sudan.

[46] WFP (February 2024): Urgent Call for Safe Access to Feed MIllions.

[47] IOM DTM (February 2024): Sudan: Weekly Displacement Snapshot 20 Feb 2024.

[48] FEWSNET (December 2023): Food Security Outlook Update.

- **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.[49]
- **Flooding:** Kassala has historically suffered from flash flooding[50] which can directly affect agriculture through replanting or total crop failure and waterlogging of larger irrigated areas, and indirectly through disruption to transport.[51] While it is difficult to assess flood risk in the scope of this paper, cataloguing MODIS NRT flood extent data may help to better inform regions where flooding could cause larger problems.

Recommendations

- **Support rehabilitation of irrigation infrastructure:** While environmental factors are promising for the area, including the Halfa-al-Jadeeda irrigation scheme, it is likely that economic and infrastructure issues, as well as the pressure of a high IDP population, are likely to limit production in Halfa al Jadeeda in the upcoming season. Given the high productivity of irrigated agriculture compared to rainfed, ensuring good production at Halfa al-Jadeeda could significantly boost food supply in the State.

- **Provide extra support to Rifi Wed Hilaio and Hamshkoreep localities:** Rifi Wed Hilaiolocality is likely to see below average agricultural productivity; although favourable rains in August and September may compensate for a poor start. Hamshkoreep locality has historically been vulnerable to acute food insecurity, however there is a small area of cropland in the locality which could contribute to food supply in the area. Depending on ground data, extra assistance to farmers, or direct food assistance may be the most appropriate to mitigate the risk of increased food insecurity in these localities.

- **Balance household production with cash crops to provide for the whole population:** Household agricultural productivity is an important part of consumption in Kassala, but displaced populations, who have limited access to land and livelihoods, are projected to be most at risk of food insecurity. Support which boosts household production and increases the food available at markets will be necessary to improve food security, especially as displacement is projected to increase.

- **Explore methods of improving supply of agricultural inputs and finance:** Given the relative accessibility of Kassala, market-based assistance may be more feasible than in more isolated areas of the country. Cash assistance to farmers should be considered, while difficulties in the supply of certain goods should also be assessed.

- **Consider parallel cash assistance to address conflict-induced lack of purchasing power.** Considering the high prices of food and reduced livelihood opportunities, particularly for displaced households which are more vulnerable to food insecurity, parallel cash assistance may be necessary to ensure that agricultural produce is successfully sold. This recent analysis of agri-food and payment systems in Sudan might provide guidance on balancing supply and demand.

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[49] IPC (2024): Sudan: Acute Food Insecurity Projection Update for October 2024; UN Geneva (2024): Press Briefing, 6 February 2024.

[50] UNOCHA (March 2023): Kassala State Profile;

[51] FAO (March 2023): The Sudan, 2022 Crop and Food Supply Assessment Mission; UNEP (2020): Sudan- First State Environment Outlook Report.

- **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.[52]

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[52] Mercy Corps (September 2023): Remote Sensing to Monitor Impact of Conflict on Agriculture: Round 2.

Annex 1: Methodology and Limitations

This assessment uses publicly available data on We used Google Earth Engine (GEE) to collect soil moisture, precipitation, and NDVI data from April 1, 2015, to January 31, 2024 in Kassala State. Following data cleaning, machine learning was used to determine the impact of soil moisture and precipitation on NDVI. Finally, a pixel-by-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.[53]

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 Kassala 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 Kassala.
- 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.

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[53] Please contact crisisanalysis@mercycorps.org to access the document.

CONTACT
Global Crisis Analysis
crisisanalysis@mercycorps.org

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45 SW Ankeny Street
Portland, Oregon 97204
888.842.0842
mercycorps.org