SUDAN CRISIS ANALYSIS

Remote Sensing to Anticipate Agriculture Conditions: South Kordofan State

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 South Kordofan State. Papers covering Gedaref, Blue Nile, and Kassala 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 South Kordofan is *versitols*- this is clay-rich soil, which is generally chemically fertile but has a relatively poor capacity to absorb water.[2] In recent years, South Kordofan has been susceptible to erratic rainfall, with long dry spells as well as flash flooding.
- Rainfall and soil moisture projections suggest that weather conditions will be relatively unfavourable for agricultural production in the majority of South Kordofan State. This is exacerbated by conflict-related barriers, with conflict already having impeded food production in recent years.
- Projections suggest that weather conditions will be favourable in Alabasiya, Altadamon and parts of Habila localities. These are areas with extensive agriculture and may have the potential to contribute vital food supplies to the whole state.
- Secondary data indicates that agricultural productivity is likely to continue to be impacted by conflict, displacement and lack of humanitarian and trade access. Production may also be negatively impacted by pests, flooding, and lack of access to agricultural inputs.

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 South Kordofan State.

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

[2] D. Smiles, P.A.C. Raats (2005): Encyclopedia of Soils in the Environment.

[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 South Kordofan State

While there is no irrigated agriculture in South Kordofan State, the State sits on the Western end of a band of relatively productive semi-mechanized agriculture which is effectively the "breadbasket" of Sudan. Traditional rainfed agriculture is also practised in South Kordofan. The main crops have been sorghum and millet in recent years; however the planted area for millet has reportedly decreased in 2022 and 2023, with the planted area in 2023 being 65% lower than the 2017-22 average. As of 2023, sorghum occupied the majority of cultivated land, followed by sesame. Relatively small areas were planted with millet, cotton, groundnuts, and other crops.[6]

Intermittent conflict has been reported in South Kordofan State from 2011 until 2016, with tensions rising again in 2021.[10] Since the outbreak of civil war on 15 April 2023, there have been regular clashes between multiple armed groups including the RSF, SAF, SPLM-N Al-Hilu, SPLM-N Abdelaziz and ethnic militia in South Kordofan State. Conflict has induced mass displacement in the state, and there have also been reports of attacks on civilians and looting of property, impacting many aspects of civilian life, including agriculture.[11]

Agriculture types in South Kordofan[5]

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.

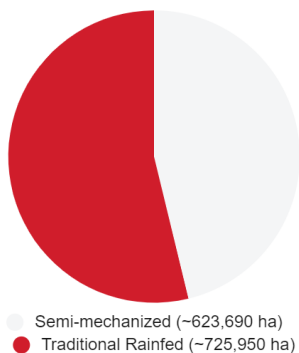*Figure 1: Estimated planted area for sorghum and millet in South Kordofan: 5-year average[7]*

Semi-mechanized (~623,690 ha)
Traditional Rainfed (~725,950 ha)

Figure 2: Estimated total planted area in South Kordofan: 2023[8]

Semi-mechanized (~756,300 ha)
Traditional Rainfed (~294,120 ha)
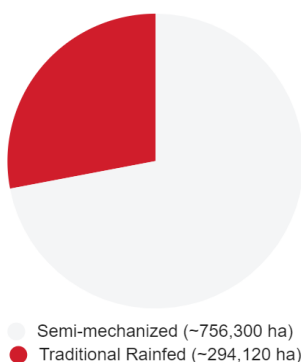
Figure 3: Estimated Sorghum and millet production in South Kordofan: 5-year average[9]

Semi-mechanized (66.9%)
Traditional Rainfed (33.1%)

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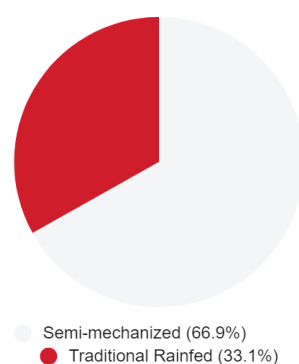
[5] FAO (2023): The Sudan, 2022 Crop and Food Supply Assessment Mission; UNEP (2020): Sudan- First State Environment Outlook Report; FAO (2023): The Sudan Summer Season Rapid Assessment.

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

[7] Analysis from secondary data- **indicative only**. Sums of five-year average from 2017/18 to 2021/22 for sorghum and millet. FAO (March 2023): The Sudan, 2022 Crop and Food Supply Assessment Mission.

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

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

[10] UNOCHA (March 2023): State Profile, South Kordofan.

[11] ACLED Conflict database, accessed 26.02.24.

Map 1: Cultivated area in South Kordofan and conflict incidents recorded by ACLED[12] since 15 April 2023
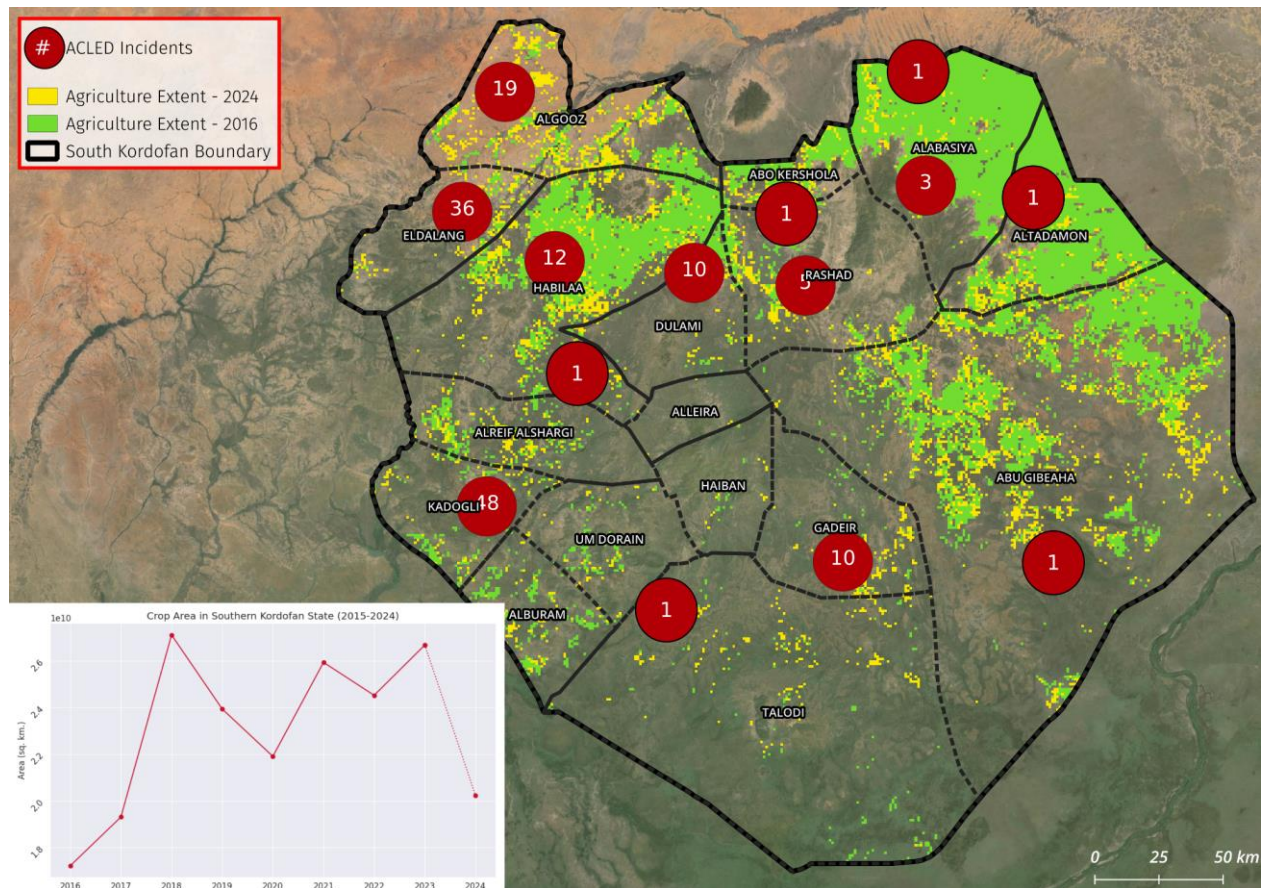
Food security in South Kordofan:

- Due to conflict and displacement, food insecurity was high in South Kordofan before April 2023, with 16% of the population projected to be in crisis (IPC Phase 3) or above.[13]
- Since April 2023, food security has severely deteriorated in South Kordofan, with 48% of the population projected to be in crisis (IPC Phase 3) or above. The localities which are projected to be in emergency (IPC phase 4) are Al Buram, Al Quoz, Ar reif ash Shargi, Drilling, and Kadugli. These localities have seen relatively higher numbers of conflict incidents than the rest of the state combined with low agricultural production and poor humanitarian access.[14]

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

[13] UNOCHA (March 2023): State Profile, South Kordofan.

[14] ACLED Conflict database, accessed 26.02.24; IPC (2024): Sudan: Acute Food Insecurity Projection Update for October 2023.

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).[15]

- **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.

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.

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

Figure 4: Precipitation, soil moisture, vegetation cover and food insecurity[16] in South Kordofan State in the last 10 years

Southern Kordofan State Precipitation, Soil Moisture, and NDVI - 04/15 - 11/23 w/ IPC Classification
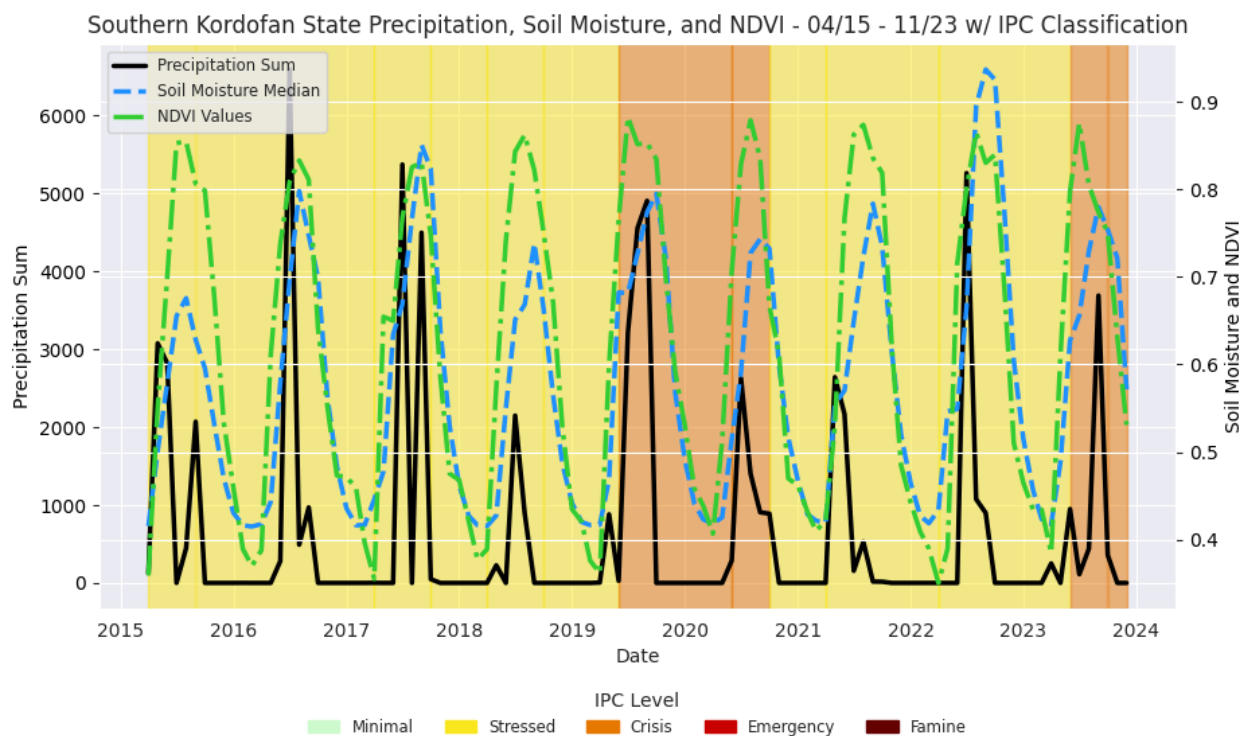
Contextualising drivers of agricultural productivity and food security

Cropland vegetation health remains consistent between 2021 and 2022, despite reports of different harvest outcomes; with 2021 under-performing and 2022 performing well. However the drivers of production can be seen in Figure 4: **analysis of precipitation data** mirrors reports of low rainfall in 2021 followed by high consistent rainfall in 2022.[17] Furthermore, the high **peak soil moisture in 2022** shown in Figure 4 may be a driver of increased agricultural productivity in South Kordofan in this year, demonstrating the importance of soil moisture in predicting agricultural output.[18] 2021 harvests were also reportedly hampered by **pest damage** from birds, and **labour shortages** driven by conflict and expansion of planted area.

Persistent **acute food insecurity,** regardless of reported agricultural production, may be due to ongoing insecurity and lack of humanitarian access.[19] The progression to crisis phase (IPC Phase 3) in 2023, despite reports of a positive harvest in Greater Kordofan in 2022, suggests that the intensification of conflict since April 2023 has diminished the benefit of this positive harvest for food security.[20]

Reported drivers of the **2023** harvest were mixed: peak cropland vegetation quality in Figure 4 remains similar to previous years, coherent with previous satellite analysis and farmers reports from South Kordofan in August

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[16] 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] FAO (March 2023): The Sudan, 2022 Crop and Food Supply Assessment Mission; FAO (March 2022): The Sudan, 2021 Crop and Food Supply Assessment Mission; FAO (2023): The Sudan Summer Season Rapid Assessment.

[18] For more detail, see the Technical Report of this analysis; contact crisisanalysis@mercycorps.org to access the document.

[19] UNOCHA (March 2023): State Profile, South Kordofan.

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

2023.[21] Reports indicate that the planted area for millet will decrease compared to 2022, but that this will be offset by an increase in sorghum planting.[22] However, as is visible in Figure 4, rainfall was reportedly poorly distributed, with long dry spells; this, alongside flash flooding, pest attacks, and lack of agricultural inputs, is projected to lead to relatively low agricultural productivity in South Kordofan compared to previous years.[23]

Projected Cropland Vegetation Quality in South Kordofan in 2024

Figures 5 and 6 below represent projections of cropland vegetation health in South Kordofan State in the next four months 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. Key results are:

- The majority of cropland in South Kordofan state is projected to have below-average vegetation health compared to previous years. This suggests unfavourable weather conditions in June and July for agricultural productivity in most of the State, which is already facing conflict-related barriers to food production and food security.
- Cropland vegetation health is projected to be normal or above average in Alabasiya and Altadamon localities: these localities are densely cultivated and therefore may have the potential to produce large volumes of food given the favourable weather conditions.
- Cropland vegetation health is projected to be mixed in Habila locality, which contains a high volume of cropland. This may suggest the potential for successful harvests in some areas of the locality.

*Figure 5: Projected cropland vegetation quality in South Kordofan State*

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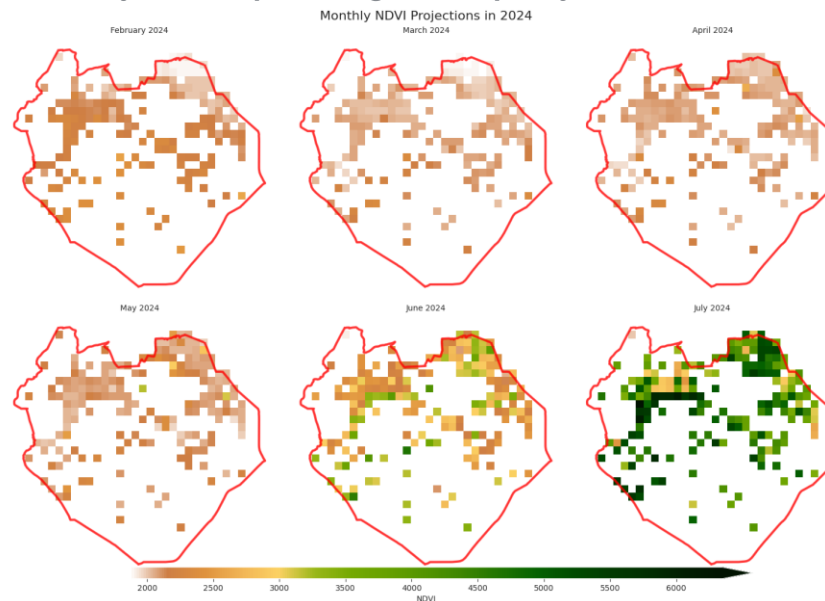
[21] Mercy Corps (September 2023): Remote Sensing to Monitor Impact of Conflict on Agriculture: Round 2.

[22] FAO (2023): The Sudan Summer Season Rapid Assessment; Mercy Corps (August 2023): Survey of Farmer Capacities and Intentions in South Kordofan and Blue Nile, Sudan.

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

Figure 6: Projected cropland vegetation quality in South Kordofan State, compared to 2015-2023 average
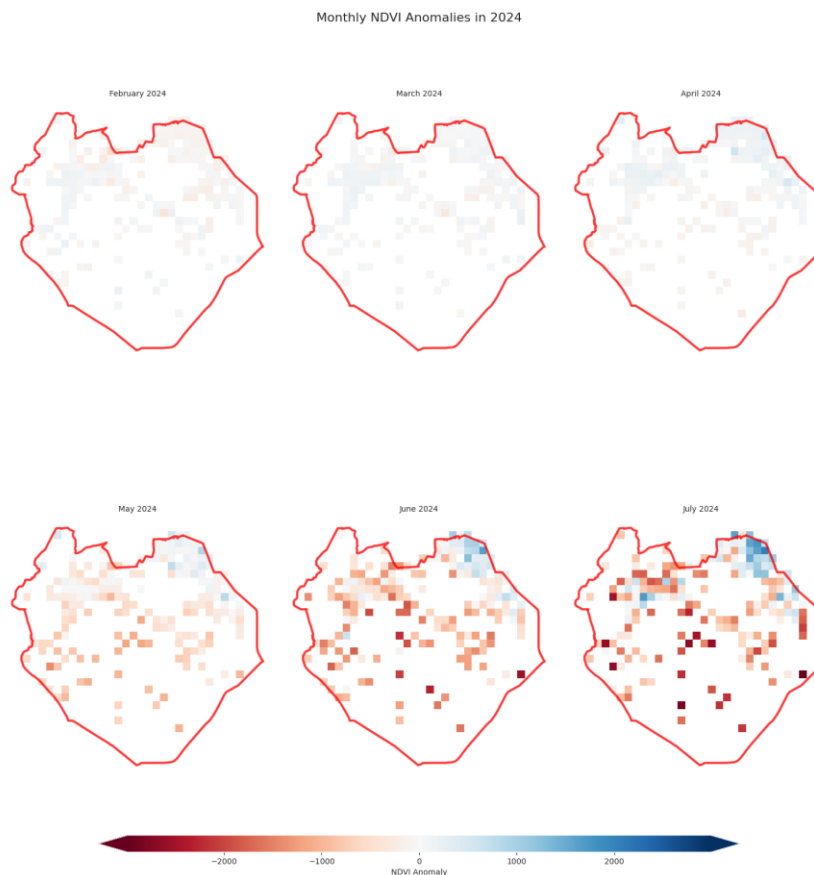
Contextualising results: other drivers of agricultural productivity

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.[24]

Expected drivers of agricultural productivity in South Kordofan in 2024:

- **Conflict:** While the conflict in Sudan has been chaotic and difficult to predict since April 2023, the parties to conflict in South Kordofan are expected to continue pursuing their objectives, potentially leading to fighting for control of other areas of South Kordofan State[25], although specific movements are difficult to predict. These ongoing clashes will likely lead to continued displacement, disruption to agriculture and trade, and looting and destruction. Conflict outside of South Kordofan, particularly in Eastern States,[26] is likely to further disrupt trade and access to agricultural inputs in South Kordofan.
- **Access:** South Kordofan, as a more conflict-affected area, has been relatively difficult to reach with humanitarian assistance. Conflict has also limited trade flows into the state, exacerbating shortages of food and agricultural inputs. Conflict in the East of the country, while unlikely to directly involve

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[24] FEWSNET (December 2023): Food Security Outlook Update.
[25] ACLED Watchlist 2024 (January 2024): Sudan, Setting the Stage for a Long War.
[26] ACLED Watchlist 2024 (January 2024): Sudan, Setting the Stage for a Long War.

South Kordofan, has reportedly further limited trade access to the state due to the disruption of key markets such as Wad Madani.[27]

- **Displacement:** In March 2023, there were estimated to be 245,000 IDPs in South Kordofan State.[28]As of February 2024, there are estimated to be almost 133,000 IDPs in South Kordofan State.[29] This decrease is likely due to the intensity of conflict in South Kordofan which has pushed households to leave the state.[30] Several IDP gathering sites are spread across the state, but there are high concentrations in localities with large cultivated areas: while in other states displacement has led to saturation of the labour market, this effect has not yet been observed in South Kordofan, where the price of labour remains high.[31]
- **Pests and diseases:** As of February 2024, FAO warns that the desert locust situation has reached threat level in Sudan. 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.[32] [33]
- **Flooding:** Localised flooding was reported in South Kordofan in 2022, but with minimal impact on overall production. However, in affected areas, flooding has severe impacts, directly affecting agriculture through replanting or total crop failure, and indirectly through disruption to transport.[34] [35] 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.
- **Agricultural inputs:** Disrupted access to agricultural inputs has reportedly led to greater food insecurity in South Kordofan in the last year.[36] Many farmers in South Kordofan reported using seeds from personal stocks in 2023 rather than buying at markets; as this continues, stocks held over from previous years are expected to be depleted by producers.[37] [38]
- **Agricultural assistance:** Despite issues with access and conflict, South Kordofan received agricultural finance and seed distributions between 2020 and 2022. (CFSAM). Since the outbreak of conflict in April 2023, this lack of finance and assistance was expected to impact 2023 production (IPC).

Recommendations

- **Support agriculture in Alabasiya and Altadamon localities:** with high cropland density, projected favourable weather conditions, and relatively low incidence of conflict events, these states present an opportunity for high food production which could be a vital contribution to food supply considering access constraints to the state. However, given the security situation in South Kordofan State, contingency planning should protect against conflict which might disrupt production in these states, or prevent the transport of produce to markets in other areas of South Kordofan.

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

[28] UNOCHA (March 2023): State Profile, South Kordofan.

[29] IOM DTM (February 2024): Sudan Weekly Displacement Snapshot

[30] ACLED Conflict database, accessed 26.02.24.

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

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

[33] UN Geneva (2024): Press Briefing, 6 February 2024

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

[35] UNEP (2020): Sudan- First State Environment Outlook Report.

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

[37] Mercy Corps (August 2023): Survey of Farmer Capacities and Intentions in South Kordofan and Blue Nile, Sudan.

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

- **Investigate the status of agriculture more closely in Habila locality:** with high cropland density, this locality also has the potential to contribute to food supply in South Kordofan, however projections of vegetation quality are mixed. Ground data may help to understand the challenges to agriculture in the locality, while continued monitoring of projected weather conditions may provide greater insight into environmental drivers of agricultural productivity.

- **Consider food and/ or cash assistance to the majority of South Kordofan State:** considering projected unfavourable weather conditions for agriculture, disruption of trade flows and repeated conflict and displacement, the population in South Kordofan State is very vulnerable to acute food insecurity. Assessments to determine the best method of delivering assistance to food insecure populations should be carried out, and this recent analysis of agri-food and payment systems in Sudan provides detailed suggestions of assistance to balance food supply and demand.

- **Prioritise conflict-sensitive assistance:** while a conflict sensitive approach to assistance is necessary across Sudan, the multi-faceted nature of conflict in South Kordofan, combined with low and diminishing resources, requires particularly careful attention when planning livelihoods support, to avoid fuelling conflict by changing the balance of resource allocation between different individuals or communities. Engagement with local civil society groups is particularly important in these contexts.

- **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.[39]

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[39] 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 Google Earth Engine (GEE) to collect soil moisture, precipitation, and NDVI data from April 1, 2015, to January 31, 2024 in South Kordofan 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.[40]

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 South Kordofan 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 South Kordofan.
- 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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[40] Please contact crisisanalysis@mercycorps.org to access the document.

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Mercy Corps is a leading global organization powered by the belief that a better world is possible. In disaster, in hardship, in more than 40 countries around the world, we partner to put bold solutions into action — helping people triumph over adversity and build stronger communities from within.
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