SUDAN CRISIS ANALYSIS

Remote Sensing to Anticipate Agriculture Conditions: Blue Nile 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 Blue Nile State. Papers covering Kassala, Gedaref, 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 Blue Nile 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, soil moisture has been the dominant factor affecting vegetation health, followed by recent rainfall, though previous conflict, socio-political and economic factors have critically affected production and food insecurity.
- Rainfall and soil moisture projections suggest that from March to July 2024, weather conditions will be relatively favourable for crop quality in Tadamon and El Damazine localities, where there is a high concentration of cultivated land.
- Projections suggest that from March to July 2024, weather conditions will be relatively unfavourable for crop quality around areas hosting vulnerable populations that have been impacted by conflict and displacement in recent years: El Demazine town, and El Russirs, Wad al Mahi and Gaysan localities.
- Secondary data indicates that agricultural production is likely to be impacted by shortages of agricultural inputs, particularly seeds and agricultural finance and ongoing conflict. Agriculture in the state may also be impacted by current and future displacement, poor humanitarian access, flooding and pest damage.

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 production in different areas of Blue Nile 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 Blue Nile State

Blue Nile is part of the "breadbasket" of Sudan, containing 4.1% of the country's arable land primarily located in northern localities (Map 1)[5] There are no federal irrigation schemes in Blue Nile, but small-scale irrigation is practised along the banks of the Nile river. The main agriculture type is semi-mechanized rainfed, and traditional rainfed.[6] In 2023, sorghum occupied the majority of cultivated area, followed by cotton, sunflower, sesame and millet and "other crops". A small area was planted with groundnuts.[7]

Agriculture types in Sudan[8]

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.

Figure 1: Estimated planted area in Blue Nile 2023[9]

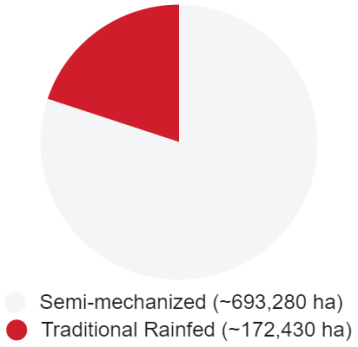
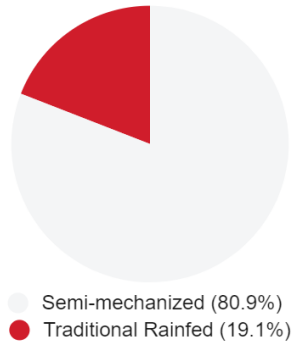


Figure 2: Estimated sorghum and millet production in Blue Nile: 5-year average[10]



Intermittent conflict has been reported in Blue Nile State from 2017 until the outbreak of conflict on 15 April 2023; in mid-2022, intercommunal clashes were reported in Wad al Mahi, Ar Rusayirs, and Geisan localities, which interrupted agriculture and trade.[11] Since 15 April, conflict events have mainly involved clashes between the SAF and the SPLM-N (Al-Hilu) and the SPLM-N (Abdelaziz). Conflict events in 2023 reportedly led to

[5] IFPRI (2003): The Architecture of the Sudanese Agricultural Sector and Its Contribution to the Economy between 1990 and 2021.

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

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

[8] 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.

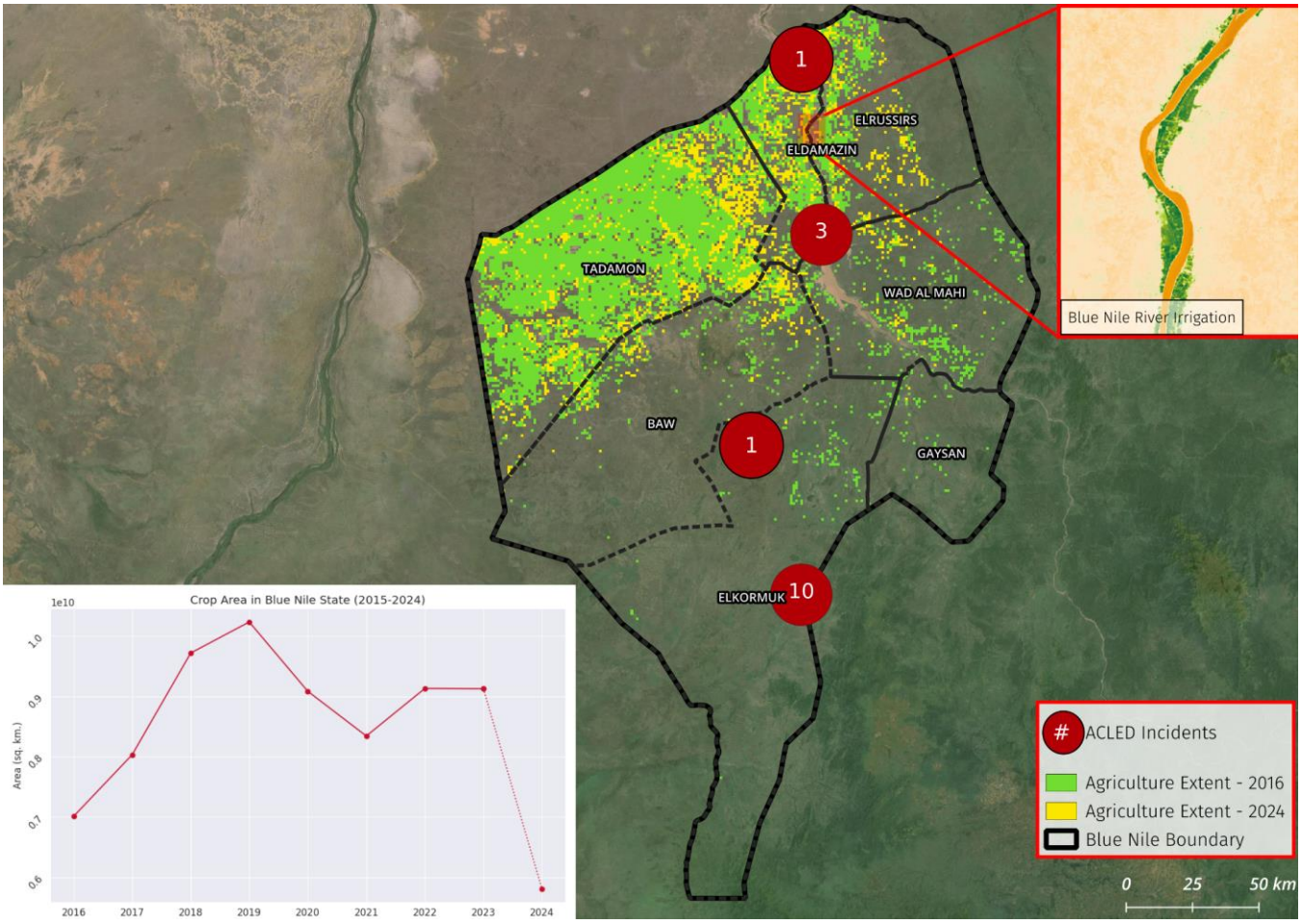
[9] FAO (2023): The Sudan Summer Season Rapid Assessment.

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

[11] UNOCHA (March 2023): State Profile, Blue Nile; WHO Press Release (December 2022): WHO leading the humanitarian response to the escalation of violence in Sudan's Blue Nile State.

looting and destruction of property,[12] though they may have had limited direct impact on farmland as according to ACLED data they have mainly occurred mainly in El Kormuk locality (see Map 1).

Map 1: Cultivated area in Blue Nile 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.

Food security in Blue Nile

- Prior to the outbreak of conflict in April 2023, 24% of the population of Blue Nile were projected to be acutely food insecure. This was expected to be caused, in part, by intercommunal conflict and displacement in 2022.[13]
- From October to February 2024, localities in Blue Nile are expected to be in IPC Phase 2 (El Damazine, El Russirs and Tadamon localities) or Phase 3 (El Kormuk, Baw, Gaysan and Wad al Mahi localities).[14] This difference in food security projections may be driven by the high concentration of cropland in El Damazine, El Russirs and Tadamon localities compared to the rest of the state (see Map 1). As the lean season begins, every locality in the state is expected to be in IPC Phase 3, with some areas in Phase 4, particularly those affected by conflict.[15]

[12] ACLED Conflict database, accessed 26.02.24.

[13] UNOCHA (March 2023): State Profile3; ACAPS (July 2023): Displacement due to conflict in Blue Nile State.

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

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

Impact of Rainfall and Soil Moisture on Cropland Vegetation since 2015

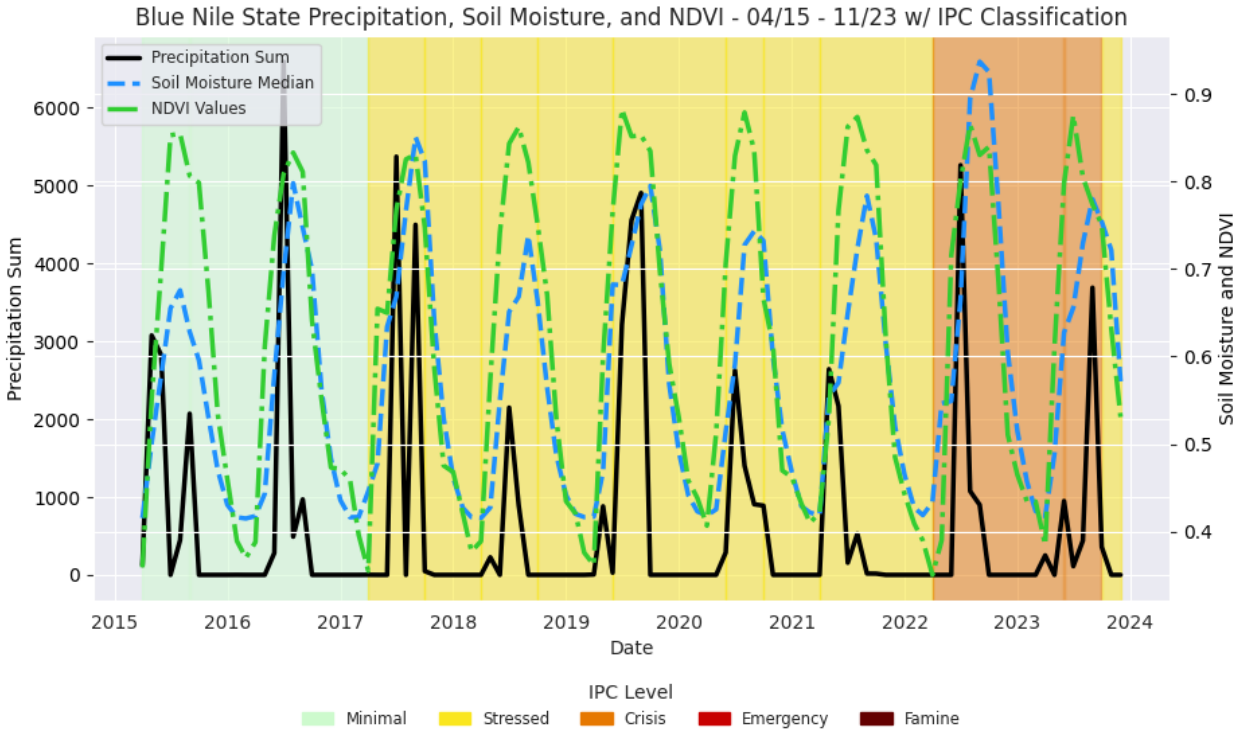
Rainfall and soil moisture

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).[16]

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.

Figure 3: Precipitation, soil moisture, cropland vegetation cover and food insecurity in Blue Nile 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.*

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

Contextualising drivers of agricultural productivity and food security

Cropland vegetation health appears to remain 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 2: **analysis of precipitation data** reflects 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 3 may be a driver of increased agricultural productivity, demonstrating the importance of soil moisture in predicting agricultural output.[18]

Difference in reported agricultural production, despite similar cropland vegetation health may also reflect the variation in reported **yields** on similar planted areas. Sorghum and millet yields, in both rainfed and semi-mechanised agriculture, were 51-99% higher in 2022 than in 2021.[19] Representations of IPC classifications demonstrate the importance of **conflict, sociopolitical and economic factors** for food security in Blue Nile; favourable weather conditions and high yields appear to have been offset by conflict and displacement reported during 2022, which led to an increase in acute food insecurity. [20]

Reported drivers of the **2023 harvest** were mixed: peak cropland vegetation health in Figure 3 remains similar to previous years, coherent with previous MercyCorps satellite analysis.[21] Reports indicate that the planted area was slightly below the five-year average in 2023, with some farmers reporting that they were unable to plant at all.[22] However, as is visible in Figure 2, rainfall was reportedly poorly distributed, with long dry spells; this is likely linked to slightly below average projections for sorghum and millet production in Blue Nile State for the 2023/24 harvest.[23]

Projected Cropland Vegetation Quality in Blue Nile State in 2024

Figures 4 and 5 below represent projections of cropland vegetation health in Blue Nile State in the next four months based on projected weather conditions (rainfall, soil moisture and soil temperature). Figure 4 represents the projected cropland vegetation, while Figure 5 represents the projected difference from average vegetation health. Key findings are:

- Cropland vegetation health in Tadamon and El Damazin localities, which have a high concentration of cultivated land, are projected to be approximately average in June, and above average in July. This suggests favourable weather conditions for agriculture in these localities, which appear to be the most important localities for food production in the state.
- Cropland vegetation health in El Russirs, Wad al Mahi and Gaysan localities are projected to see below average cropland vegetation quality throughout June and July. 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 production in this area over the season. While these localities are less intensely

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

[20] ACAPS (July 2023): Displacement due to conflict in Blue Nile State.

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

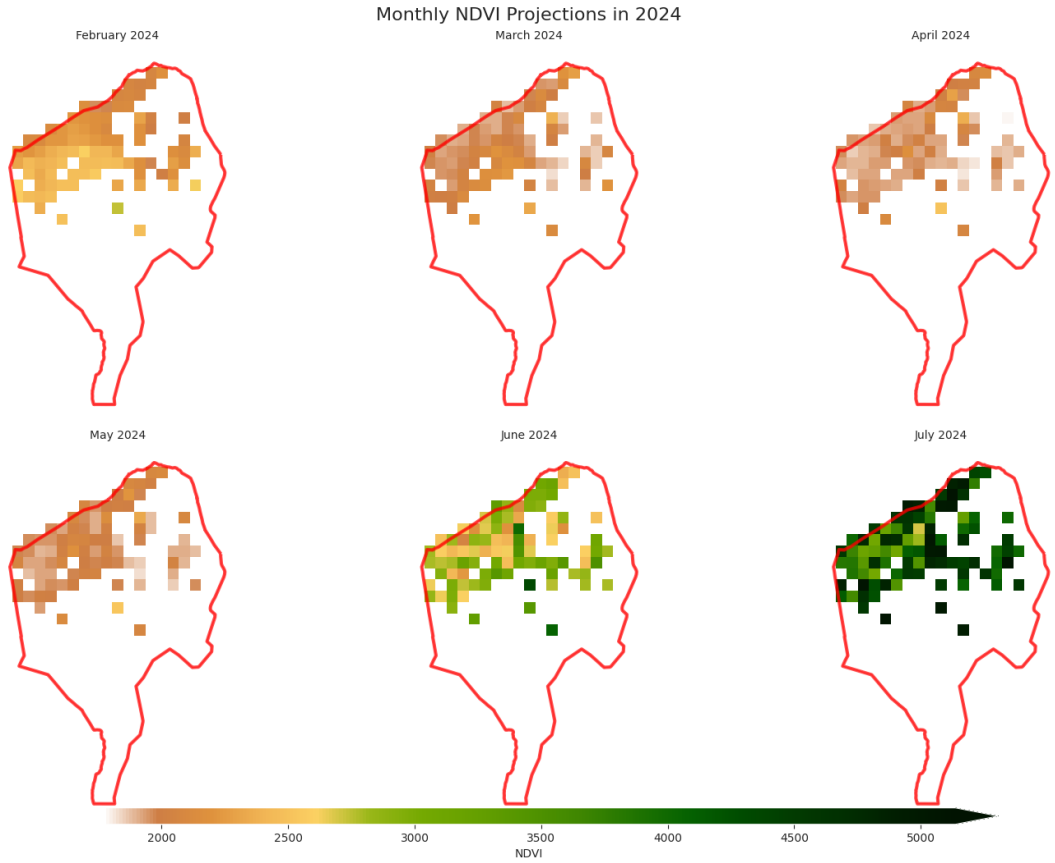
[22] Mercy Corps (August 2023): Survey of Farmer Capacities and Intentions in South Kordofan and Blue Nile, Sudan; FAO (2023): The Sudan Summer Season Rapid Assessment.

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

cultivated, they have also been impacted by conflict and displacement in recent years, which may render the populations in these localities more vulnerable to food insecurity following poor harvests.

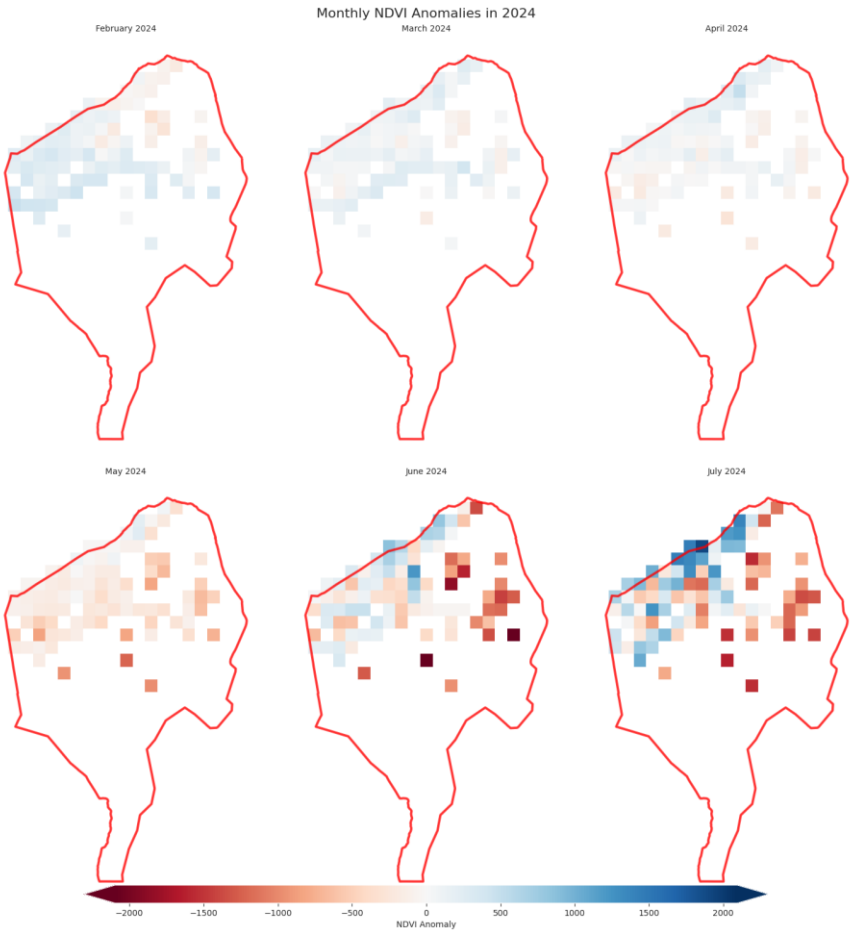
- While the size of each area analysis (~10km x 10km) in the projections makes it difficult to apply projection maps to specific settlements, there appears to be an area of below-average cropland vegetation quality surrounding El Damazine town and the Nile River, where small-scale irrigation is usually practised. This may reflect the large number of IDPs in the city since April 2023, or disruption to irrigated agriculture, but may also simply reflect the natural growth of the urban area of El Damazine town since 2015.[24]

Figure 4: Projected cropland vegetation quality in Blue Nile State



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

Figure 5: Projected cropland vegetation quality in Blue Nile State, compared to 2015-2023 average



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 Blue Nile in 2024:

- **Agricultural inputs:** Lack of inputs, particularly seeds, was highlighted as a key barrier to agriculture by farmers in Blue Nile State in the last summer season. Many reported using seed stocks from previous years due to lack of funds to buy seeds on the market: as prices are projected to remain high into 2024, stocks held over from previous years are expected to be further depleted.[26] Shortages and high prices of other agricultural inputs such as tractors, machinery, fertilisers and herbicides, reported across Sudan, are likely to have impacted agriculture in Blue Nile.[27]
- **Agricultural assistance:** Blue Nile State received moderate levels of agricultural finance and relatively large distributions of seed from the Sudanese government and FAO in recent years. In 2023

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

[26] Mercy Corps (August 2023): Survey of Farmer Capacities and Intentions in South Kordofan and Blue Nile, Sudan; FEWSNET (December 2023): Food Security Outlook Update.

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

lack of agricultural finance was cited as a reason for poor agricultural production across the country,[28] while farmers in Blue Nile reported that lack of seeds was a main barrier to cultivation.[29] Lack of government assistance is expected to continue into 2024 as conflict persists, constraining the capacity of the Sudanese government. The state appears to have relatively good humanitarian presence,[30] but the presence of multiple armed actors,[31] and poor road infrastructure, may hinder the ability of humanitarian partners to deliver on-the-ground assistance to farmers, particularly during the rainy season.[32]

- **Conflict:** The conflict in Sudan since 15 April 2023 has been chaotic and difficult to predict, and it is unclear whether projected RSF advances into the South East of the country[33] will reach Blue Nile. However, clashes between the SPLM-N and SAF may continue into 2024. Conflict in Blue Nile is likely to have the same negative impacts as conflict in previous years: looting, destruction, and interruption to cultivation and trade.[34] The location of armed groups in Blue Nile State is also expected to obstruct the movement of pastoralists, which may lead to conflicts over land use.[35]
- **Grain storage:** Blue Nile is a location for grain storage; should conflict spread to Blue Nile, widespread looting is expected. The threat of conflict may lead to panic sales or movement of stocks to rural areas, as was observed in Sennar and Al Jazirah.[36]
- **Displacement:** While intercommunal clashes had led to the displacement of over 38,000 individuals within Blue Nile State on 11 April 2023,[37] the estimated number of IDPs in the State has risen to over 133,000 since the outbreak of civil war on 15 April 2023. Several IDP gathering sites are clustered around the River Nile and El Demazine town.[38] Displaced populations are projected to be particularly vulnerable to food insecurity across Sudan in 2024, due to a lack of access to livelihoods.[39]
- **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.[40]
- **Flooding:** Blue Nile is often affected by flooding,[41] which can directly affect agriculture through replanting or total crop failure and waterlogging of irrigated areas, and indirectly through disruption to transport.[42] 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.

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

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

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

[31] ACLED Conflict database, accessed 26.02.24.

[32] UNOCHA (March 2023): State Profile, Blue Nile.

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

[34] ACLED Conflict database, accessed 26.02.24.

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

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

[37] IOM DTM (April 2023): Emergency Event Tracking, Ar Rusayris, Blue Nile.

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

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

[40] IPC (2024): Sudan: Acute Food Insecurity Projection Update for October 2023; UN Geneva (2024): Press Briefing, 6 February 2024.

[41] ACAPS (July 2023): Displacement due to conflict in Blue Nile State.

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

Recommendations

- **Support agriculture in Tadamon and El Demazine localities:** the favourable early-season weather conditions and high concentration of cultivated land in these localities present opportunities to boost food production in the State. Based on previous reports, seed distributions and provision of other agricultural inputs may be a priority for farmers, however these reports may be skewed towards smallholder farmers who have traditionally relied on seed distributions. Larger, semi-mechanized producers have historically relied on agricultural finance; cash-based assistance could be explored to support the semi-mechanized sector.

- **Further assessments should investigate the priority needs of farmers across the rest of the state:** shortages of other agricultural inputs, reported across the country, are also likely to impact Blue Nile. Farmers in locations where weather conditions are less favourable may be particularly vulnerable, particularly those engaging in small-scale and subsistence activities.

- **Consider food and/or cash assistance to El Russirs, Was al Mahi and Gaysan localities, and to IDP populations, as well as potential market systems development:** conflict and displacement-affected populations are likely to be more vulnerable to food insecurity in 2024.[43] Areas hosting large numbers of these populations are also projected to see unfavourable weather conditions for agriculture. Therefore, assistance to directly address food insecurity may be necessary, with modalities determined depending on market and supply chain functionality.

- **Consider parallel cash assistance to address conflict-induced lack of purchasing power across the state:** 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. Recent analysis of agri-food and payment systems in Sudan provides guidance on balancing supply and demand.

- **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.[44]

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

[44] 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 from Google Earth Engine (GEE) to collect soil moisture, precipitation, and NDVI data from April 1, 2015, to January 31, 2024 in Blue Nile 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.[45]

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 Blue Nile 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 relationship 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 Blue Nile.
- 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.

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

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