

SUDAN CRISIS ANALYSIS

Remote Sensing to Monitor Impact of Conflict on Agriculture

AUGUST 2023

This paper is part of a series of crisis analysis briefing papers by Mercy Corps following the outbreak of conflict in Sudan in April 2023. It aims to better understand and anticipate the impact of conflict on agriculture, given the critical role of agricultural production and livelihoods in preventing further deterioration of food security. The paper used remote sensing techniques to measure vegetation levels in agricultural areas and compare with previous years, to identify changes that may warrant further exploration and analysis.

Key Findings

- Until the end of July, remote sensing analysis showed that vegetation levels across agricultural areas in Sudan were generally high compared to long-term averages. This could be attributed to good early season rainfall and following an above-average harvest for many staple crops in 2022.
- A notable outlier was Khartoum – which showed a stark decrease in vegetation levels. When cross referenced with violent incident data and contextual details of specific locations, there are indications that agricultural activity has been severely disrupted by hostilities in the capital.
- Also showing a decrease in vegetation levels are areas of White Nile and Al Jazirah containing large-scale industrial farms. This could indicate that conflict-related fuel price shocks have impeded agricultural activities requiring fuel-powered machinery.
- In the east of the country, the onset of drought-like conditions means that vegetation levels may decrease in the near future.
- Given that the remote sensing analysis does not differentiate between different types of vegetation it cannot alone provide conclusive assessments on agriculture production. However, given aid actors' limited access to many parts of Sudan, it may be able to provide indications of potential shocks warranting further analysis, as well as valuable localised insights when layered with contextual knowledge and other variables.

Introduction

Conflict in Sudan has had a profound impact on food security across the country. At the beginning of August, 20.3 million people – 42% of the population – were classified as acutely food insecure,¹ an increase of (3-3.5 million) people in just four months and higher than initial projections.² Any decrease in agricultural production poses a critical risk to food security: prior to the conflict, Sudan produced roughly as much millet and sorghum as it consumed – staple foods in rural areas where two-thirds of the population live – and a quarter of wheat consumed domestically.³ Further, agriculture was the main source of income and livelihood for 60-80% of the population,⁴ including many women and girls in states such as East and South Darfur and South Kordofan.⁵

Since April, the conflict has created challenges for households reliant on domestic agricultural production and agricultural livelihoods. This includes direct threats of conflict – looting of food stocks, insecurity and displacement impacting production – as well as disruption of markets, trade routes, and imports/exports.⁶ During the May-July planting season, farmers faced increased prices for inputs such as fuel, seeds, agrochemicals and labour, whilst destruction of markets and food factories has been documented in Khartoum, Darfur and North Kordofan.⁷

Challenges may increase with ongoing displacement of people across the country and increased competition over resources, which adds additional pressure to the seasonal increased risk of violence due to resource-related disputes between sedentary farmers and migratory pastoralists, particularly in Darfur after the rainy season and during harvests.⁸ These conflict-related stressors are potentially compounded by climate shocks: between June and September 2023, ICPAC predicts above-normal rainfall in most of Blue Nile, Sennar and White Nile states and elsewhere. potentially leading to increased risk of flooding. However, as of early August 2023, in many areas increased rainfall appears to have supported the initial planting season. In other areas, below-

Key Food Crops in Sudan



- Sorghum: staple food for most rural and lower income households in central and eastern Sudan; the most common crop grown by crop-producing households. Most common crop in Eastern region, Khartoum, White Nile and Blue Nile, second most important in Kordofan.
- Millet: staple food in Darfur and parts of Kordofan; the second most common crop grown by crop-producing households.
- Wheat: staple food in northern Sudan, often grown for commercial purposes.
- Common cash crops: sesame (key crop in Kordofan), groundnuts.

¹ IPC (August 2023) Sudan: IPC Acute Food Insecurity Analysis, June 2023-February 2024 (<https://reliefweb.int/report/sudan/sudan-ipc-acute-food-insecurity-analysis-june-2023-february-2024-issued-august-2-2023>)

² WFP (May 2023) Conflict in Sudan: Food Security Analysis and Forecast (<https://docs.wfp.org/api/documents/WFP-0000148784/download/>)

³ Insecurity Insight (July 2023) The Sudan Crisis, Conflict and Food Insecurity (<https://reliefweb.int/report/sudan/sudan-crisis-conflict-and-food-insecurity-july-2023>)

⁴ Sudan Forests National Corporation (2021) Republic of Sudan National Land Cover Map: 2020 Report (https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/documents/files/sudan_land_cover_report.pdf)

⁵ CARE Sudan (2023) Gender Analysis in Sudan (<https://careevaluations.org/evaluation/gender-analysis-in-sudan-exploring-gender-dimensions-of-humanitarian-action-and-womens-voice-and-leadership-in-east-darfur-gadarif-kassala-south-darfur-and-south-kordofan/>)

⁶ FAO (May 2023) GIEWS Update Sudan: Dramatic increase in Acute Food Insecurity due to the Ongoing Conflict (<https://www.fao.org/3/cc6119en/cc6119en.pdf>)

⁷ NRC (July 2023) Sudan: One Hundred Days of War (https://www.nrc.no/globalassets/pdf/reports/sudan-100-days-of-war/2023-nrc-sudan_100_days_final.pdf)

⁸ Insecurity Insight (July 2023) The Sudan Crisis, Conflict and Food Insecurity (<https://reliefweb.int/report/sudan/sudan-crisis-conflict-and-food-insecurity-july-2023>)

normal rainfall may lead to increased risk of conflict over water resources, reduction in hydropower production and water supply for irrigation.⁹

To better understand the impact of these complex interrelated factors, this paper uses satellite imagery analysis to monitor the Normalized Difference Vegetation Index (NDVI) in agricultural areas of Sudan. It compares vegetation levels since April 2023 to average vegetation levels in previous years, which can serve as a rough proxy to indicate potential agricultural production later in the year. It also aims to understand which areas have suffered a greater decrease in vegetation, which may indicate potentially lower agricultural yields and increased vulnerability of communities.

Some caveats apply given limitations of NDVI analysis. The index does not differentiate between different types of vegetation so, for example, certain agricultural crops can be indistinguishable from other types of vegetation given similar reflectance properties that NDVI relies upon – with potentially important implications for conclusions regarding agricultural production. This points to the merit of validating vegetation indices with other data sources and including contextual expertise of Sudan’s agricultural sector.¹⁰

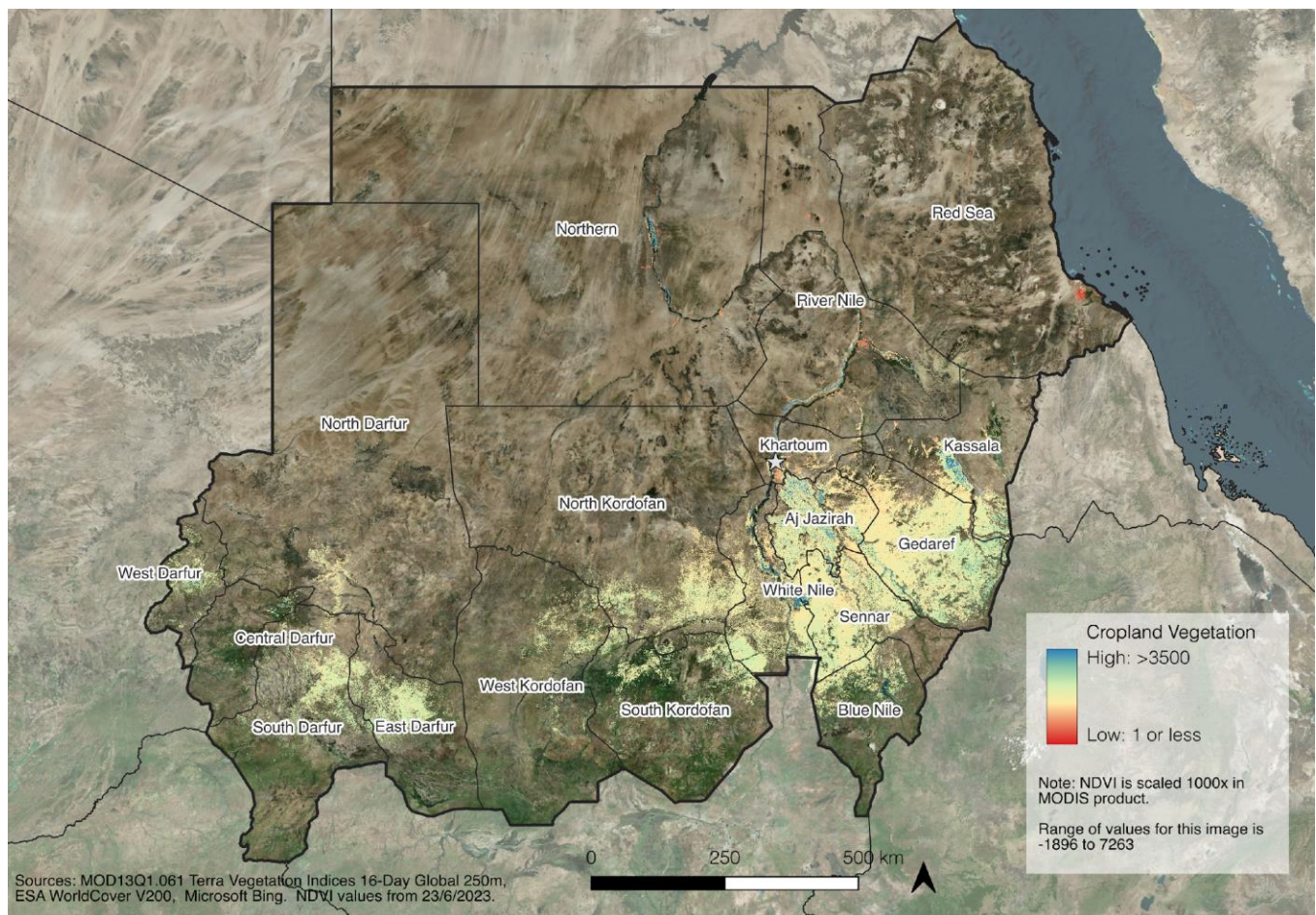
⁹ ICPAC (2023) Seasonal Forecast June to September 2023. IGAD. (<https://www.icpac.net/publications/summary-for-decision-makers-june-to-september-2023-season/>)

¹⁰ Also considered for the analysis was the Soil Adjusted Vegetation Index (SAVI), which adds a soil brightness correction factor to the NDVI equation, thus optimising the index for places with sparser vegetation like Sudan. However, given the value simply adds a standard adjustment to NDVI, it is highly correlated and the percent change standardization values used are effectively the same between the two indices. Choosing NDVI allowed the analysis to be run with both daily MODIS datasets as well as the pre-packaged 8-day and 16-day datasets, which proved lighter weight for the graphs presented in this paper.

Agricultural Areas in Sudan

- Map 1 shows the areas in Sudan which are used for agriculture. As of 2020, this comprised 17.5% of land use in the country. Cultivable land is mostly between Blue Nile and White Nile states (31% and 57% respectively), towards Jazirah and Gedaref (61% and 67%), as well as in the Darfurs and selected areas of the Kordofans.¹¹
- The main subsistence crops are millet, sorghum, and to a lesser extent wheat. Commercial crops are grown particularly on irrigated land along the Blue and White Nile Rivers.¹²
- In the east of the country (Kassala, Gedaref, Blue Nile, Sinnar, White Nile, South Kordofan), Sorghum comprises 80% of cultivated land, producing around 45% of Sudan's requirement. Agriculture is mostly semi-mechanised and rainfed, though there are some large-scale irrigation schemes using seasonal flooding, for example in Al-Jazirah. In Darfur and much of Kordofan, agriculture is predominantly traditional and rainfed.

Map 1: Cropland vegetation in Sudan in June 2023



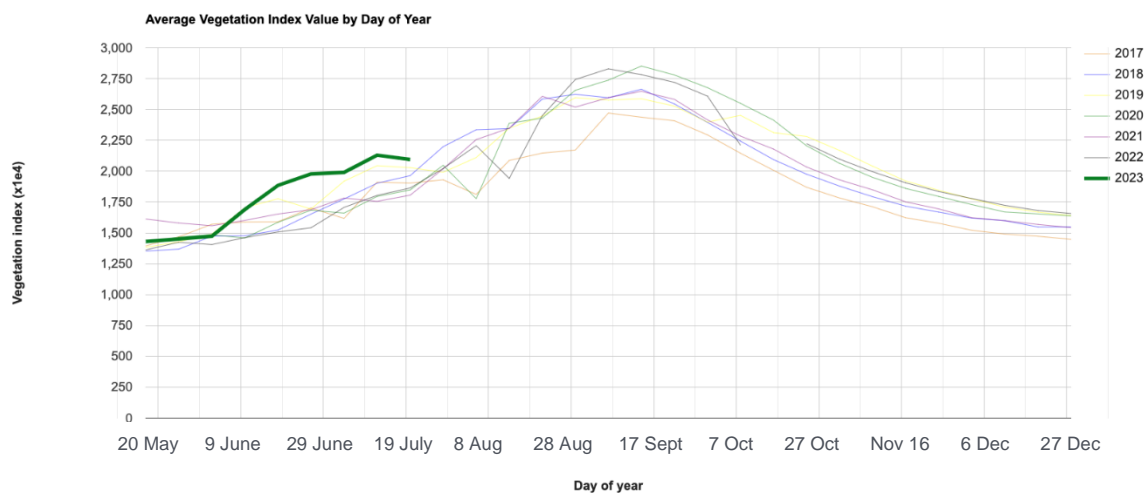
¹¹ Sudan Forests National Corporation (2021) Republic of Sudan National Land Cover Map: 2020 Report (https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/documents/files/sudan_land_cover_report.pdf)

¹² Insecurity Insight (July 2023) The Sudan Crisis, Conflict and Food Insecurity (<https://reliefweb.int/report/sudan/sudan-crisis-conflict-and-food-insecurity-july-2023>)

Vegetation in Agricultural Areas April-July 2023

- Figure 1 shows the average vegetation index in agricultural areas across the entire country throughout 2023, compared with the average vegetation index in previous years (2017-2022). Between the start of June and mid-July 2023, the vegetation index was higher compared to recent years.
- This is likely largely due to higher early season rainfall in June 2023, compared to average rainfall in June.¹³ This was the case for 2022, which saw above-average cereal production across Sudan due to favourable weather conditions: compared to 2021, the total production of sorghum, millet and wheat increased by 45%, representing a 13% increase over the average production in 2017-2021.¹⁴
- This was due to above-average rainfall that was distributed across the season, with particularly favourable middle and late season rainfall.

Figure 1: Average Vegetation Index in agricultural areas in 2023 compared to previous years



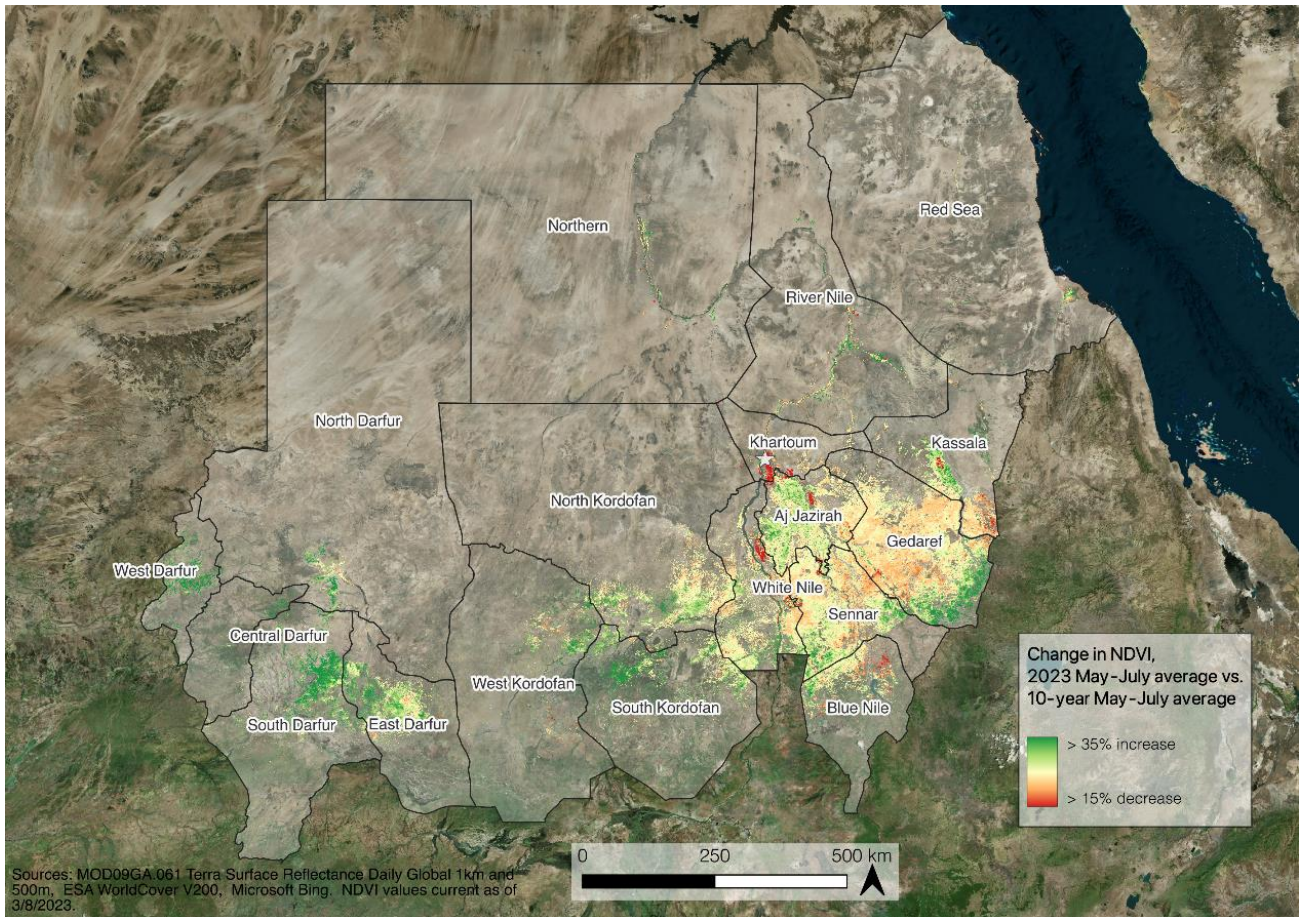
- However, the geographical vegetation index highlights disparities across the country. On Map 2, green indicates that there has been an increase in vegetation compared to the 10-year average (in some locations, more than 35%), whilst red indicates a decrease in vegetation of more than 15%, and orange, a decrease of between 0-15%.
- In Blue Nile, Gedaref and Sennar, the slight decrease in vegetation roughly corresponds with locations that have started to be affected by drought conditions. The FAO Agricultural Stress Index (ASI) highlights parts of these states as having large proportions of cropland area (over 25%) affected by severe drought, likely largely attributable to increased temperatures.¹⁵
- Khartoum is also a notable outlier. The decrease in vegetation in agricultural areas in Khartoum may be partially an early sign of impact of conflict. Large hotspots for vegetation decrease are also apparent in White Nile and Al Jazirah despite stable or increased indices in adjacent areas, suggesting non-weather-related causes.

¹³ FAO (2023) Earth Observation: Sudan Country Indicators, Precipitation Indicators (<https://www.fao.org/giews/earthobservation/country/index.jsp?type=33&code=SDN#>)

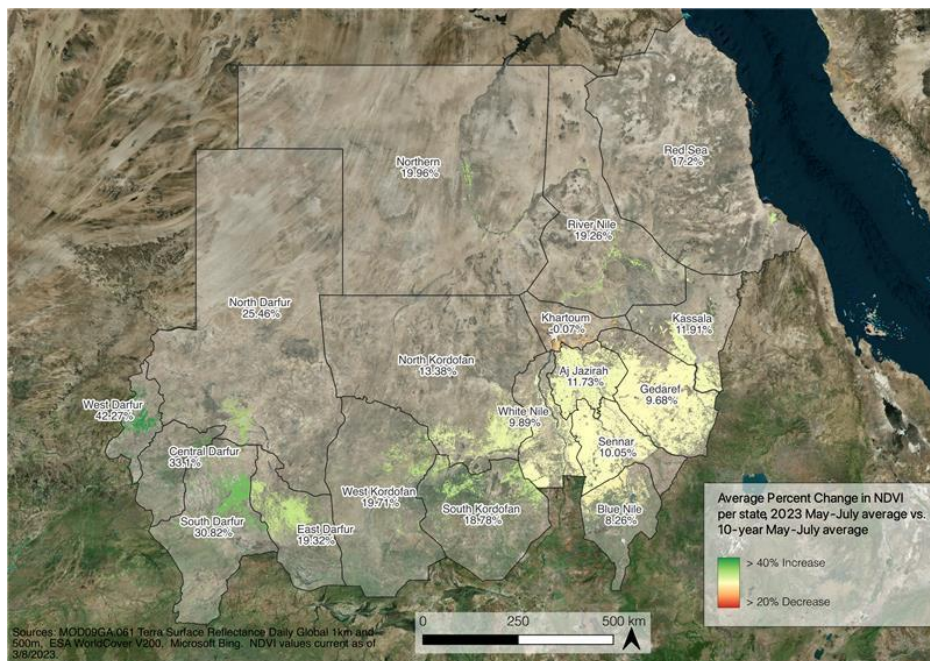
¹⁴ FAO (2023) Global Information and Early Warning System (<https://www.fao.org/giews/countrybrief/country.jsp?code=SDN>)

¹⁵ ICPAC (2023) Temperature Probabilistic Forecast June to September 2023. (https://www.icpac.net/seasonal-forecast/june-september-2023/?region=1&resource_type=5)

Map 2: Change in vegetation in agricultural areas in 2023 compared to 10-year average



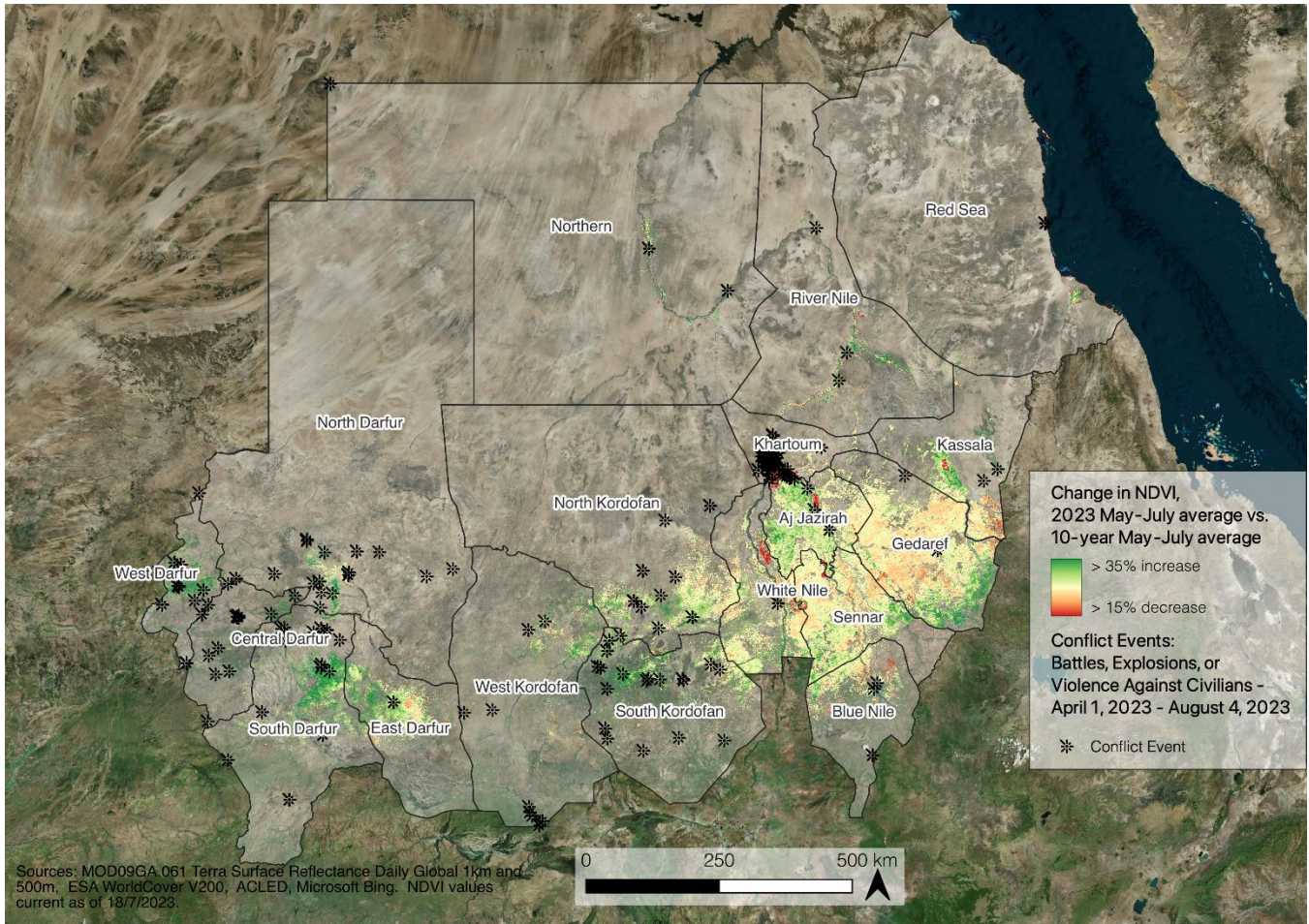
Map 3: State-level overall change in vegetation in agricultural areas in 2023



Impact of Conflict

- Map 4 below shows the change in vegetation in agricultural areas overlaid with locations where conflict events (battles, explosions, violence against civilians) have been recorded between April and August 2023, using data collected by ACLED.
- In total, 60% of the conflict incidents recorded by ACLED were in Khartoum. Although it was not possible to verify with farmers on the ground, the decrease in vegetation shown in satellite imagery indicates that planting was severely disrupted and agriculture is likely showing early signs of stress.
- Vegetation decreases detected in large areas of White Nile and Al Jazirah correspond with locations of large-scale industrial farms. This may indicate that fuel price shocks may have impeded agricultural activities requiring fuel-powered machinery. This type of industrial farming dominates sorghum production, pointing to potential disruption to the production cycle of Sudan's key staple crop should higher fuel prices and shortages persist due to the conflict.
- Although vegetation in agricultural areas of Darfur and the Kordofans has not shown a decrease as of mid-July, these areas have also suffered clashes. This may be due to lagged effect, and should be monitored as the season progresses, or may point to a need to further differentiate between vegetation types to rule out NDVI increase due to a proliferation of weeds due to conflict-driven neglect of or inaccessibility to agricultural land.
- Other studies support either direct or indirect connections between conflict and decreased agricultural production. Indeed, a Mercy Corps survey of farmers across Blue Nile and South Kordofan in June-July 2023 found that of the farmers who were not intending to plant, 31% stated that this was due to 'recent conflict and insecurity'. 53% also stated that they had no money to purchase seeds, which may also be related to conflict. It is also worth noting that the lowest intention to plant was in Kadugli, South Kordofan (15%).

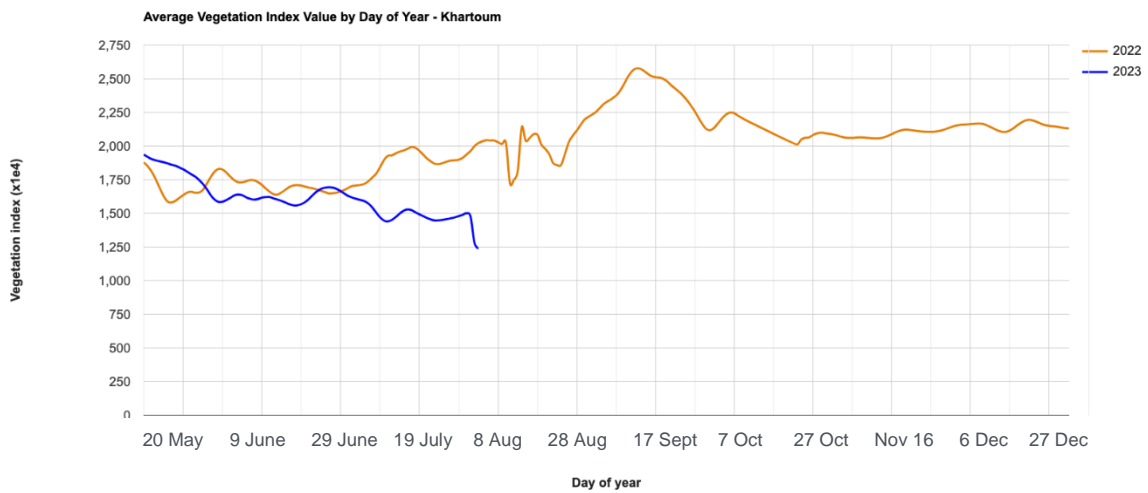
Map 4: Change in vegetation in agricultural areas in 2023 compared to 10-year average, compared to conflict locations



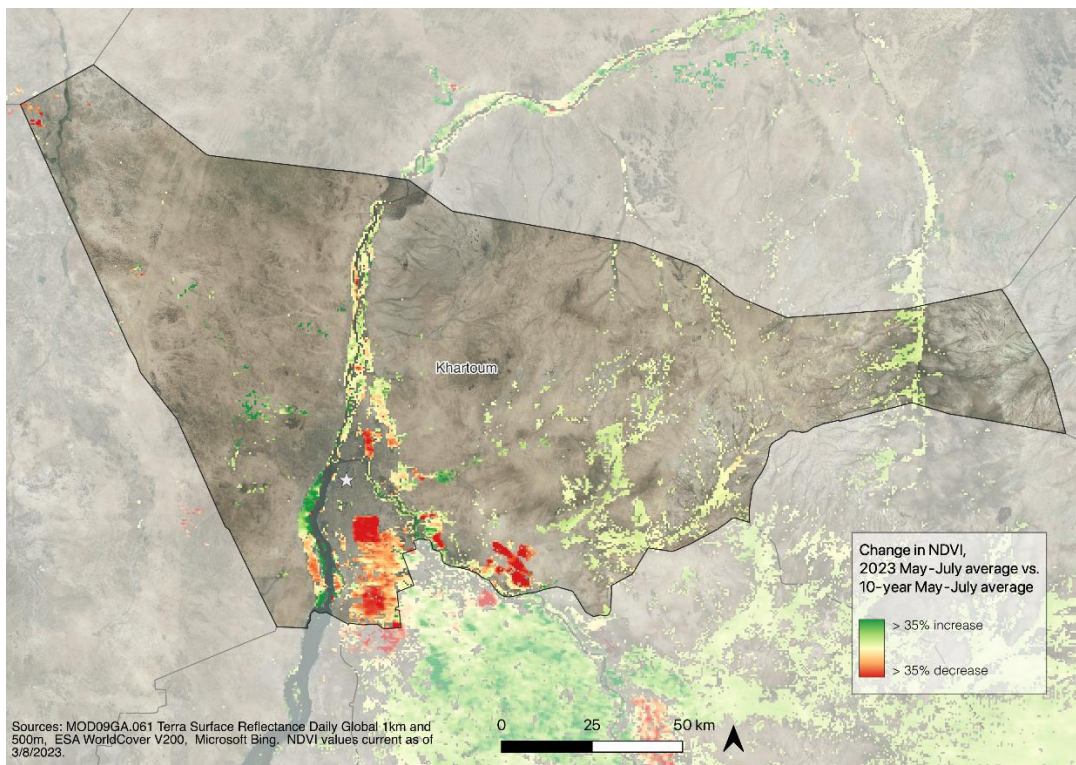
Zoom-in: Khartoum

- Vegetation in agricultural areas of Khartoum is already showing signs of severe stress. Compared to 2022, the vegetation index has dropped steadily since the end of June. This stands in stark contrast to the rest of the country (see Figure 1), indicative of the impact of conflict on the planting season.

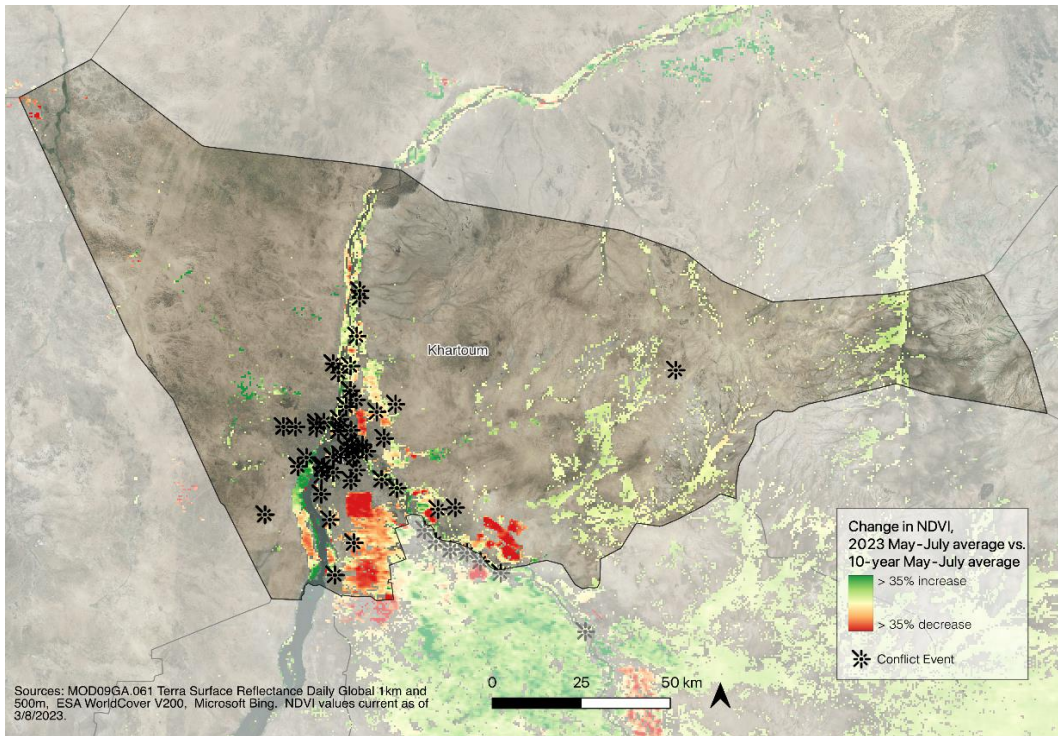
Figure 2: Average Vegetation Index in Khartoum in 2023 compared to 2022



Map 5: Change in vegetation in agricultural areas in Khartoum in 2023 compared to 10-year average



Map 5: Change in vegetation compared to conflict locations in Khartoum



- Certain areas towards the south of Khartoum state have shown a particularly severe decrease, more than 35% compared to the ten-year average (areas in red in Map 5). Map 6 shows a satellite image of this area, the Soba Agricultural Scheme – a large agricultural area adjacent to dense urban settlement. Local sources said these comprise smallholding and commercial crop and livestock farms irrigated by canals from the Nile and underground wells, with products supporting the food needs of residents in Khartoum.¹⁶ One source added that agricultural activity in this area has been severely disrupted by the presence of or occupation by armed groups in the area, proximate violent conflict, lack of agricultural inputs and a fall in demand.

Map 6: Change in vegetation in agricultural areas in Khartoum in 2023 compared to 10-year average



¹⁶ Mercy Corps staff and local sources contacted by Mercy Corps.

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