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Impact of Armed Conflict on Crop Production in Greater Khartoum, Sudan

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ABSTRACT

Since April 2023, Sudan has been engulfed in a violent conflict between the Sudanese Armed Forces and the Rapid Support Forces, resulting in widespread displacement, destruction of infrastructure, and the collapse of essential services. As with agricultural production in rural communities across Sudan, urban and peri-urban farming systems in Greater Khartoum, the area around the capital city, have also been harmed by the conflict.

An integrated assessment of the impact of conflict on crop production in Greater Khartoum was conducted using recent satellite imagery from 2024/25 winter season (October 2024 to March 2025), along with household-level data from the 2024 IFPRI Smallholder Farmers Survey covering the 2023/24 winter season (October 2023 to March 2024). Key findings from the assessment include:

- ◆ **Decline in cropping activities:** Analysis of satellite imagery showed clear evidence of a decline in cropping activities between December 2022 and December 2024. Land use analysis showed a 22 percent reduction in total cultivated area over this period. Notably, land under center-pivot irrigation declined by 87 percent. Normalized Difference Vegetation Index (NDVI) analysis showed a 36 percent decline in vegetated land, indicating both reduced cultivation and plant cover.
- ◆ **Widespread disruption to farming:** Thirty-six percent of the farmers surveyed in Khartoum state reported not cultivating any crops in the 2023/24 winter season primarily because of conflict-related challenges that they could not overcome. Of those that did farm, over three-quarters reported that the conflict had disrupted their agricultural activities.
- ◆ **Shifts in crop selection and agricultural input use:** Vegetables and fruits are now the most commonly grown crops, followed by fodder and beans. Less than one-quarter of farmers now use improved seeds, largely due to conflict-related input shortages. However, despite the conflict, access to fertilizer markets has been maintained—87 percent of farmers reported that they continue to use fertilizer.
- ◆ **Localized resilience:** Some areas of Greater Khartoum, particularly Karari locality, have maintained relatively high levels of cultivation, reflecting localized resilience and reasonable safety and access to agricultural landholdings.

By combining spatial and socioeconomic data, the study highlights the complex and multi-dimensional nature of agricultural disruption in conflict-affected areas, like Greater Khartoum. Several policy responses and other actions needed for recovery and to strengthen the resilience of affected farmers are suggested by the study findings:

- ◆ Promote resilient and inclusive farming systems and agricultural value chains.
- ◆ Restore agricultural infrastructure and input supply chains.
- ◆ Improve farmer mobility and market access.
- ◆ Provide emergency assistance and recovery packages to farmers.
- ◆ Strengthen agricultural monitoring systems.

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1) BACKGROUND

Since April 2023, Sudan has been engulfed in a violent conflict between the Sudanese Armed Forces and the Rapid Support Forces, resulting in widespread disruption across all sectors of society. The conflict has triggered one of the largest displacement crises in the country's history, with over 7.4 million individuals internally displaced and 4.3 million having crossed Sudan's borders into neighboring countries (DTM Sudan 2025). In addition to the humanitarian toll, the war has devastated infrastructure and severely disrupted essential services, including electricity, water, and healthcare.

While urban centers, such as Khartoum, have experienced the most destruction, the conflict also extends into rural areas, threatening food production, natural resources, and household welfare. Agriculture is a cornerstone of Sudan's economy. In 2023, the agricultural sector contributed 35 percent of GDP and made-up 40 percent of total employment (World Bank 2025). The conflict has particularly affected agricultural production. Conflict-related disruptions to imports and internal trade have led to soaring prices for agricultural inputs and fuel (FAO 2024). Although at the start of the conflict, agricultural producers demonstrated significant economic resilience compared to other sectors, persistent shortages and logistical constraints have made it increasingly difficult for many to sustain their production, particularly of food. Agricultural GDP is expected to contract by 34 percent and agricultural employment by half if the conflict continues through 2025 (Ahmed et al. 2025).

As the conflict enters its third year, continuing population movements and shifts in economic activities are reshaping demand for food, services, and infrastructure. These dynamics are also affecting those areas around Khartoum where many engage in agricultural production.

In conflict, mapping agricultural production becomes a critical tool for monitoring food security and addressing any emerging constraints populations may face in their access to food. During such crises, when access to land, water, and markets is constrained, spatial analysis helps identify areas of vulnerability. Moreover, after the conflict has ended, such mapping can inform recovery strategies that aim to bring agricultural land back into production and restore local food systems.

This study presents an integrated assessment of agricultural disruption in the Greater Khartoum area—that is, agricultural areas of Khartoum state—that involved combining geospatial data from satellite imagery with household-level insights from the 2024 IFPRI Sudan Smallholder Farming Households Survey. By merging spatial data with household-level socioeconomic conditions, the study provides a comprehensive and timely understanding of how the ongoing conflict has affected agricultural production, land use, and farmer livelihoods in the area around the capital.

Remote sensing techniques—including Normalized Difference Vegetation Index (NDVI) analysis and land use classification of satellite images—are employed to detect changes in cultivated land in Khartoum state between December 2022 and December 2024. In conflict-affected regions, reliable land use data are scarce (Oymatov et al. 2023). Satellite imagery and other remotely sensed imagery are widely used in such contexts to monitor cultivation patterns, identify crop types, estimate yields, and assess land suitability (Bazarov et al., 2021). Even after the conflict has ended, continuing use of these methods will permit the systematic monitoring of agricultural areas and their development.

To ensure methodological consistency and comparability, the winter season was selected for both the NDVI baseline (2022/23) and the follow-up (2024/25), as well as for the 2023/24 household-level data from the 2024 IFPRI Smallholder Farmers Survey assessing agriculture in Khartoum State. Annually, Khartoum state experiences three primary vegetable cropping seasons (Abdalla 2018). The winter cropping season offers the best conditions for open-field cultivation and is the most productive and climatically stable season. In contrast, the hot, dry summer season from April to June often necessitates greenhouse production due to extreme temperatures, limiting the viability of large-scale farming (Abdelrazig et al. 2015).

2) OBJECTIVES OF THE STUDY

This study aims to assess the impact of the ongoing conflict on agricultural land use and crop production in Khartoum state during the 2024/25 winter season. Using remote sensing and spatial analysis techniques, the study compares agricultural land use patterns in December 2024 in the middle of the 2024/25 winter cropping season to those in December 2022 in the baseline 2022/23 winter season. This was done to:

- ◆ Quantify changes in cultivated land area,
- ◆ Identify zones of reduced cultivation or abandonment, and
- ◆ Evaluate the broader effects of the conflict on agricultural activity.

In addition to geospatial analysis, the study incorporates data from the 2024 IFPRI Sudan Smallholder Farming Households Survey to gain deeper insights into farming practices and challenges facing farming households in Khartoum state during the conflict period (Mohamed et al. forthcoming). This survey data captures information on the crop operations of farmers, including their crop choices, access to inputs, and disruptions to production.

The study provides a quantitative assessment of changes in crop production in Greater Khartoum and a qualitative understanding of the constraints faced by farmers. This information can serve as an empirical foundation for the design of evidence-based agricultural recovery policies and strategies for Khartoum state, as well as for other conflict-affected regions of Sudan.

3) DATA SOURCES AND METHODS

This study adopts a mixed-methods approach to assess the impact of conflict on crop production in Khartoum state. By integrating geospatial analysis of recent satellite imagery with household survey data, the research provides a comprehensive view of both physical changes in land use and the socioeconomic challenges faced by farmers. The combination of remote sensing techniques and primary data collection from farming households enables a multi-dimensional understanding of agricultural disruption during the 2024/25 winter season.

3.1 Sources of data

The primary source of geospatial data for this study is Sentinel-2 satellite imagery, which was selected for its high-resolution multispectral capabilities. Two reference periods were analyzed: December 2022 (serving as the pre-conflict winter season baseline) and December 2024 (capturing winter season cropping conditions during the conflict). Sentinel-2,

part of the Copernicus Earth observation program, provides imagery across 13 spectral bands—including visible, near-infrared, and shortwave infrared—with spatial resolutions of 10, 20, and 60 meters.

The satellite imagery was accessed through the Copernicus Open Access Hub and processed using Google Earth Engine. The analysis focused on vegetation indices and land use and land cover classification to detect changes in cultivated land, particularly to identify areas of abandonment or reduced agricultural activity in the 2024/25 winter season. This geospatial approach enables a spatially explicit assessment of conflict-related disruptions to farming in Khartoum state.

In conflict-affected settings like Sudan, access to reliable agricultural land use data collected at the field level is limited due to displacement, insecurity, and institutional breakdowns (Oymatov et al. 2023). Satellite-based observations offer a valuable alternative, providing consistent, large-scale coverage that supports timely and objective analysis of trends in how agricultural land is being used. In this study, Sentinel-2 imagery was used to assess changes in land cover between the pre-conflict period (December 2022) and the conflict period (December 2024) as the basis for spatial analysis of farming disruptions in Greater Khartoum.

This study also utilizes data from the 2024 IFPRI Sudan Smallholder Farming Households Survey, which was administered between July and November 2024. The survey covered 13 out of Sudan's 18 states, with several areas—particularly in the Darfur region—remaining inaccessible due to network disruptions. Data collection was carried out using Computer-Assisted Telephone Interviewing (CATI), rather than face-to-face interviewing. Respondents were interviewed by calling them over the mobile telephone network. A structured standardized questionnaire was programmed into a digital data collection platform, which trained enumerators then used to record the data they obtained from survey respondents. The survey questionnaire included modules on agricultural practices, access to inputs and markets, household-level shocks, food insecurity, and household coping mechanisms.

Over 2,000 interviews were conducted nationwide, including 397 respondents in Khartoum state. This dataset provides critical insights into the extent of disruption to agricultural activities during the 2023/24 winter season, the broad set of challenges smallholder farmers across Sudan face due to the conflict, and how they have adapted to them.

The study also incorporated a range of secondary materials to provide essential contextual insights. These materials included both published and unpublished institutional reports, academic literature, and credible online references. They were used to inform and support the results obtained from both the interpretation of the remote sensing images and the analysis of household-level survey data by offering background on the broader political, economic, and environmental conditions affecting agriculture in Khartoum state.

3.2 Satellite imagery interpretation methods

3.2.1 Land use classification

Land use classification in this study was conducted through manual visual interpretation of satellite imagery. This approach is particularly effective in complex or heterogeneous landscapes, where automated classification algorithms may struggle with accuracy.

Khartoum state mixes both urban and rural land uses, so it has one of the most complex landscapes in Sudan. Manual interpretation allows for the integration of expert judgment, contextual knowledge, and adaptability to variations in image quality and land cover patterns.

Multispectral imagery was manipulated in analysis to enhance the differentiation of vegetation and other land cover types. Sentinel-2 imagery, with its rich spectral resolution, provided the basis for identifying cultivated areas, abandoned plots, and non-agricultural land. This method was critical for detecting subtle changes in land use that may have been a result of conflict-related disruptions to traditional land use practices.

3.2.2 Normalized Difference Vegetation Index (NDVI) assessment of vegetation cover

To assess changes in vegetation cover over time, the Normalized Difference Vegetation Index (NDVI) was calculated using Sentinel-2 imagery from both December 2022 and December 2024. NDVI is a widely used indicator for evaluating vegetation health and density. It is based on a contrast between near-infrared reflectance (NIR) and red reflectance (RED):

$$\text{NDVI} = (\text{NIR} - \text{RED}) / (\text{NIR} + \text{RED})$$

where NIR are those radiation wavelengths that are strongly reflected by healthy vegetation, and RED are those that are absorbed by chlorophyll in plants.

NDVI values range from -1 to +1. Values close to +1 indicate dense healthy vegetation, while values near 0 represent bare soil, built-up areas, or sparsely vegetated land. NDVI values below zero typically correspond to water bodies or non-vegetated surfaces.

In this study, NDVI was used to distinguish vegetated areas from non-vegetated features, such as urban infrastructure, roads, and exposed soil. This distinction was essential for quantifying changes in cropped area and identifying zones of land abandonment or degradation linked to the conflict.

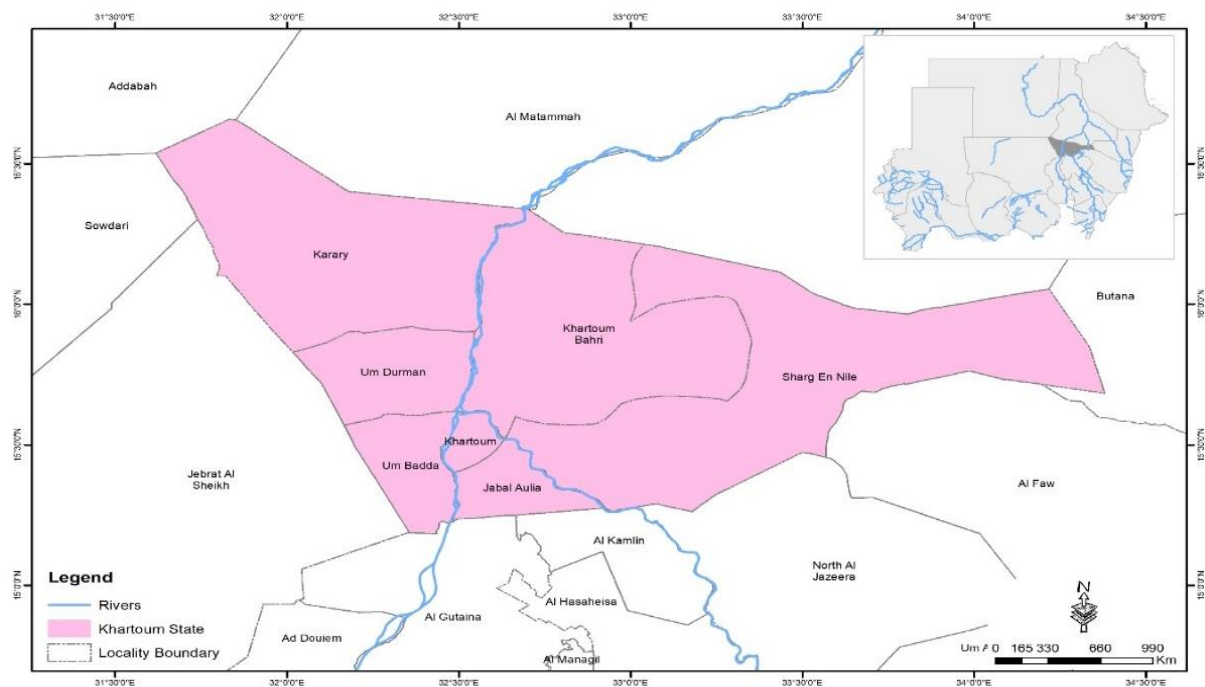
4) OVERVIEW OF THE STUDY AREA

Khartoum state is the smallest of Sudan's 18 states by land area (22,142 km²), but it is the most densely populated, with an estimated 8.7 million residents in 2020 (OCHA 2023). Geographically, the state lies between longitudes 31.5°E and 34°E and latitudes 15°N and 16°N. It has a semi-desert climate. The average annual rainfall is approximately 200 mm, but there is high variability in seasonal rainfall totals (Ahmad et al. 2002; Hamad and El-Battahani 2005). In consequence, agriculture in Khartoum state is highly dependent on irrigation.

Khartoum city is situated at the confluence of the White Nile and Blue Nile rivers. Administratively, Khartoum state consists of seven localities: Khartoum, Omdurman, Bahri (Khartoum North), Sharq an-Nil, Jabal Awliya, Om Badda, and Karari (Figure 1).

Before the outbreak of the current conflict, Khartoum was Sudan's principal political, economic, and logistical hub, and its agricultural activities—though constrained by urban expansion—remained vital for the local food supply and the livelihoods of many residents. The concentration of conflict in Khartoum has had profound implications for farming, market access, and land use patterns in the state.

Figure 1: Location and administrative boundaries of Khartoum state



Source: DIVA-GIS (2024). GIS data retrieved from <https://diva-gis.org/data.html>; map layout by the authors.

Agricultural activity in Khartoum state is seasonal, shaped by temperature fluctuations, rainfall variability, and water availability. The state experiences three distinct cropping seasons (Abdalla 2018):

- ◆ **Winter** (October–March): Characterized by milder temperatures, this season supports open-field cultivation of crops, such as wheat, beans, and a wide variety of vegetables.
- ◆ **Hot Dry Summer** (April–June): Extreme heat and harsh field conditions limit outdoor cultivation, prompting a shift toward greenhouse farming (Abdelrazig, Mahmoud, and Abdalla 2015).
- ◆ **Rainy Season** (July–September): Frequent flooding affects large portions of the floodplain, constraining agricultural productivity and access to farmland.

Long-term climate changes further compound these seasonal challenges. Elagib (2010) documented a significant warming trend in Sudan between 1941 and 2005 and projected a 2.6°C increase in the annual average temperature by 2070. Such climatic changes pose serious risks to the viability of agricultural production in Khartoum state, especially when combined with the vulnerabilities introduced by the ongoing conflict and the associated displacement of much of the state’s population.

5) ANALYSIS AND DISCUSSION OF RESULTS

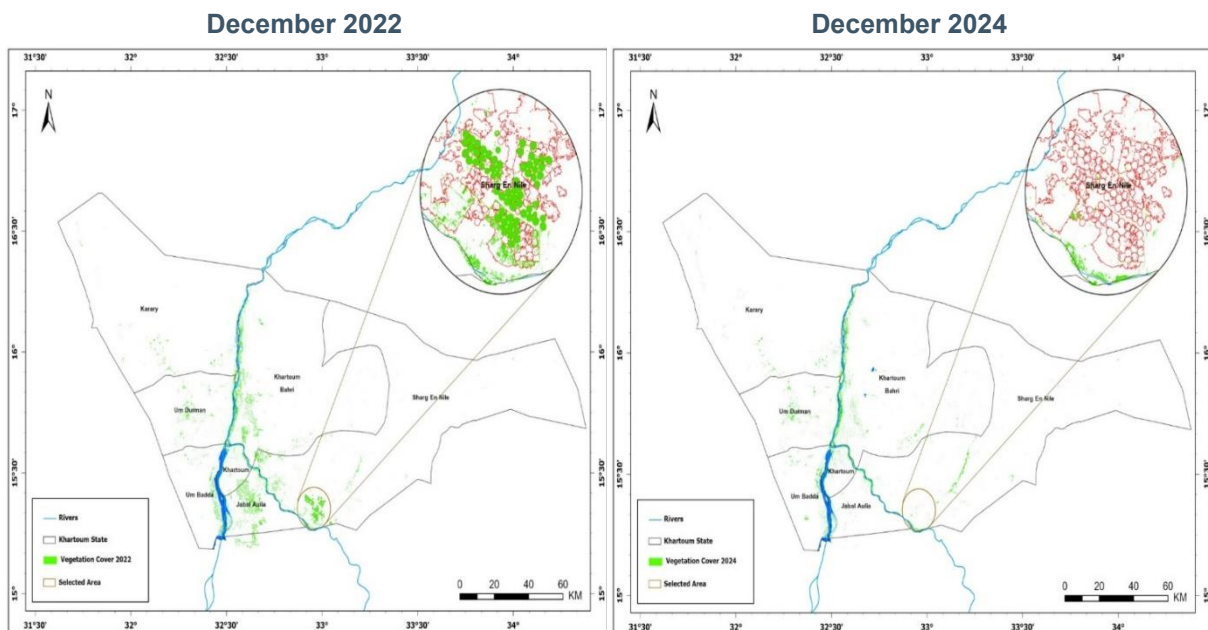
5.1 Vegetation change based on NDVI analysis

The Normalized Difference Vegetation Index (NDVI) analysis of the satellite imagery reveals a marked decline in cultivated or otherwise vegetated land across Khartoum state between December 2022 and December 2024 (Figure 2). This reduction in NDVI values is a strong

proxy for decreased agricultural activity in the Khartoum area and reflects the widespread disruption to farming caused by the conflict that began in April 2023.

The decline in NDVI values is indicative of reduced green vegetation cover, which may result from land abandonment, displacement of farming households, or limited access to inputs and irrigation. These findings align with survey data showing that a significant proportion of farmers in Khartoum state either did not cultivate or faced severe constraints during the 2024/25 winter season. The spatially extensive vegetation loss underscores the impact of conflict on land use patterns and agricultural productivity in Sudan's most urbanized and economically central state.

Figure 2: NDVI-based comparison of vegetation cover in Khartoum state in December 2022 and December 2024



Source: Authors' calculations based on NDVI derived from Sentinel-2 satellite imagery
Note: NDVI = Normalized Difference Vegetation Index

The analysis shows an estimated decline in vegetated land across Khartoum state of 36 percent—from 49,165 ha in December 2022 to 31,620 ha in December 2024. This sharp decrease is likely a direct consequence of the ongoing conflict, which has disrupted agricultural activities, displaced farming communities, and contributed to environmental degradation. The loss of green vegetation cover has serious implications for food security, household livelihoods, and ecological resilience, particularly in a region already vulnerable to climate variability and resource scarcity.

While cropland in Khartoum state has significantly declined since the conflict began, the NDVI analysis indicates that grazing areas remain abundant and relatively well-vegetated. This pattern may reflect a reduction in livestock numbers due to conflict-related mortality or displacement, which has led to lower grazing pressure around Khartoum. In turn, this reduced pressure may have allowed vegetation in pasture zones to regenerate, contributing to the higher NDVI values observed in areas of Khartoum state typically used for grazing.

This dual trend—declining cultivation alongside persistent or recovering pasture cover—offers an important insight into the shifting dynamics of land use in conflict-affected regions.

There is a complex interplay between human displacement, agricultural disruption, and ecological response, which underscores the need for differentiated recovery strategies that address both crop production and livestock systems.

5.2 Results of land use classification from satellite imagery

Land use classification using satellite images reveals a notable decline in cultivated land across all major farm types in Khartoum state between 2022 and 2024. As shown in Table 1, the total cultivated area decreased by 21.8 percent over this period, reflecting widespread economic disruption caused by the conflict, continuing insecurity, and shortages of essential resources for agricultural production, such as water and electricity.

Table 1: Change in cultivated land area in Khartoum state between 2022 and 2024, by irrigated farm type

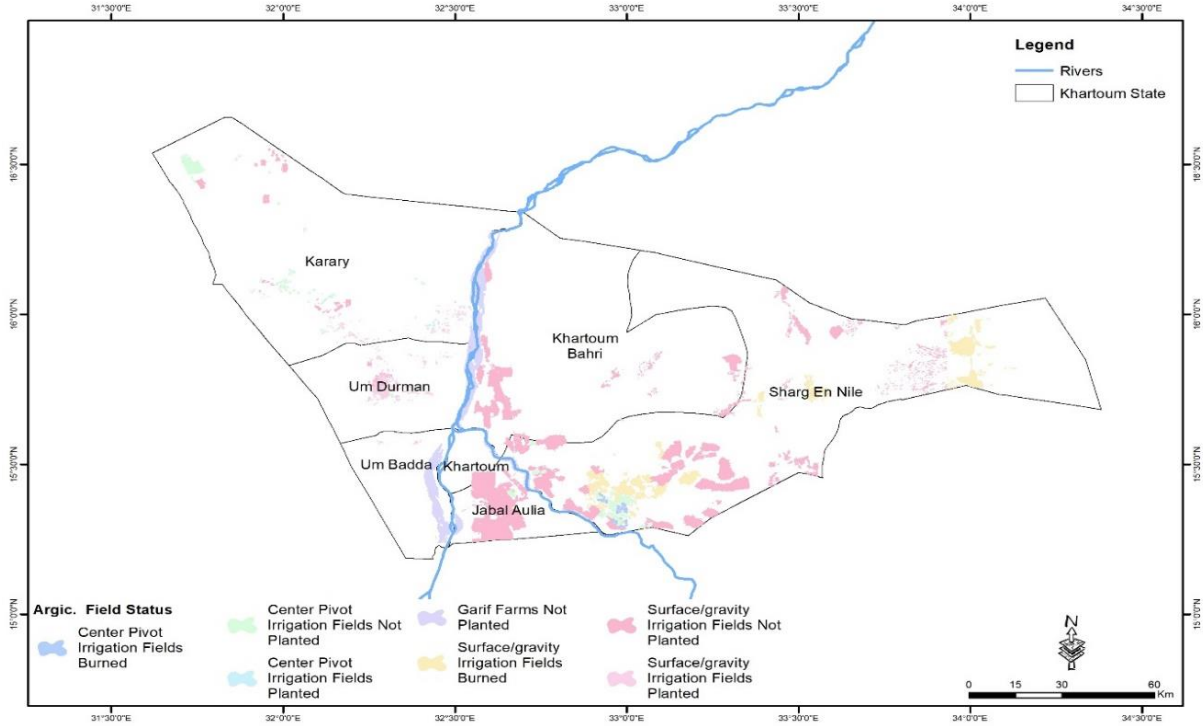
Irrigated farm type	December 2022 area, km ²	December 2024 area, km ²	Percentage change
<i>Garif</i> farms	363	345	-5.0
Center-pivot irrigated fields	1,129	150	-86.7
Surface or gravity irrigated fields	2,168	1,586	-26.8
TOTAL	2,660	2,081	-21.8

Sources: D’Silva et al. (2023); Authors’ calculations based on visual interpretation of Sentinel-2 satellite imagery.

The most dramatic reduction was observed in center-pivot irrigation fields, for which the area under crop production contracted by 87 percent, likely due to their high dependence on stable electricity and water supply—both of which have been severely cut by the conflict. Surface or gravity irrigated fields also saw a significant decline in area under crops of 27 percent, while the small-scale, pump-irrigated *garif* farms experienced a more modest reduction of 5 percent. These trends underscore the vulnerability of irrigated agriculture to systemic shocks associated with the conflict and highlight the urgent need for targeted support to restore farming operations in the region.

An area-based classification of agricultural land in Khartoum state was conducted using manual visual interpretation of Sentinel-2 satellite imagery from December 2024. This approach categorized farmland based on field type and irrigation method, providing a detailed spatial overview of agricultural patterns during the conflict period. The classification results are presented in Figure 3, highlighting the distribution and extent of different field types across the state.

Figure 3: Agricultural land classification in Khartoum state in December 2024, based on satellite imagery



Source: Author’s calculations based on visual interpretation of Sentinel-2 satellite imagery for December 2024.

Table 2 highlights the widespread disruption to agricultural activity in Khartoum state during the 2024/25 winter season. Almost 80 percent of the irrigated land was left uncultivated, and 16 percent had been burned, underscoring the severe impact of the ongoing conflict on cropping systems in Khartoum state. These findings show large-scale abandonment of their irrigated fields by farmers due to their inability to cultivate because of insecurity, displacement, or lack of inputs. The burned fields reflect direct physical damage to agricultural land, further compounding the challenges faced by farmers in the region. This dual pattern of abandonment and destruction reflects the depth of the crisis and its implications for food production, rural livelihoods, and land rehabilitation efforts.

Table 2: Agricultural land use in Khartoum state, by field type, December 2024

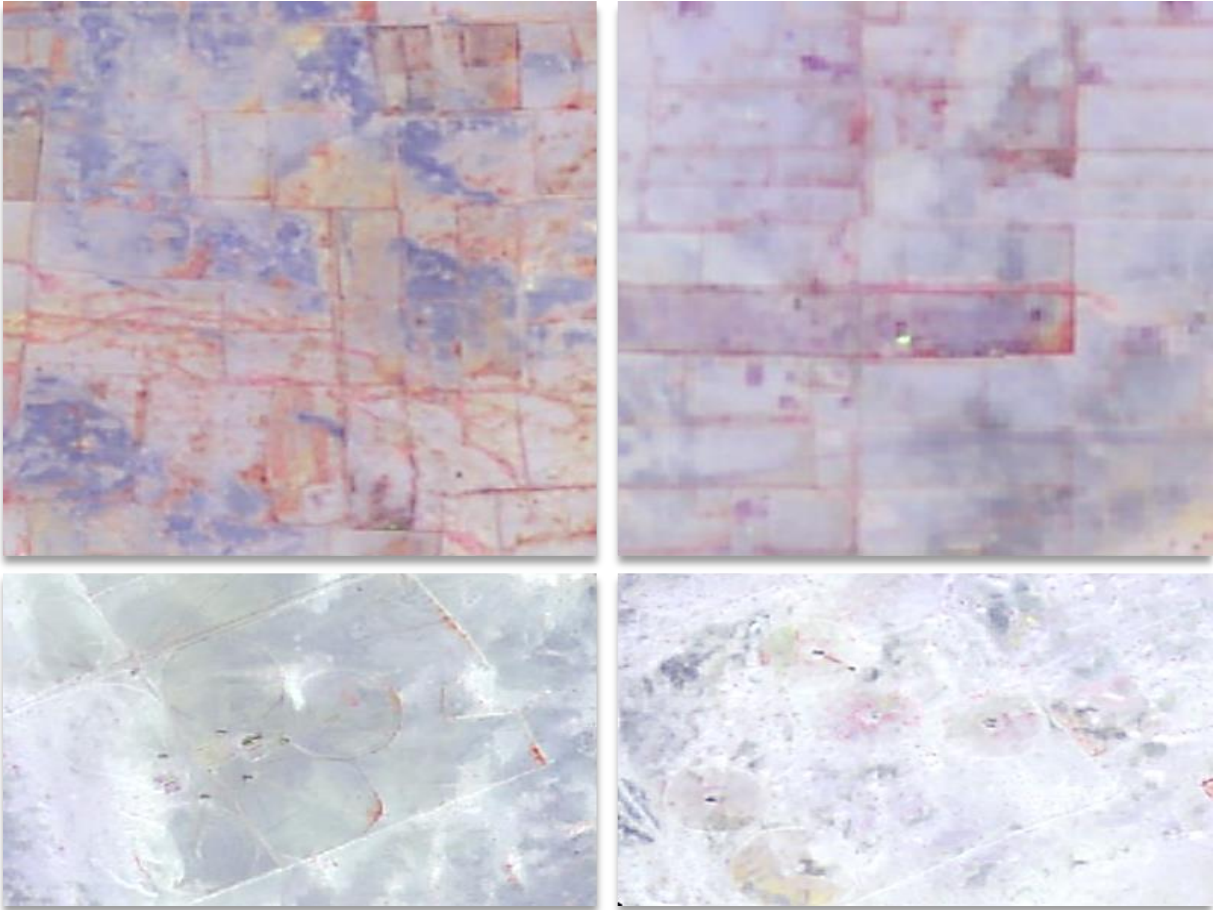
Irrigated farm classification	Area (km ²)	Percentage (%)
Center-pivot irrigation fields—not planted	121.2	5.8
Surface or gravity irrigation fields—not planted	1,183.3	56.9
Garif farms—not planted	344.8	16.6
Not planted, total	1,649.3	79.2
Center-pivot irrigation fields—burned	22.3	1.1
Surface or gravity irrigation fields—burned	310.3	14.9
Burned, total	332.6	16.0
Center-pivot irrigation fields—planted	6.6	0.3
Surface or gravity irrigation fields—planted	92.3	4.4
Planted, total	98.9	4.8
Total	2,081.8	100.0

Source: Author’s calculations based on visual interpretation of Sentinel-2 satellite imagery for December 2024.
 Note: Garif farms were not classified as planted due to their location within active conflict zones, either in Khartoum locality or on Tuti Island.

Satellite image classification for December 2024 indicates that the majority of agricultural fields in Khartoum state were not cultivated during the reference period. Notably, the Omdurman locality, particularly the Karari and Om Badda regions west of the Nile, showed relatively higher levels of active cultivation. These areas experienced lower levels of conflict and remained more accessible to farmers, allowing limited agricultural activity to continue despite broader insecurity.

In contrast, particularly fields located outside of designated irrigation schemes appeared barren in the December 2024 satellite images, having been abandoned and not cultivated recently. The prolonged inactivity on this farmland has rendered these areas less distinguishable in satellite imagery, even at high-resolution scales such as 1:60,000 (Figure 4). These spatial patterns highlight the uneven impact of conflict on agricultural land use and underscore the importance of localized assessments in post-conflict recovery planning.

Figure 4: Barren and uncultivated agricultural fields in Khartoum state, December 2024



Source: Authors' calculations based on NDVI derived from Sentinel-2 satellite imagery for December 2024.

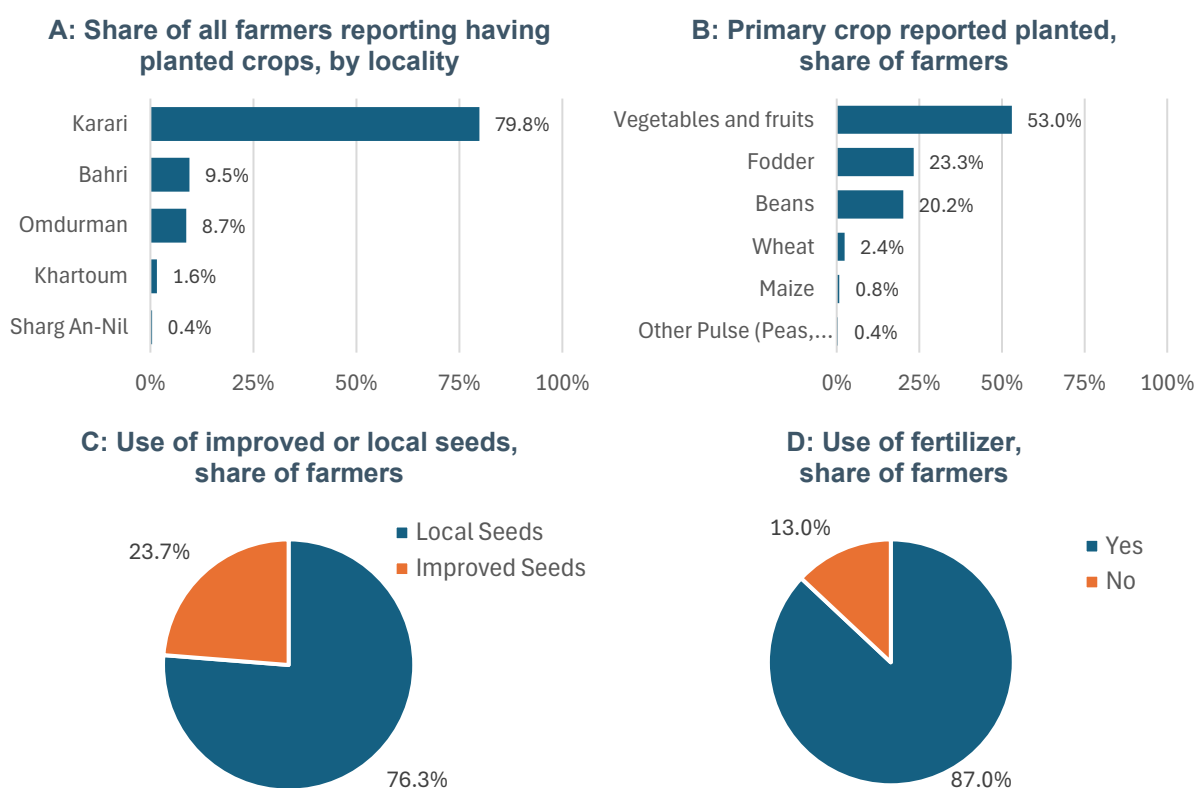
This decline in the area of land that is cultivated in Khartoum state has direct implications for food security, livelihoods, and post-conflict recovery efforts. Understanding these patterns is critical for guiding policy interventions, resource allocations, and targeted support to affected farming communities.

5.3 Results from the 2024 IFPRI Farming Households Survey

The 2024 IFPRI Sudan Smallholder Farming Households Survey interviewed 2,101 farming households across 13 states in Sudan. In Khartoum state, 397 households participated in the survey. The majority of respondents in Khartoum state were located in Karari and Omdurman localities. These areas have been under the control of the Sudanese Armed Forces since the outbreak of the conflict in April 2023.

Of the 397 households surveyed in Khartoum state, 253 reported planting crops during the 2023/24 winter season—36 percent of farmers reported not cultivating any crops. Almost 80 percent of the active farmers were in Karari locality, highlighting the spatial clustering of agricultural activity during the conflict (Figure 5).

Figure 5: Engagement in farming, crop types, and input use in 2023/24 winter season by farmers in Khartoum state



Source: 2024 IFPRI Sudan Smallholder Farming Households Survey (Mohamed et al., forthcoming)

Note: Based on survey sub-sample of 253 farmers who reported engaging in crop production during the 2023/24 winter season

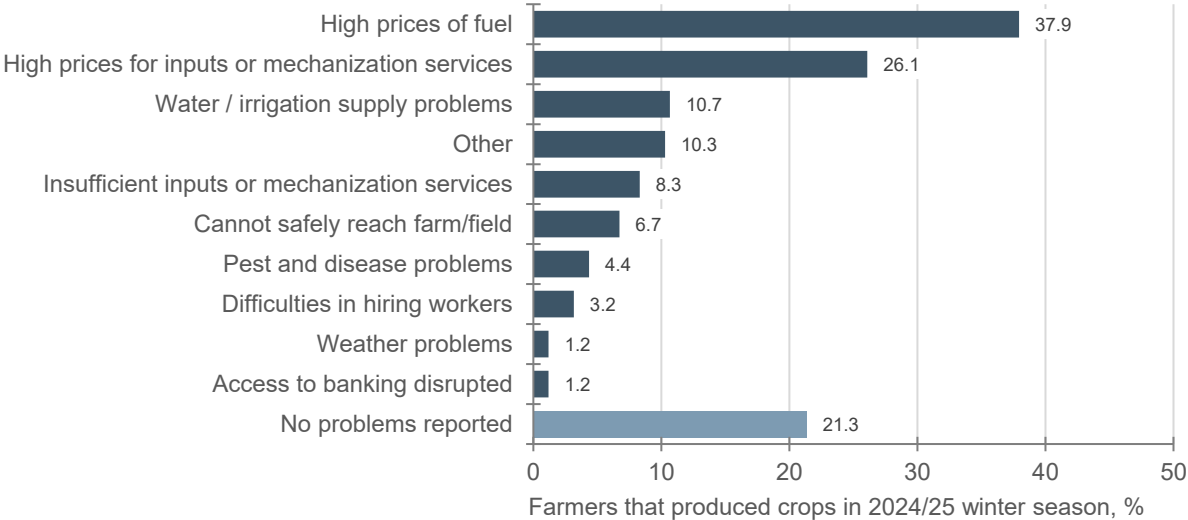
Crop selection during the 2023/24 winter season varied considerably among the surveyed farmers that engaged in production in Khartoum state. Over half of the respondents reported cultivating vegetables and fruits, followed by fodder crops and beans.

In terms of input use, most farmers relied on seed from local varieties, with less than one-quarter reporting that they used improved seed—nationally, 40 percent of farmers surveyed reported using improved seed (Figure 5). This limited use of improved crop varieties is largely attributed to conflict-related disruptions, which have made agricultural inputs both scarce and expensive. Farmers resorted to using seeds retained from the previous harvest due to the unavailability of commercial seed supplies (FAO 2024).

In contrast, fertilizer use remained relatively high, with 87 percent of farmers reporting that they applied fertilizer to their 2023/24 winter crop application—the national average is 77 percent. Despite the conflict, access to fertilizers appears to be less constrained than for improved seeds.

Crop production in Khartoum state during the 2023/24 winter season was significantly disrupted by both the conflict and other factors. Among the 85 percent of farmers who did engage in crop production, the most frequently reported challenges were high fuel prices and the high cost of agricultural inputs and mechanization services (Figure 6). These issues are closely linked to conflict-induced market instability and logistical constraints. Additional challenges included water and irrigation supply shortages and restricted availability of inputs or machinery. The range of challenges noted by the farmers surveyed underscores the multifaceted nature of the crisis affecting agricultural livelihoods in the region.

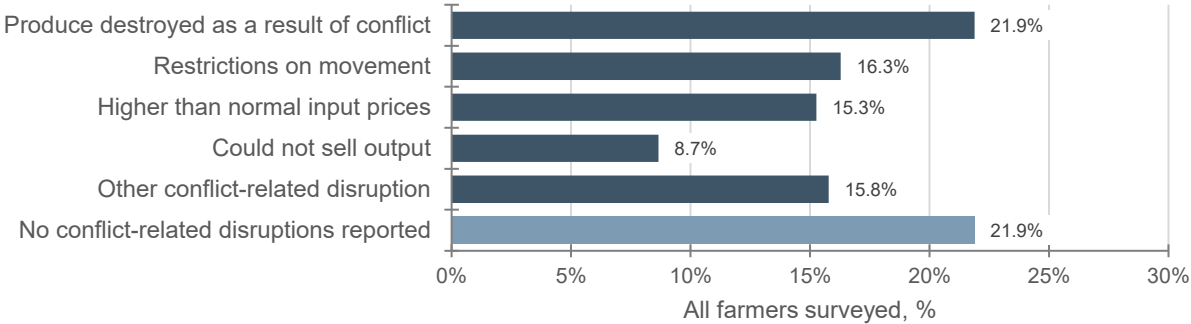
Figure 6: Key challenges in crop production reported by farmers who engaged in farming during the 2023/24 winter season in Khartoum state



Source: IFPRI 2024 Sudan Smallholder Farming Households Survey (Mohamed et al., forthcoming).
 Note: Based on sub-sample of 253 Based on survey sub-sample of 253 farmers who reported engaging in crop production during the 2023/24 winter season

The survey included a question on whether the farmer’s agricultural activities were specifically disrupted by conflict during the 2023/24 winter season. Seventy-eight percent of the farmers surveyed in Khartoum state reported that their farming was negatively affected by the conflict in some way. These disruptions had severe consequences. Over one-fifth of survey farmers in Khartoum state reported that their crops were destroyed as a direct result of the war—representing the most extreme form of loss (Figure 7). Movement restrictions, cited by about one in six farmers, further limited access to farms, markets, and essential services. Similar shares of farmers reported facing unusually high input prices, as well as other conflict-related challenges. Some farmers, about 9 percent, reported that they were unable to sell their produce, reflecting breakdowns in market access and trade channels.

Figure 7: Reported conflict-related disruptions to farming activities during the 2023/24 winter season in Khartoum state



Source: 2024 IFPRI Sudan Smallholder Farming Households Survey (Mohamed et al., forthcoming)
 Note: Based on sub-sample of 393 farmers from Khartoum state. Four cases from the full sample had missing data.

These survey findings underscore the widespread and multifaceted impact of conflict on agricultural livelihoods in Khartoum state, affecting both the production and the market engagement of farmers. The analysis of the survey data corroborates the results of the satellite imagery analysis. Together, these analyses highlight the multi-dimensional nature of agricultural disruption caused by the conflict in Khartoum state. The results emphasize the urgent need for coordinated interventions to restore basic services, enhance security, and support farmers in resuming their productive activities. Addressing these challenges is critical to safeguarding livelihoods and stabilizing food systems in Khartoum state and in the many other conflict-affected areas of Sudan.

6) CONCLUSION AND POLICY IMPLICATIONS

The crop production in Khartoum state was marked by severe disruptions to agricultural activity, driven primarily by the ongoing conflict that began in April 2023. Farming household survey data show that almost 80 percent of farmers experienced conflict-related disruptions, with 15 percent not cultivating any crops that season. High input costs, movement restrictions, and market breakdowns were among the most frequently cited challenges the farmers reported facing.

Satellite-based NDVI analysis confirmed a significant decline in vegetated and cultivated land—estimated at 36 percent between December 2022 and December 2024—highlighting the spatial extent of agricultural disruption. Image classification further revealed that the total area cultivated in Khartoum state contracted by about 22 percent over this period, with cultivation on center-pivot irrigation fields falling by over 85 percent. This abandonment of irrigated crop production in Khartoum state during the conflict underscores the vulnerability of irrigated agriculture to systemic shocks. Abandoned and burned fields were widespread. Of the irrigated fields that were assessed in the satellite image land use classification analysis, about 95 percent were found to be damaged or left uncultivated.

Despite these challenges, some areas—particularly in Karari—showed higher levels of cultivation, suggesting localized resilience and the importance of spatially targeted interventions. The dual trends of declining cropland at the same time as pasturelands were recovering also point to shifting land use dynamics and ecological responses to reduced human activity on these agricultural lands.

Together, these findings underscore the multi-dimensional impact of conflict on agricultural systems in Greater Khartoum and highlight the urgent need for coordinated recovery efforts. The following policy recommendations outline urgent and strategic actions needed to restore agricultural production, assist households in recovering their agricultural livelihoods, and build household economic resilience in conflict-affected areas.

1. Promote resilient and inclusive agricultural systems.
 - Encourage climate-smart and conflict-resilient farming practices.
 - Support efforts to better adapt crop and livestock systems to evolving land use patterns and changing ecological conditions.
2. Restore agricultural infrastructure and input supply chains.
 - Rehabilitate irrigation systems and electricity networks, especially in areas with high dependence on mechanized farming.
 - Facilitate access to improved seeds, fertilizers, and machinery through conflict-sensitive distribution channels.
3. Improve farmer mobility and market access.
 - Establish secure corridors for farmers and traders to access farms and markets.
 - Reconnect producers to local and regional value chains to enable the sale of agricultural outputs.
4. Provide emergency assistance and recovery packages to farmers.
 - Deliver targeted support to farmers who lost crops or were unable to cultivate. This support could be provided through cash transfers, input subsidies, and technical assistance.
 - Prioritize interventions in severely affected localities.
5. Strengthen agricultural monitoring systems.
 - Integrate satellite-based monitoring with ground-level surveys to track land use changes and identify emerging risks.
 - Develop conflict-sensitive agricultural planning tools to guide response strategies and resource allocations.

This study is subject to several limitations that may affect the interpretation and generalizability of its findings:

- ◆ **Limited field validation:** Due to restricted access to the conflict-affected areas, ground-truthing of the satellite imagery that was used in the analysis was minimal. This constraint may reduce the accuracy of land classification results and vegetation assessments, particularly in areas with complex or transitional land use patterns.
- ◆ **Potential for misclassification:** While remote sensing techniques are effective for large-scale land monitoring, they are susceptible to misclassification—especially in

heterogeneous landscapes or zones with overlapping land uses. In this study, manual interpretation was used to mitigate this risk. Nonetheless, limitations in image quality and contextual data remain.

- ◆ **Survey implementation challenges:** The household survey faced several operational difficulties. Mobile telephone network disruptions posed the most significant obstacle. Additionally, a high proportion of contact numbers for survey respondents were invalid or unreachable. Moreover, security risks in conflict zones prevented ground-level operations and follow-up interviews, limiting the ability of the survey enumerators to validate responses or conduct in-person assessments.

Despite these limitations, the study generated a robust set of both spatial and household survey data that offers valuable insights into the state of agriculture in Greater Khartoum during a period of profound disruption.

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