USING SATELLITE IMAGERY TO MAP THE IMPACT OF CONFLICT ON RURAL MARKETS IN SUDAN

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SPARC
Supporting Pastoralism and Agriculture in Recurrent and Protracted Crises

MERCY CORPS

Introduction

Mercy Corps, through funding by FCDO's Supporting Pastoralism and Agriculture in Recurrent and Protracted Crises (SPARC), explored the use of remote sensing data to understand the impacts of the conflict in Sudan on market activity and agricultural production throughout the country. This analysis serves two purposes:

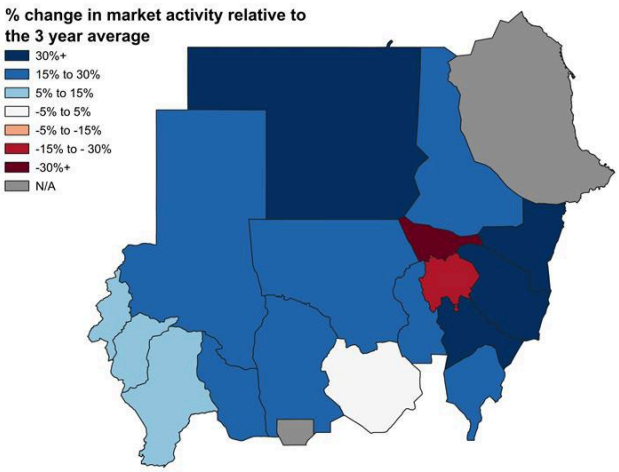
1. Identifying impacts of conflict events on rural markets and agricultural production, with an emphasis on rural and inaccessible areas not otherwise captured through existing humanitarian assessments
2. Testing the feasibility and usefulness of this approach in understanding economic activity and agricultural production in fragile and conflict affected settings where in-person data collection is limited and access is unpredictable

Our analysis draws on mapping of rural markets developed by Tillmann von Carnap at University of Oslo, comparing the size of markets since the conflict against their average size between 2020 – 2022. We also use conflict data from ACLED, displacement data from IOM, and Normalized Difference Vegetation Index (NDVI) to identify patterns and trends across the country.

Key Findings

- **Overall trends:** While there is variation across states and specific locations, rural markets in Sudan have not experienced substantial decline since the conflict began. This holds true regardless of territorial control. In 2024, the average market
- **Displacement and rural markets:** Rural market activity appears to be influenced by displacement patterns. Where displacement is primarily rural and IDPs are hosted within the community, market activity grows in a sustained manner. This is believed to reflect market actors adapting to the increased demand and higher levels of agricultural production among IDPs.

2024 Annual rural market day activity in Sudan relative to the 3-year average



- **Conflict impacts:** While overall rural market activity across Sudan has not been significantly curtailed by the conflict, specific conflict events – attacks on markets and civilians, battles – do reduce the activity of nearby markets. Where conflict is focused on urban centers, rural markets show increased activity, likely a result of traders shifting to alternative venues. With disrupted urban markets, trade also becomes more localized, and the mix of crops and goods traded shifts as demand from urban centers and across state lines declines. When conflict occurs in rural areas, nearby markets are affected but typically recover in 9 to 12 months, even after the most disruptive events like battles. However, successive conflict events can delay this recovery significantly.
- **Markets' influence on farming:** Where market activity is steady or growing, agricultural production in nearby areas increases in subsequent periods. This is likely driven by farmers' access to inputs during the planting season, and confidence in finding demand for their products. However, market volatility and shrinking can have strong negative impacts on local agricultural production.

- **Triangulation with other data is needed:** Our analysis shows trends in volume of trade and agricultural production but cannot untangle *who* engages with the markets and sells the crops, nor see the terms of trade. Data from other studies and Mercy Corps programming has shown alarming rises in cost of food and agricultural inputs, so overall functionality of markets does not contradict the acute need among the population.

Recommendations for market-based interventions in Sudan

1. Avoid undermining local markets and proactively support their adaptive capacities
    a. Assess existing trade and production before launching interventions to ensure aid does not displace local traders or disincentivize producers - both of whom are essential to supporting populations' needs
    b. Prioritize cash-based assistance in areas where markets are functional and cash is accessible, as this supports—rather than replaces—local supply chains
2. Align interventions with community adaptations
    a. Analyze shifts in crop choices and trade routes driven by rural communities, and design interventions that reinforce positive adaptations (e.g., drought-resistant crops) and mitigate harmful coping strategies
    b. Engage IDPs and host communities in program design to ensure interventions reflect their evolving needs and market access constraints
3. Prioritize adaptive programming and flexible funding based on real-time market and conflict data
    a. Adapt delivery models based on evolving market activity based on real-time of frequent market monitoring, remote sensing, in-depth market assessments and conflict analyses
    b. Incorporate crisis modifiers in grants to allow rapid pivots when conflict dynamics shift
    c. Conduct joint risk analyses with local traders, producers, and cooperatives to preempt shocks (e.g., price spikes, supply chain breakdowns)

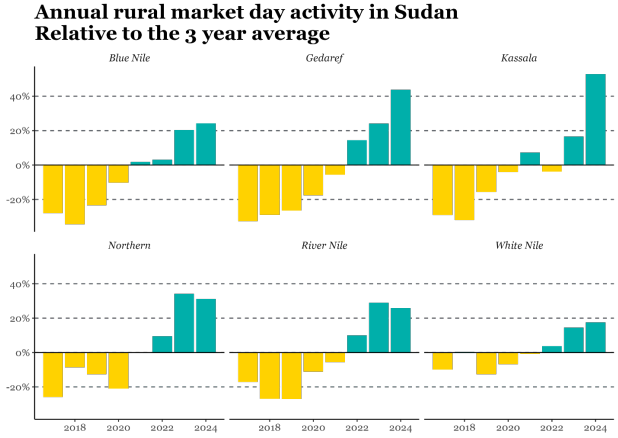
Methods and lessons learned for remote sensing in the Sudan conflict

In addition to the analysis itself, this study also sought to test the usefulness of remote sensing to understand economic activity in the context of insecurity and extreme inaccessibility in Sudan. Satellite imagery offers a unique opportunity to see the status of markets and farms in areas most affected by conflict, identify areas of intensive need, and identify recovering areas where market-based support can achieve greater impact.

In practice, remote sensing has strong potential to complement other forms of monitoring, but is limited by the high analytical demands and challenges of interpretation. NDVI and von Carnap's market mapping can both draw on extensive historical data to identify changes in trends before and after the conflict, an advantage compared to humanitarian data which usually only begins to be collected after a crisis begins. Key considerations include:

- Neither NDVI nor market mapping levels are directly interpretable – while meaningful, they do not directly measure the volume of trade or quantity of crop production. This makes them useful for identifying changing trends after conflict or policy events, and to compare between regions, while a one-time snapshot is not useful. However, both types of data are sensitive to conflict and particularly battles, reinforcing that they appear to be good proxies for economic and farming activity.
- The rural markets captured in the dataset experience their own marked seasonality, which is offset slightly from the seasonality of crop production. In states which are primarily crop producers, these markets peak in the planting season, while in states which import crops the markets peak after harvest. This likely reflects the use of markets as a means to access inputs in production areas, and as a distribution system for food and crops in importing states.
- The study looked at market activity in several ways to better interpret results:
    - Market closures: The most straightforward lens was market closures, either for extended periods (over 3 months) or permanently, but less than 2% - 9 of 484 markets – fit this category. This is a useful finding on its own but makes further analysis challenging due to the infrequency.
    - Counter-seasonal status: The most complex analysis involved categorizing the size of each markets' peak and lean season, and identifying which markets bucked their seasonality – booming during the lean period or shrinking when expected to be active. The results challenged easy interpretation, with a mixture of growing, shrinking, and normal markets in each state. This approach may be useful for more specific, contextually informed regional analyses.
    - Change in market size: The study ultimately settled on changes in market size compared to a three-year average from 2020 to 2022 years, prior to the conflict.

Displacement, safe states and rural markets



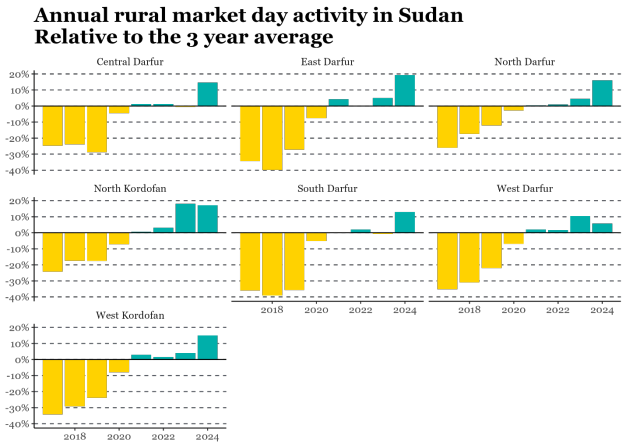
Rural markets in Sudan have shown incredible resilience to the impacts of the conflict, with market activity growing significantly across most states and localities. This trend is most pronounced in 'safe' states that have seen large influxes of IDP. Most notably Kassala, Gedaref, Northern and River Nile states have seen little to no conflict and large influxes of IDPs, as compared to Blue Nile and White Nile where active conflict has occurred within geographically limited locations.

Many IDPs in these states are living within host communities, leading to population growth in rural areas and likely linked to increased market activity there.

For example, 89% of IDPs in Gedaref are staying within the host community as opposed to rented accommodation or public buildings, 40% of whom are staying in rural areas.

Similarly Northern and River Nile have also seen large influxes of IDPs to rural areas (395 thousand and 437 thousand IDPs respectively) and have seen sustained large increases in rural market activity.

Urban conflict and rural markets



Similar patterns occur across the Darfur region: in Central, East and South Darfur where conflict between the SAF and the RSF alongside intercommunal conflict has played out around multiple towns, there was a slight negative impact on rural market activity in 2023. In 2024 we saw rural markets rebound in those states after the end of active conflict, recovering and in many cases showing increased market activity.

This trend is likely driven by a number of factors: The closure of trade routes has limited the opportunity for export as trade is forced to become largely localized over short distances. The cultivation of cash crops has been severely impacted by the conflict[1], with farmers replacing cash crops with food crops in response to the scarcity of food and the high prices in the market. This reduces the incentive for farmers, transporters and traders to go to primary markets due to the reduced profit margins. The highly urbanized nature of the conflict, the targeting of markets and insecurity along roadways has pushed trade from

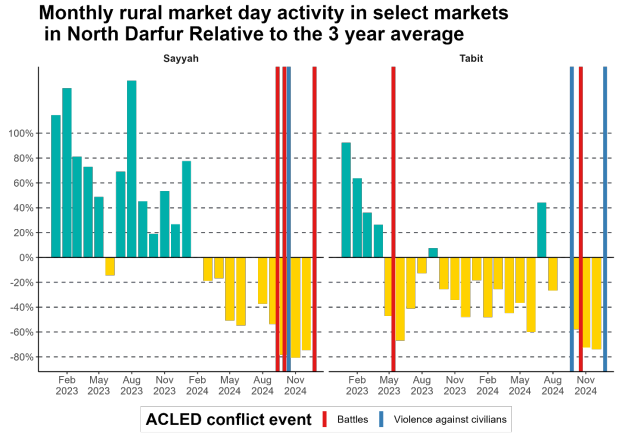
[1] Dr. Omer Egemi, Calum Mclean et al. (2024). Cash Consortium of Sudan Political Economy and Conflict Analysis

primary markets in urban and peri-urban locations and towards smaller rural markets due to security concerns.

Where violence is heavily centered around the state capital or other urban centers, we see rural market activity grow significantly. This was true in North Darfur that avoided the worst of the conflict in 2023 and its related disruptions. Violence in the state started in earnest in 2024 and focused on the state capital of El Fasher. During that year the highly urban El Fasher locality held the majority of IDPs, but we still saw large increases in rural market activity across the state.

While it is too early to draw conclusions, we also saw a decrease in rural market activity in West Darfur in 2024. The first of the Darfuri states to see large scale battles followed by near total control by the RSF, violence in urban centers such as Ag Geneina ended at an earlier stage than other states, as a result the decrease may be a sign of recovery of markets in urban centers or a reflection of other dynamics and warrants further investigation.

Local dynamics and recovery

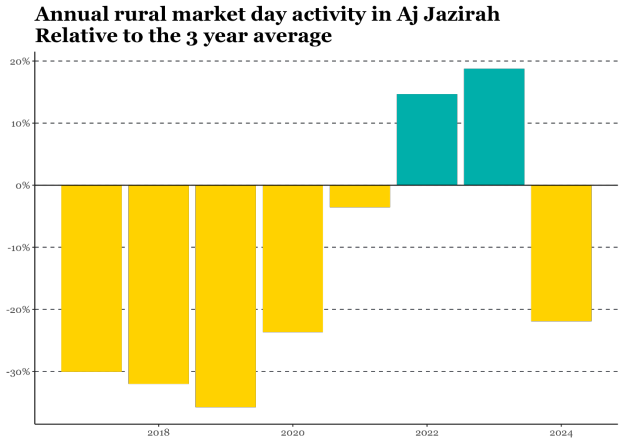


The impact of conflict manifests more clearly when conflict events occur in or around specific markets. Activity in those markets shows drastic decreases of over 60% after conflict events, highlighting how patterns at the state or locality level can obscure the impacts of the conflict at the local level. Successive conflict events can delay recovery with Battles having the most significant impact on market activity.

At smaller distances (10km-40km) the impact of conflict on local markets is most pronounced with battles having the most negative impacts, over larger distances (80km-90km) the impact of conflict on market activity becomes more complicated, and we may in fact see increased market activity representing shifting trade and market dynamics as conflict may drive market actors towards safer markets.

While recent conflict suppresses market activity, nearly all markets tend to recover or even rebound 9-12 months after major conflict events. Different conflict types show different transition points with battles representing the longest recovery periods, followed by violence against civilians where markets transition to recovery after 5 to 6 months and finally markets transition to recovery 3 to 4 months after incidents of remote violence.

The Impact of contextual developments on markets



Aj Jazirah provides a clear case of how large contextual developments can drive market activity. Originally a state of refuge, as of November 2023 Aj Jazirah was hosting over 445 thousand IDPs, of whom 64% were staying with host communities. During that time, we saw a modest increase in rural market activity at a time when the majority of IDPs were in urban areas particularly in and around Wad Madani.

In December of 2023 the RSF took control of the state, with widespread violence in rural and agricultural areas throughout 2024. The widespread and sustained violence led to massive displacement out of the state and has had a severe impact on rural market activity in 2024. With the SAF takeover of Jazirah and Khartoum in 2025 we are seeing accelerating returns to the state that may drive recovery in rural markets.

Agriculture and market activity

At local scales (10 to 30 km), the ability markets to operate on a sustained and non-volatile pattern seems to directly impact agriculture, with analysis of NDVI data showing an 8-fold increase in the vegetation index in hotspots with sustained market activity and limited volatility. Likely driven by farmers confidence in their ability to access purchasers including for cash crops as well as the inputs needed for the planting season.

At The 40-50km range sustained market activity still shows a strong positive relationship with NDVI, but more importantly market volatility no longer has a strong negative impact, implying that regional market infrastructure creates vegetation benefits that persist even when direct market mechanisms fail. The natural integration of regional market systems gives farmers the ability to access multiple markets, making agriculture production more resilient and making it a potentially optimal scale in which market responses can operate.

The nature of market-vegetation relationships provides a framework for designing agricultural development strategies that work with the natural spatial structure of market-agricultural systems.