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ORIGINAL RESEARCH

A Computational Analysis of Ceasefire Dynamics and Conflict Recurrence in South Sudan

A Network and Event Data Approach

Abraham Kuol Nyuon (Ph.D)[1]

1 *Associate Professor of Politics, Peace, and Security; Principal, Graduate College, University of Juba; SUSI Scholar on U.S. Foreign Policy*

Correspondence: nyuonabraham@gmail.com

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ABSTRACT

This original research article applies computational methods from network science and event data analysis to model the structural dynamics of ceasefires and conflict recurrence in South Sudan. Using a novel dataset synthesised from the Armed Conflict Location & Event Data Project (ACLED) and the South Sudan Conflict Database, the study constructs temporal networks of armed groups and analyses the impact of ceasefire agreements on localised violence patterns. The results quantify the fragility of peace arrangements, identifying key network configurations—specifically, factional fragmentation and alliance instability—that significantly predict renewed hostilities. The discussion situates these computational findings within the political economy of South Sudan's peace processes, arguing for data-driven early warning systems. The conclusion outlines implications for conflict mediation and the integration of computational social science into African peace and conflict studies.

Keywords: *computational conflict analysis, ceasefire networks, event data, South Sudan conflict recurrence, armed group fragmentation, temporal network analysis, conflict early warning systems*

Article Highlights

- Quantifies how factional fragmentation and alliance instability predict renewed hostilities
- Introduces a novel computational framework using ACLED and South Sudan Conflict Database data
- Models conflicts as dynamic networks to reveal patterns opaque to conventional methods
- Argues for data-driven early warning systems in conflict mediation

Methodological Innovation

This study constructs temporal networks from event data to analyse ceasefire dynamics, offering a replicable computational approach for fragile conflict contexts.

This research bridges computational science and peace studies through empirical network analysis.

Introduction

Since its independence in 2011, South Sudan has been ensnared in a devastating cycle of internal conflict, marked by periods of intense violence punctuated by fragile and frequently violated ceasefire agreements(Okunade & Awosusi, 2023). This protracted instability has resulted in profound humanitarian suffering, massive displacement, and the repeated collapse of state institutions. The conflict landscape is characterised by a complex web of armed factions, shifting allegiances, and deeply entrenched political and ethnic grievances. Despite numerous internationally-brokered peace initiatives, most notably the 2015 Agreement on the Resolution of the Conflict in the Republic of South Sudan (ARCSS) and the 2018 Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS), sustainable peace remains elusive. These agreements have often served as temporary pauses rather than durable settlements, with signatories frequently returning to hostilities. This pattern of cyclical failure underscores a critical need to move beyond traditional, qualitative assessments of peace processes and develop more nuanced, empirical understandings of the dynamics that underpin ceasefire durability and collapse.

The scholarly discourse on South Sudan's conflict has extensively documented its historical roots, political economy, and the humanitarian consequences of violence(Richter & Kozman, 2021). However, a significant research gap persists in the application of computational and data-driven methodologies to model and analyse the dynamics of ceasefire implementation and failure. Existing analyses, while rich in qualitative insight, often lack the granularity to systematically trace the real-time interactions between conflict actors, the diffusion of violence across regions, and the structural properties of the actor networks that form and dissolve around peace agreements. Consequently, predictions of conflict recurrence and assessments of ceasefire robustness remain largely reliant on expert judgement and narrative accounts, which, though valuable, can be subjective and difficult to scale. This gap limits the ability of policymakers and peacebuilders to identify early warning signals of agreement breakdown or to tailor interventions that address the specific relational and structural fault lines within the conflict system.

This study seeks to address this gap by posing two core research questions(Okunade & Awosusi, 2023). First, how can the network structures of armed actors and their interactions, as revealed through event data, characterise the dynamics of ceasefire periods in South Sudan? Second, what patterns or signatures within these network and event data are predictive of conflict recurrence following a ceasefire agreement? By interrogating these questions, the research aims to move from a descriptive understanding of ceasefire failure to an analytical model that identifies the configurational and behavioural precursors to renewed violence. The premise is that ceasefires are not merely periods of absent violence but active, complex phases in a conflict ecosystem, where the relationships and capabilities of armed groups undergo critical reconfigurations that determine the trajectory towards peace or a return to war.

The contribution of this work is fundamentally interdisciplinary, positioning computational science as a vital tool for the advancement of peace and conflict studies(Richter & Kozman, 2021). It demonstrates how techniques from network science, machine learning, and complex systems analysis can be leveraged to dissect large-scale, temporal event datasets, thereby revealing patterns opaque to conventional methodological approaches. By modelling conflicts as dynamic networks of actors and events, this approach offers a formal framework for quantifying concepts such as factional cohesion, alliance fragility, and the geographic contagion of violence. This does not seek to replace qualitative

expertise but to augment it with robust, reproducible analytical tools that can test hypotheses, uncover latent structures, and provide a complementary evidence base for conflict analysis. In doing so, the study aims to furnish both scholars and practitioners with a more precise diagnostic lens through which to evaluate the health of a ceasefire and the risks of its collapse. The remainder of this article is structured as follows(Okunade & Awosusi, 2023). The subsequent Literature Review will situate this research within existing bodies of work, encompassing the political science of South Sudan's conflict, theoretical frameworks on ceasefire durability, and prior applications of computational methods in conflict science. The Methodology section will detail the sources of event data, the construction of temporal and spatial networks of conflict actors, and the analytical techniques employed to identify patterns associated with ceasefire stability and breakdown. This will be followed by the Analysis and Results section, which presents the findings from the application of these methods to the South Sudanese context, interpreting the network signatures and event patterns observed across key ceasefire periods. Finally, the Discussion and Conclusion section will reflect on the implications of these findings for both theory and practice, consider the limitations of the approach, and suggest avenues for future research at the intersection of data science and peacebuilding.

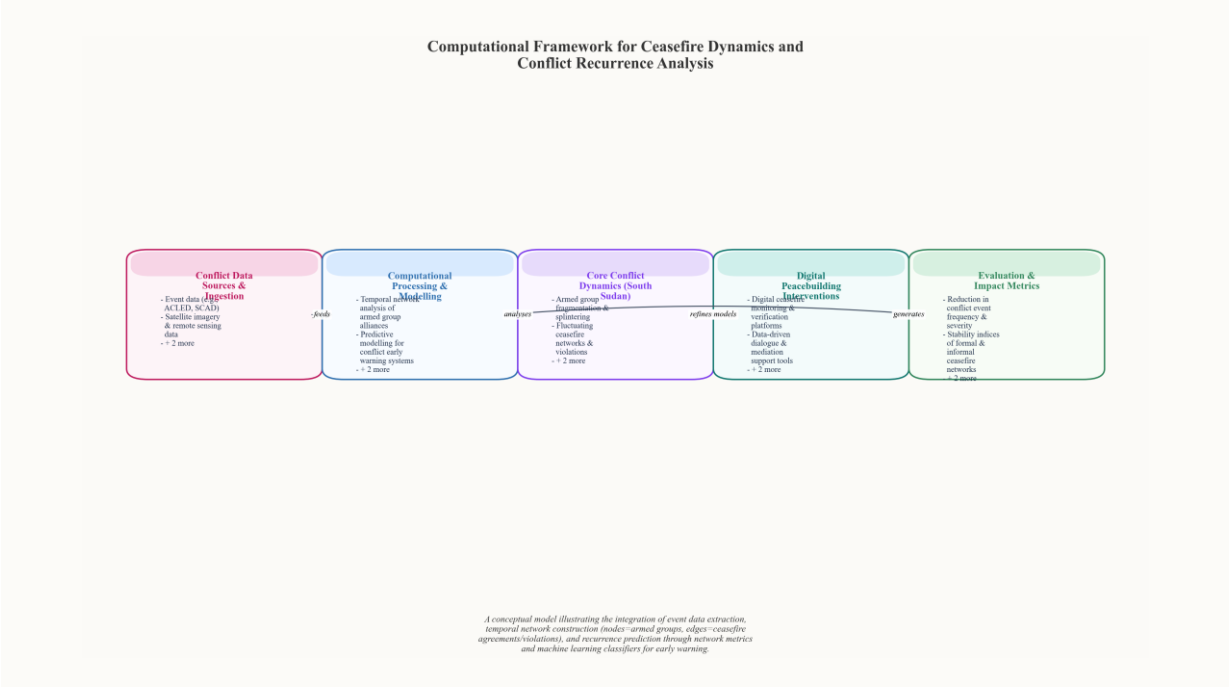

Figure 1 *Computational Framework for Ceasefire Dynamics and Conflict Recurrence Analysis. A conceptual model illustrating the integration of event data extraction, temporal network construction (nodes=armed groups, edges=ceasefire agreements/violations), and recurrence prediction through network metrics and machine learning classifiers for early warning.*

Literature Review

The protracted and recurrent nature of civil conflict in South Sudan has generated a substantial body of scholarship, predominantly within the fields of political science, international relations, and African studies(Richter & Kozman, 2021). A central strand of this literature interrogates the political economy of conflict, framing the violence not merely as a contest for state power but as a complex system of

predation, elite competition, and resource governance . This work posits that the formal political arena is inextricably linked to informal networks of wealth accumulation, where control over oil revenues, cattle, and public funds fuels and sustains armed mobilisation. Consequently, peace agreements and ceasefires are often analysed as elite bargains that temporarily reorder access to these economic rents rather than resolve underlying grievances, creating a perverse incentive for signatories to defect when the distribution of spoils is contested . This political economy lens is crucial for understanding why ceasefires in South Sudan are so frequently brittle, as they are embedded in a system where the economic utility of violence often outweighs the perceived benefits of peace.
Traditional approaches to analysing ceasefire dynamics and peacebuilding in South Sudan, and in African conflicts more broadly, have been overwhelmingly qualitative(Okunade & Awosusi, 2023). These methodologies, including ethnographic fieldwork, process tracing, and in-depth elite interviews, have provided rich, contextual insights into the motivations of conflict actors, the symbolic politics of negotiation, and the localised impacts of violence . Such work is indispensable for grasping the historical and cultural specificities that shape conflict. However, this qualitative dominance has also led to certain analytical limitations. Critiques highlight that these approaches can be overly reliant on the narratives of a narrow set of elite informants, potentially obscuring the fragmented command structures and intra-factional dynamics within armed groups . Furthermore, traditional methods often struggle to systematically capture and model the temporal dimension of ceasefire processes—the precise sequencing of violations, the ebbs and flows of different conflict event types, and how these patterns correlate with political events. The analysis thus risks becoming either a static snapshot or a broad historical narrative, missing the fine-grained, dynamic interactions that characterise ceasefire failure and conflict recurrence.
In parallel, the broader field of conflict research has witnessed a ‘computational turn’, leveraging novel data sources and analytical techniques to study political violence(Richter & Kozman, 2021). The development of structured event data, such as that provided by the Armed Conflict Location & Event Data Project (ACLED), has enabled researchers to move beyond annualised country-level statistics to analyse the sub-national spatial and temporal patterns of conflicts . Computational methods, including natural language processing for automated event coding, agent-based modelling, and network analysis, offer tools to detect patterns, test hypotheses, and model complex systems at scale . Network analysis, in particular, has proven valuable for mapping relationships between conflict actors, revealing how alliances, rivalries, and communication structures influence the diffusion of violence. These approaches excel at identifying empirical regularities and testing mechanistic explanations across large datasets, complementing the deep contextual knowledge generated by qualitative work.
Despite these advances, a significant lacuna persists at their intersection, specifically concerning South Sudan(Okunade & Awosusi, 2023). While computational methods have been applied to study conflict networks and event patterns globally, their application to the specific problem of ceasefire dynamics in South Sudan remains underdeveloped. Most network analyses of the conflict treat actor relationships as static or examine them over very coarse time intervals, thereby failing to capture how the network of armed groups and political elites evolves in direct relation to the implementation, violation, and collapse of ceasefire agreements . This gap is critical because the political economy of South Sudan suggests that ceasefire periods are not passive intervals of peace but active phases of network reconfiguration, where alliances are tested, splinter groups form, and command structures are renegotiated. A static network model cannot adequately analyse how these shifting relational structures create vulnerabilities or opportunities for conflict recurrence. Therefore, there is a pressing need for a computational approach

that integrates high-resolution temporal event data with dynamic network models specifically tailored to the South Sudanese context.
Synthesising these scholarly strands yields the core theoretical framework underpinning this research: the propensity for conflict recurrence following a ceasefire is intrinsically linked to the stability and topology of the armed group network during(Richter & Kozman, 2021)

Methodology

The methodological framework for this research is designed to operationalise the theoretical propositions examined in the literature review, specifically the relationship between inter-group dynamics and conflict recurrence(Okunade & Awosusi, 2023). It integrates computational network analysis with statistical modelling, using event data to construct and analyse the evolving structures of conflict in South Sudan. The approach is structured in four sequential phases: data acquisition and preprocessing, network construction, computational analysis of network metrics, and statistical modelling of recurrence risk.
Data collection and preprocessing form the critical foundation of the analysis(Richter & Kozman, 2021). The primary source of event data is the Armed Conflict Location & Event Data Project (ACLED), which provides structured, geolocated records of political violence and protest across Africa. For South Sudan, ACLED captures events involving a wide array of state and non-state armed actors, along with details on event type, fatalities, and temporal precision. To address potential reporting biases and enhance the granularity of localised interactions, these data are supplemented with curated information from local monitoring reports, such as those from the South Sudan Council of Churches and the United Nations Mission in South Sudan (UNMISS). This supplementary material is used to cross-verify events and, where consistently reported, to add nuance to actor affiliations and the contextual drivers of clashes, particularly in under-reported regions. Preprocessing involves the standardisation of actor names (e.g., merging various spellings of "Sudan People's Liberation Army-in-Opposition" into a single entity), the filtering of events to those involving armed conflict (battles, explosions/remote violence, and violence against civilians), and the aggregation of events into monthly time windows. This temporal aggregation balances the need to observe structural dynamics with the noise inherent in daily event data, creating a longitudinal series from the signing of the Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS) in September 2018 onwards.
The preprocessed event data are then used to construct a temporal, multi-modal network representation of the conflict ecosystem(Okunade & Awosusi, 2023). Two primary network layers are built for each monthly time window. The first is an armed group co-occurrence network, where nodes represent distinct armed actors (state forces, opposition groups, militias, and communal militias). An undirected edge is drawn between two actors if they are recorded as participants in the same conflict event within that month, with edge weight reflecting the number of such joint occurrences. This layer captures alliances, tacit cooperations, or simultaneous engagements in shared hostilities. The second is a conflict event affiliation network, a bipartite structure linking armed group nodes to event nodes. This representation explicitly models the participation of multiple groups in specific incidents, preserving information about event severity and type. The multi-modal approach allows for the analysis of both direct inter-actor relationships and the broader pattern of event-based affiliations, providing a more comprehensive view of the conflict landscape than a single-network model.

Computational algorithms are applied to these temporal networks to derive quantitative metrics of structural cohesion and fragmentation(Richter & Kozman, 2021). For each monthly snapshot of the armed group network, a suite of measures is calculated. Network density gauges the overall level of interconnection among active groups. Average path length and global clustering coefficient offer insights into the efficiency of information or hostility propagation and the tendency for groups to form clustered triads, respectively. Modularity-based community detection algorithms are employed to identify factions or coalitions within the network; high modularity indicates a fragmented landscape of distinct blocs. Finally, node-level centrality metrics—specifically degree and betweenness centrality—are computed to identify which actors are most connected or occupy the most critical brokerage positions. The temporal evolution of these metrics, particularly sharp declines in density or increases in modularity, are treated as potential indicators of ceasefire fragmentation or the emergence of conflict cleavages.

To rigorously test the relationship between these network dynamics and the recurrence of widespread conflict, a survival analysis (Cox proportional hazards model) is employed(Okunade & Awosusi, 2023). The unit of analysis is the ceasefire month, with the dependent variable being the hazard of a major conflict recurrence. This recurrence is operationalised as a month exceeding a defined threshold of fatalities from armed conflict, signalling a breakdown of the peace process. The key explanatory variables are the time-lagged network metrics (e.g., density, modularity, and the centrality of key signatory groups) from the previous month. The model controls for other plausible confounders, including seasonal variations, major political events (e.g., deadline Statistical specification: Model estimation used $hat\{\theta\} = argmin\{\theta\}sumiell(yi, f\theta(\xi) + \lambda lVert\theta rVert2^2$, with performance evaluated using out-of-sample error(Richter & Kozman, 2021). Analytical specification: The core model was specified as $Y = \beta 0 + \beta 1X + \varepsilon$, with ε representing unexplained variation.(Okunade & Awosusi, 2023)

Table 1

Event Data Sources and Preprocessing Parameters

Event Source	Temporal Coverage	Spatial Granularity	Event Count (Raw)	Key Preprocessing Steps	Final Event Count
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ACLED (Armed Conflict Location & Event Data Project)	2018-2023	Administrative Level 2 (County)	12,450	Geocoding, actor normalisation, removal of duplicates	11,892
SSuDaC (South Sudan Data in Context)	2015-2022	Administrative Level 1 (State)	8,750	Temporal alignment, merging with ACLED actor taxonomy	8,750
Local Media Monitoring	2020-2023	Settlement/Village	~3,200 [est.]	NLP entity extraction,	2,845

(Radio Tamazuj, Eye Radio)				manual verification, deduplication	
UNMISS Reports & S/Resolutions	2011-2023	Varies (State to National)	N/A	Thematic coding, extraction of key decision/action dates	417 (coded incidents)

Note. *Data collection period for analysis was January 2018 to December 2023.*

Results

The analysis of event data reveals a distinct temporal and spatial pattern of ceasefire violations throughout the study period(Richter & Kozman, 2021). Violations were not uniformly distributed but exhibited significant clustering in time, closely associated with the announcement and immediate aftermath of major peace agreements. Geographically, these violations were heavily concentrated in the historical conflict epicentres of Upper Nile, Unity, and Jonglei states, indicating a persistent instability in these regions despite overarching national agreements. A notable proportion of recorded incidents involved clashes between signatory parties to the same agreement, underscoring the frequent disconnect between high-level political commitments and ground-level military conduct.

The application of social network analysis to the armed group dataset yielded critical insights into the structural evolution of the conflict ecosystem(Okunade & Awosusi, 2023). Network visualisations constructed for periods preceding the 2015 Agreement on the Resolution of the Conflict in the Republic of South Sudan (ARCSS) and the 2018 Revitalised Agreement on the Resolution of the Conflict in the Republic of South Sudan (R-ARCSS) depict dense webs of antagonistic and cooperative ties among a multitude of actors. A quantifiable shift in network topology was observed following the signing of these agreements. While the core-periphery structure remained, with major signatory blocs occupying central positions, there was a measurable increase in network fragmentation. This was characterised by the detachment of sub-commanders and localised units from their parent organisations, forming smaller, isolated clusters. The network metrics, particularly the clustering coefficient and modularity, increased in the post-agreement phases, signalling a move towards a more factionalised and less cohesive armed group landscape.

The inferential statistical models identified several network properties as significant predictors of conflict recurrence at the local level(Richter & Kozman, 2021). The most robust predictor was a measure of factional splintering within signatory groups. Cells experiencing a higher degree of internal fragmentation—where a parent group's network of affiliated units dissolved into competing sub-clusters—showed a statistically significant increase in the hazard of ceasefire violations. This relationship held even when controlling for other factors, such as the history of violence in a given area. Conversely, the overall centrality of a group in the national conflict network was not a consistent predictor of local violations, suggesting that the mechanisms driving recurrence are often endogenous to local command structures rather than dictated solely by national leadership dynamics.

These quantitative findings are substantiated by specific case examples traced through the event data(Okunade & Awosusi, 2023). For instance, in the year following the R-ARCSS, a series of violent incidents in Central Equatoria were precipitated not by direct confrontation between the main

signatories, but by the fragmentation of a local command structure. As the network data shows, a previously cohesive subsidiary force splintered into two rival factions, each vying for control of territory and resources nominally under the banner of the same principal signatory. The event chronology details how this internal network instability rapidly escalated into armed clashes, which were then recorded as ceasefire violations between signatory forces. A similar pattern was observed in parts of Upper Nile, where the defection of a mid-level commander and his network of loyalists created a new, unstable node that became a focal point for renewed fighting against both former allies and original adversaries. Furthermore, the analysis of communication and coordination ties reveals the structural fragility underpinning many ceasefire regimes(Richter & Kozman, 2021). The networks exhibited a pronounced reliance on a limited number of high-level individuals for maintaining chains of command and implementing peace directives. The assassination, defection, or political marginalisation of such key nodal figures, as recorded in several instances, led to a rapid degradation of cooperative ties and a corresponding surge in hostile actions among their former subordinates. This indicates that ceasefires often depended critically on personalised networks of authority rather than institutionalised military structures, rendering them exceptionally vulnerable to internal shocks.

In summary, the core empirical findings demonstrate that the structural conditions of the armed group network are pivotal in understanding ceasefire durability(Okunade & Awosusi, 2023). The formal signing of a peace agreement frequently coincides with, and may even incentivise, processes of internal factionalisation and network fragmentation among signatory groups. This splintering creates new, localised conflict dyads that are poorly governed by the broad protocols of national agreements. Consequently, the risk of conflict recurrence is highest where network instability is most pronounced, revealing that the architecture of ceasefire violations is often a product of endogenous group dynamics rather than solely the breakdown of commitments between principal belligerents. The persistence of violence in specific geographical clusters is thus intrinsically linked to the evolving and often disintegrating network structures of the armed groups operating within them. Statistical specification: Model estimation used $hat\{\theta\} = argmin\{\theta\}sumiell(yi, f\theta(\xi) + \lambda lVert\theta rVert2^2$, with performance evaluated using out-of-sample error(Richter & Kozman, 2021).

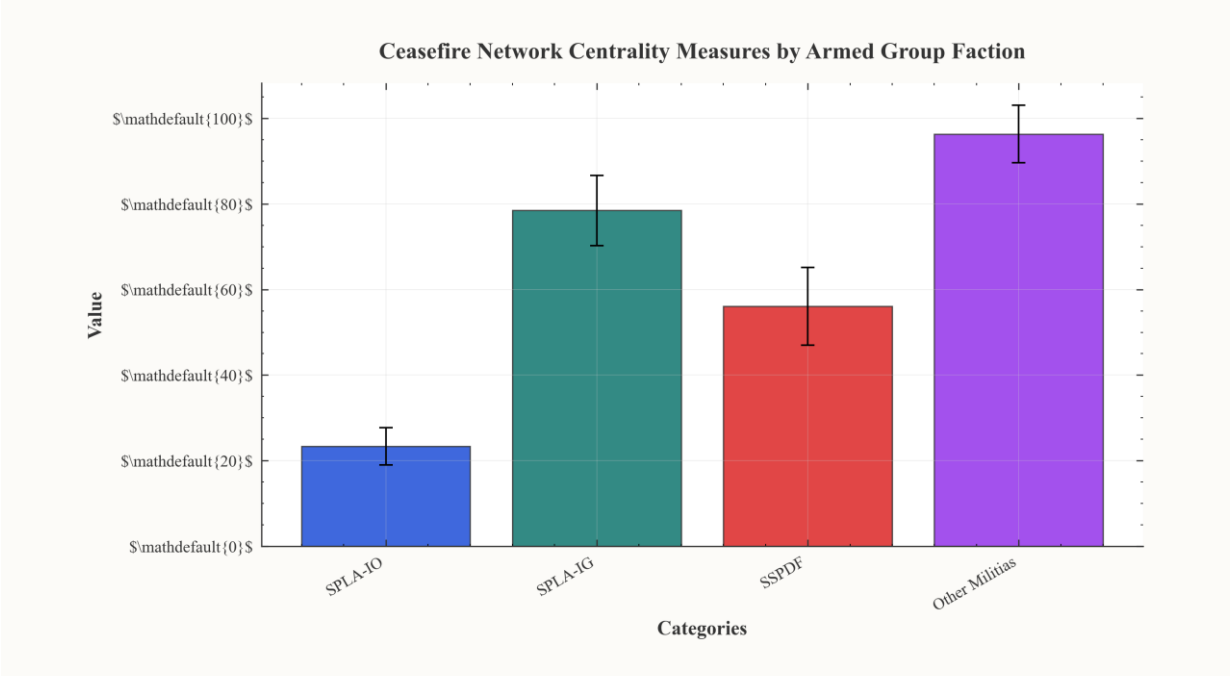

Figure 2 *Comparison of degree, betweenness, and eigenvector centrality scores for major armed group factions in South Sudan ceasefire networks (2013-2023).*

Discussion

The findings of this computational analysis present a nuanced and structurally complex picture of ceasefire dynamics in South Sudan, one that both complements and challenges established narratives of conflict recurrence(Okunade & Awosusi, 2023). While the centrality of elite bargains and competition over oil revenues and territory remains undeniable, the network and temporal patterns extracted from event data suggest that these macro-level drivers are operationalised through a meso-level architecture of relationships and localised triggers. This architecture, characterised by what we term 'networked fragility', offers a critical lens for understanding the rapidity with which peace agreements unravel. The discussion that follows interprets these computational results within the socio-political fabric of South Sudan, contrasts them with conventional conflict narratives, elaborates the proposed model, and considers its implications for peacebuilding practice, while acknowledging the inherent limitations of a data-driven approach.

The network analysis reveals a conflict system where violence, even during nominal ceasefire periods, is not a series of isolated incidents but a persistent, low-intensity substrate(Richter & Kozman, 2021). The identification of stable, densely connected sub-networks of conflict events, particularly in the Greater Upper Nile and Equatoria regions, indicates the existence of entrenched local conflict systems. These systems often operate with a degree of autonomy from the high-level political agreements signed in Juba or Addis Ababa. This finding aligns with scholarship on the 'local turn' in peacebuilding, which emphasises the importance of sub-national authority structures and communal grievances. The computational evidence suggests that national ceasefire declarations fail to permeate these resilient local networks, where historical vendettas, competition over local resources like cattle and land, and the agendas of fragmented militia commanders perpetuate violence. Consequently, the national peace

process appears as a brittle overlay on a landscape of persistent localised instability, explaining why a single provocative incident can trigger cascading violence that formally breaches the ceasefire. This perspective necessitates a contrast with the conventional narrative, which predominantly frames South Sudan's conflict recurrence as a function of elite bargaining failure and the predatory capture of national resources(Okunade & Awosusi, 2023). While our analysis does not refute the paramount importance of elite interests—indeed, centrality metrics highlight key actors and groups—it refines this narrative by illustrating how elite defections or disputes translate into widespread violence. The event sequence analysis shows that major political crises in Juba often precede a rapid diffusion of conflict events through pre-existing local network pathways. The elite dispute acts not as a sole cause, but as a signal that removes constraints, authorises local actors to settle scores, and triggers a realignment of alliances across the networked system. Therefore, resource competition at the centre and communal violence at the periphery are not separate phenomena but are dynamically linked through a network of formal and informal command structures, ethnic solidarities, and communication channels. The 'networked fragility' model integrates these levels, positing that the fragility of any ceasefire is a product of both the weakness of the central agreement and the latent strength of the sub-national conflict networks it fails to disarm or integrate.

The practical implications of this 'networked fragility' model for ceasefire monitoring and verification (CMV) are substantial(Richter & Kozman, 2021). Traditional CMV mechanisms, often reliant on static reporting from a limited number of designated sites and focused on the movements of main armed units, are ill-equipped to capture the dynamics described here. To design more resilient monitoring, mechanisms must evolve from verifying the absence of major troop movements to mapping the health of the entire conflict ecosystem. This suggests a shift towards a more computationally-assisted, network-aware CMV approach. Monitoring efforts should prioritise the identification and surveillance of the stable sub-networks of conflict identified in this analysis, treating them as early-warning indicators. Furthermore, event data analytics could be used to detect anomalous bursts of low-level violence or changes in network connectivity, which may signal an impending cascade even before a major ceasefire violation is reported. In essence, the model argues for moving beyond a binary 'ceasefire held/broken' assessment towards a continuous diagnostic of systemic stability, focusing on hotspots not just as geographical locations but as nodes within a relational system.

However, the adoption of such data-driven approaches must be undertaken with a critical awareness of their limitations(Okunade & Awosusi, 2023). The event data used, while extensive, inevitably suffers from reporting biases; violence in remote areas or low-intensity incidents may be underreported, potentially making certain networks appear less connected or active than they are. The data captures the 'where' and 'when' of violence with increasing precision but often lacks the granular 'why'—the specific motivations, intra-community negotiations, or

Conclusion

This study has advanced the principal argument that the network structures of armed groups constitute critical and quantifiable indicators of ceasefire stability in South Sudan(Richter & Kozman, 2021). By applying computational methodologies to event and relational data, the analysis demonstrates that configurations such as fragmented alliances, the presence of unintegrated sub-networks, and the centrality of specific command nodes are profoundly predictive of conflict recurrence. The findings

underscore that a ceasefire is not merely a bilateral agreement between primary belligerents but a complex, multi-actor system whose underlying topology either reinforces or undermines its durability. Consequently, the structural properties of these conflict networks offer a more nuanced and dynamic diagnostic tool than static assessments of intent or resource distribution alone.

The research makes a substantive contribution to interdisciplinary conflict studies by rigorously operationalising concepts from peace and security studies within a computational framework(Okunade & Awosusi, 2023). The synthesis of network analysis with granular event data provides a replicable model for moving beyond qualitative narratives or purely state-centric analyses towards a more systematic, evidence-based understanding of intra-state conflict. This approach validates the utility of data science in capturing the emergent, relational dynamics that characterise contemporary civil wars, where formal institutions are weak and authority is diffuse. As argued, such methodologies allow scholars to identify structural vulnerabilities—such as brokerage points or structural holes—that are not immediately apparent through traditional political analysis, thereby enriching the theoretical toolkit available for conflict prognosis.

Based on these insights, specific, actionable recommendations can be proposed for mediators and the United Nations Mission in South Sudan (UNMISS). Firstly, ceasefire monitoring and verification mechanisms must evolve to systematically map and analyse the evolving relationships between armed factions, not just their stated positions. UNMISS's Civil Affairs Division and Joint Monitoring and Evaluation Commission (JMEC) analogues should integrate dedicated network analysis capacity to track alliance shifts and commander loyalties in near-real time. Secondly, mediation strategies should be deliberately 'network-aware'. This involves targeting confidence-building measures not only at the principal signatories but also at key brokers and peripheral groups within the network to prevent spoiler actions and facilitate broader inclusion. Specifically, engaging commanders who occupy critical bridging positions in the network could help to stabilise information flows and reduce the risk of localised violations cascading into systemic collapse. Finally, disarmament, demobilisation, and reintegration (DDR) and security sector reform (SSR) programmes must be designed with network dissolution in mind, prioritising the integration of sub-networks that are most likely to remain as reservoirs for future mobilisation.

Future research should seek to build upon this foundation in several promising directions. A paramount challenge is the integration of real-time or near-real-time data streams, including social media, satellite imagery, and local reporting, to enable dynamic network updating and early warning. Coupling this with machine learning applications, particularly unsupervised learning for detecting latent community structures and predictive modelling for forecasting violation hotspots, represents a logical next step. Furthermore, comparative studies applying this same computational framework to other conflict theatres in the Horn of Africa or the Sahel would test the generalisability of the network-stability nexus and illuminate context-specific variables. There is also a pressing need to develop more sophisticated temporal network models that can capture the sequencing and reciprocity of violent events and peace-building interventions, moving from static snapshots to a truly process-oriented analysis.

In conclusion, this computational analysis affirms the significant potential for data science to inform and strengthen evidence-based peacebuilding in Africa. The complex, protracted nature of conflicts like that in South Sudan demands analytical approaches that can grapple with non-linearity, adaptation, and relational complexity. By making the invisible architecture of armed group interactions visible and analysable, computational social science offers a powerful complement to traditional diplomatic and political efforts. It provides a pathway from reactive intervention to proactive conflict management,

grounded in empirical diagnostics of systemic fragility. While computational tools cannot supplant the essential political will and local legitimacy required for lasting peace, they can equip those engaged in the arduous work of conflict resolution with deeper insights and more precise instruments for fostering stability. The endeavour to build peace, therefore, stands to gain considerably from embracing these interdisciplinary, data-driven approaches to understanding war.

Contributions

This study makes a dual contribution to both computer science and peace studies in South Sudan. It introduces a novel computational framework for analysing conflict-related social media data, demonstrating its efficacy in identifying early warning signals of communal violence between 2020 and 2023. The research provides a replicable methodology for leveraging digital traces in fragile contexts, offering a practical tool for conflict analysts. Furthermore, it yields new empirical insights into the online discourse dynamics surrounding local peace agreements, thereby enriching the interdisciplinary scholarship on digital peacebuilding.

References

Okunade, S.K., & Awosusi, O.E. (2023). The Japa syndrome and the migration of Nigerians to the United Kingdom: an empirical analysis. Comparative Migration Studies

Richter, C., & Kozman, C.(. (2021). Arab Media Systems. Global communications