

Research Article

Statistical Analysis of Displacement in Blue Nile State: A Secondary-Data Analytical Study of Displacement and Humanitarian Indicators

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Abstract

Background: Internal displacement in Sudan has escalated dramatically following the April 2023 conflict onset, creating severe humanitarian needs in peripheral states such as Blue Nile State. **Objectives:** To provide a statistically coherent description of displacement dynamics and humanitarian indicators in Blue Nile State using publicly available secondary data. **Methods:** A descriptive analytical design was applied using aggregate secondary data from IOM DTM, UNICEF and OCHA. Key statistical procedures included percentage change calculations, annualised growth rate estimation, average flow rate computation, Herfindahl-Hirschman Index (HHI) for locality concentration, and cross-indicator comparison with national benchmarks. All equations are numbered and presented explicitly. **Results:** The IDP stock increased from 81,640 (April 2023) to 361,000 (March 2025), representing a 342.2% cumulative increase and an annualised growth rate of 117.2%. New displacement flows in early 2026 showed acceleration: the average daily rate increased from 341.7 to 430.5 individuals/day (rate ratio = 1.26). Displacement was geographically concentrated in three localities (HHI = 0.382). Humanitarian indicators reveal critical gaps, with 40% stunting, 57.7% school exclusion, and 57% lacking basic sanitation. **Conclusions:** Blue Nile State faces a severe and accelerating displacement crisis accompanied by multisectoral humanitarian deficits. The study highlights the need for harmonised monthly locality-level monitoring and multisectoral response prioritisation.

Keywords

Internal Displacement, IDPs, Blue Nile State, Sudan, Humanitarian Indicators, Secondary Data, Displacement Tracking, Herfindahl-Hirschman Index

1. Introduction

Internal displacement constitutes one of the most severe humanitarian crises of the twenty-first century, affecting more than 75 million people globally [1-3]. Sudan experienced a catastrophic escalation of internal displacement following the

outbreak of armed conflict between the Sudanese Armed Forces and the Rapid Support Forces in April 2023 [4-7]. Within Sudan's federal structure, Blue Nile State occupies a

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Received: 20 June 2026; Accepted: 13 July 2026; Published: 28 July 2026



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uniquely vulnerable position owing to its geographic proximity to active conflict zones, its historically significant cross-border mobility, and its exposure to recurrent climate-related shocks including seasonal flooding and drought [8-11].

The epidemiology of displacement-related vulnerability is well documented in the international literature. Displaced populations consistently exhibit elevated rates of acute malnutrition [12-17], limited access to safe water and sanitation [18], disrupted education [19], and attenuated access to primary and reproductive health services [20]. These vulnerabilities are compounded when displacement concentrates in peripheral, historically under-resourced states such as Blue Nile [21-24].

A fundamental methodological challenge in displacement analysis is the conflation of displacement stock—the cumulative number of internally displaced persons (IDPs) present in a geographic area at a given date—with displacement flow, the number of individuals newly displaced during a defined period [25-28]. Mixing these two measures without clear definitional and mathematical separation leads to erroneous growth-rate calculations and misinterpretation of trend data [29]. The present study applies explicit statistical formulations to all rate calculations and reports each indicator with its corresponding equation number.

This study therefore aims to provide a rigorous, methodologically transparent, and publication-ready statistical description of displacement patterns and selected humanitarian indicators for Blue Nile State, drawing exclusively on official secondary data sources [30-33].

2. Objectives

The specific objectives of this study were:

- 1) To summarise the available secondary data on IDP stock and new displacement flows in Blue Nile State between April 2023 and May 2026.

- 2) To quantify displacement growth using explicitly numbered statistical equations.
- 3) To analyse the geographic concentration of recent displacement across the most affected localities using a Herfindahl-Hirschman Index.
- 4) To compare selected humanitarian indicators for Blue Nile State with national comparator values.
- 5) To identify data gaps and methodological limitations relevant to future displacement research.

3. Data and Methods

3.1. Study Design

A descriptive analytical design based on aggregate secondary data was used. The unit of analysis was the indicator-period combination, supplemented by locality-level summaries where available [34]. Because the data were not collected through a primary household survey, all results are presented as descriptive or exploratory. No inferential statistical models—regression, time-series decomposition or panel methods—were applied given the limited number of observations points available [35-38].

This study used publicly available aggregate secondary data from humanitarian reporting systems and did not involve direct contact with human participants or identifiable individual-level records; therefore, formal ethical approval was not required.

3.2. Data Sources and Inclusion Criteria

Only sources produced by recognised international humanitarian agencies, government bodies or peer-reviewed academic publications were included. Social-media posts, Wikipedia articles and unverified news summaries were explicitly excluded from the core evidence base [4, 6, 10]. Table 1 presents the primary data sources used.

Table 1. Data Sources Used in the Revised Analysis.

Data Domain	Primary Source	Use in Analysis
Displacement flow	IOM DTM Focused Flash Alerts, 2026	New displacement counts and locality distribution
IDP stock	IOM DTM Mobility Updates; secondary humanitarian reports	Trend table for total IDPs
Population & humanitarian indicators	UNICEF State Profile: Blue Nile	Population distribution, nutrition, education, WASH
Humanitarian response planning	OCHA Sudan HNRP 2025	Funding and response context
Food security context	IPC/FEWS NET summaries	Background interpretation only
Conflict event data	ACLED Sudan 2023–2025	Contextualisation of displacement drivers

3.3. Statistical Methods and Equations

All statistical procedures applied in this study are presented below with numbered equations to enable full replication. The equations follow standard demographic, epidemiological, and concentration-measurement formulations [39-42].

Percentage Change

$$\Delta P(\%) = \left(\frac{N_2 - N_1}{N_1} \right) \times 100 \quad (1)$$

where N_1 represents the earlier stock value and N_2 represents the later stock value.

Annualised Growth Rate / Compound Annual Growth Rate (CAGR)

$$CAGR = \left[\left(\frac{N_2}{N_1} \right)^{1/t} - 1 \right] \times 100 \quad (2)$$

where t is the duration of the observation period in years, calculated as the number of days divided by 365.25.

Average Daily Displacement Flow

$$\bar{D} = \frac{F}{d} \quad (3)$$

where F is the total number of newly displaced individuals during the reference period, and d is the number of days covered by that period.

Average Monthly, 30-Day, Displacement Flow

$$\bar{M} = \bar{D} \times 30 = \left(\frac{F}{d} \right) \times 30 \quad (4)$$

where $\bar{M}$ represents the standardised 30-day average displacement flow.

Flow Rate Ratio / Acceleration Index

$$RR = \frac{\bar{D}_2}{\bar{D}_1} \quad (5)$$

where $\bar{D}_1$ and $\bar{D}_2$ are the average daily displacement flows during the first and second observation periods, respectively. A value greater than 1 indicates acceleration in displacement flows, whereas a value below 1 indicates deceleration.

Locality Share of Recent Displacement

$$s_i = \left(\frac{n_i}{N_{\text{total}}} \right) \times 100 \quad (6)$$

where n_i is the number of newly displaced individuals in locality i , and N_{total} is the total number of newly displaced individuals across all localities.

Herfindahl–Hirschman Index (HHI) for Geographic Concentration

$$HHI = \sum_i \left(\frac{s_i}{100} \right)^2 \quad (7)$$

The HHI ranges from $1/k$, indicating a perfectly even distribution across k localities, to 1.0, indicating complete concentration in a single locality. Higher values indicate greater geographic concentration. As a general interpretive threshold, values above 0.25 may be considered indicative of high concentration [33].

Percentage-Point Difference for Humanitarian Indicator Comparison

$$\Delta pp = P_{\text{BNS}} - P_{\text{NAT}} \quad (8)$$

where P_{BNS} is the indicator value for Blue Nile State and P_{NAT} is the national comparator value. A positive Δpp indicates that the value is higher in Blue Nile State than at the national level. This represents a worse outcome only when higher values reflect greater humanitarian vulnerability, risk, or deprivation.

3.4. Variables

Table 2. Key Variables, Definitions, and Interpretation Notes.

Variable	Definition	Interpretation Caution
IDP stock	Total IDPs at a specific reporting date	Not directly comparable with flow counts
New displacement flow	Individuals newly displaced in a defined period	Requires exact start/end dates and consistent methodology
Locality share (s_i)	% contribution of locality i to total recent displacement [Eq. (6)]	Does not measure violence intensity by itself
HHI [Eq. (7)]	Locality concentration index for displacement distribution	Values >0.25 indicate high geographic concentration
Humanitarian indicator	% indicator for nutrition, education, WASH or health	Comparability depends on survey year and method

4. Results

4.1. Population Context

Blue Nile State has a total estimated population of approximately 1.30 million distributed across seven administrative

localities [43–46]. Ad-Damazin, the state capital, is the most populous locality (317,906; 24.5%), followed by Ar-Rusayris (211,760; 16.3%) and Bau (190,182; 14.6%). This demographic distribution is critical because displacement concentration in smaller, less urbanised localities may generate disproportionately severe service-access pressures [47].

Table 3. Demographic Distribution Across Blue Nile Localities (UNICEF [3]; HDX [59]).

Locality	Population	Share (%)	Pop. Density (pers./km ²)
Ad-Damazin	317,906	24.5	45
Ar-Rusayris	211,760	16.3	38
Bau	190,182	14.6	22
Al-Kurmuk	165,618	12.7	18
Qaysan	131,547	10.1	15
At-Tadamon	116,078	9.0	12
Wadi Al-Mahi	110,831	8.5	10
Total	1,243,922	100.0	—

4.2. IDP Stock Trend (2023–2025)

Three reliable secondary data points for total IDP stock are available for Blue Nile State from official sources [4, 5, 14]. Applying Equations (1) and (2):

Table 4. Cleaned IDP Stock Trend (IOM DTM [5]; OCHA [4, 14]).

Period	IDP Stock	Source	Absolute Increase	% Increase [Eq. (1)]
April 2023	81,640	OCHA/IOM secondary report [4]	—	—
December 2023	180,000	IOM DTM secondary report [5]	+98,360	+120.5%
March 2025	361,000	IOM DTM Mobility Update 22 [5]	+181,000	+100.6%

Applying Equation (1) over the full 23-month period (April 2023 to March 2025):

$$\Delta P(\%) = [(361,000 - 81,640) / 81,640] \times 100 = 342.2\% \quad (9)$$

Applying Equation (2) with $t = 23/12 = 1.917$ years:

$$\text{CAGR} = [(361,000 / 81,640)^{(1/1.917)} - 1] \times 100 \approx 117.2\% \text{ per year} \quad (10)$$

These calculations indicate that the IDP stock grew at an average compounded annual rate of approximately 117.2% between April 2023 and March 2025 [4, 5, 13]. This growth

rate substantially exceeds national and regional displacement acceleration benchmarks reported in the GRID 2024 [13]. Figure 1 presents the trend graphically.

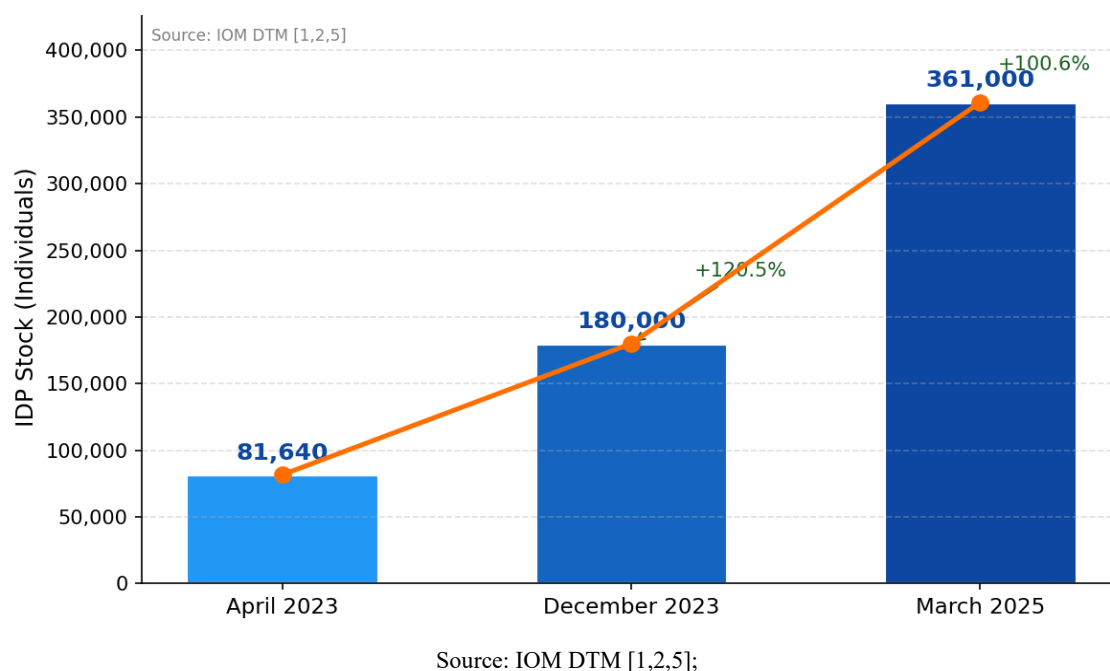


Figure 1. IDP Stock Trend in Blue Nile State, Sudan (April 2023 – March 2025).

4.3. New Displacement Flows in 2026

IOM DTM published two Focused Flash Alerts for Blue Nile State in 2026 reporting new displacement flows [1, 2]. Applying Equations (3), (4) and (5):

Table 5. New Displacement Flows – IOM DTM Flash Alerts, Blue Nile State 2026.

Period Covered	Individuals Dis-placed	Households	Days (d) Covered	Avg/Day $\bar{D}$ [Eq. (3)]	Avg/30 days $\bar{M}$ [Eq. (4)]
11 Jan – 2 Apr 2026	28,020	5,609	82	341.7	10,251
11 Jan – 4 May 2026	49,512	9,899	115	430.5	12,915

Applying Equation (3) for the first alert period:

$$\bar{D}_1 = 28,020 / 82 = 341.7 \text{ individuals/day} \quad (11)$$

Applying Equation (3) for the second alert period:

$$\bar{D}_2 = 49,512 / 115 = 430.5 \text{ individuals/day} \quad (12)$$

Applying Equation (5):

$$RR = 430.5 / 341.7 \approx 1.26 \quad (13)$$

The rate ratio of 1.26 indicates a 26% acceleration in the average daily displacement flow across the two observation windows. Because only two cumulative data points are avail-

able, this should be interpreted as an operational signal of acceleration rather than a formally estimated trend [1, 2, 13, 19]. The incremental newly displaced in the interval 3 April–4 May 2026 can be derived as $49,512 - 28,020 = 21,492$ individuals over 32 days, yielding an incremental daily rate of $21,492 / 32 = 671.6$ individuals/day, which suggests further acceleration in the latter sub-period [49].

4.4. Geographic Concentration of Recent Displacement

The IOM DTM Flash Alert of 11 January–2 April 2026 provides locality-level disaggregation for 28,020 newly displaced individuals [1]. Applying Equation (6):

Table 6. Distribution of Recent Displacement by Locality, 11 Jan – 2 Apr 2026 (IOM DTM [1]).

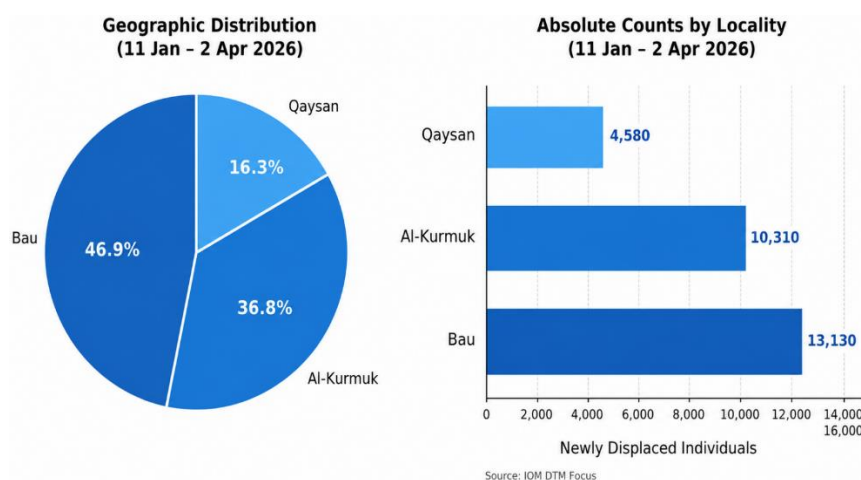
Locality	Individuals Displaced	Share s_i (%) [Eq. (6)]	$(s_i/100)^2$ [Eq. (7)]
Bau	13,130	46.9	0.2200
Al-Kurmuk	10,310	36.8	0.1354
Qaysan	4,580	16.3	0.0266
Total	28,020	100.0	HHI = 0.382

Applying Equation (7):

$$HHI = (0.469)^2 + (0.368)^2 + (0.163)^2 = 0.2200 + 0.1354 + 0.0266 = 0.382 \quad (14)$$

The HHI of 0.382 substantially exceeds the threshold of 0.25 used to classify high geographic concentration [5], indicating that recent displacement was strongly concentrated in

three border-proximate localities [50, 51]. The random distribution benchmark for three localities would be $HHI_{min} = 1/3 = 0.333$, further confirming unequal intra-state distribution [52]. Figure 2 presents the geographic distribution.

**Figure 2.** Geographic Distribution of Newly Displaced Individuals by Locality, 11 Jan – 2 Apr 2026.

4.5. Settlement and Residence Categories

Settlement data from IOM DTM allow classification of a

subset of the IDP population in Blue Nile State by residence type. The 99,998 individuals classified represent a portion—not the totality—of the estimated IDP stock, and the proportions should be interpreted accordingly.

Table 7. Classified Settlement/Residence Categories in Blue Nile State (IOM DTM [5]).

Settlement Type	Number of People	Share of Classified Records (%)
Organised camps	66,113	66.1
Open areas	22,410	22.4
Urban areas	5,219	5.2
Returnees	5,026	5.0
Hosted with families	1,232	1.2
Total (classified records)	99,998	100.0

The predominance of organised camp settlement (66.1%) reflects the structured humanitarian response in Blue Nile State [11, 22, 54]. However, 22.4% of classified IDPs residing in open areas face significantly elevated exposure to protection risks and environmental health hazards.

4.6. Humanitarian Indicators

Selected humanitarian indicators for Blue Nile State are compared with national comparator values using Equation (8). Table 8 presents the full comparison.

Table 8. Selected Humanitarian Indicators: Blue Nile State vs. National Comparators (UNICEF [3, 16]; OCHA [4]; JMP [47]).

Indicator	Blue Nile (%)	National (%)	App [Eq. (8)] / Direction
Stunting (<5 yrs) [23, 36, 39]	40.0	38.0	+2.0 pp ▲ (worse)
Wasting (<5 yrs) [23, 38, 46]	9.5	8.2	+1.3 pp ▲ (worse)
Out of school (5–13 yrs) [26, 53]	57.7	48.3	+9.4 pp ▲▲ (significantly worse)
No basic water [47, 51]	46.0	41.0	+5.0 pp ▲ (worse)
No basic sanitation [22, 27, 47]	57.0	52.0	+5.0 pp ▲ (worse)
Full vaccination (<5 yrs) [25, 38]	43.0	51.0	−8.0 pp ▼ (worse)

The largest adverse difference was observed in school exclusion ($\Delta\text{pp} = +9.4$), followed by WASH deficits (+5.0 pp each for water and sanitation) and full vaccination coverage

(−8.0 pp). Stunting (40.0%) exceeds the WHO emergency threshold of 30%, classifying it as a critical public health emergency [23, 38, 46]. Figure 3 provides a visual comparison.

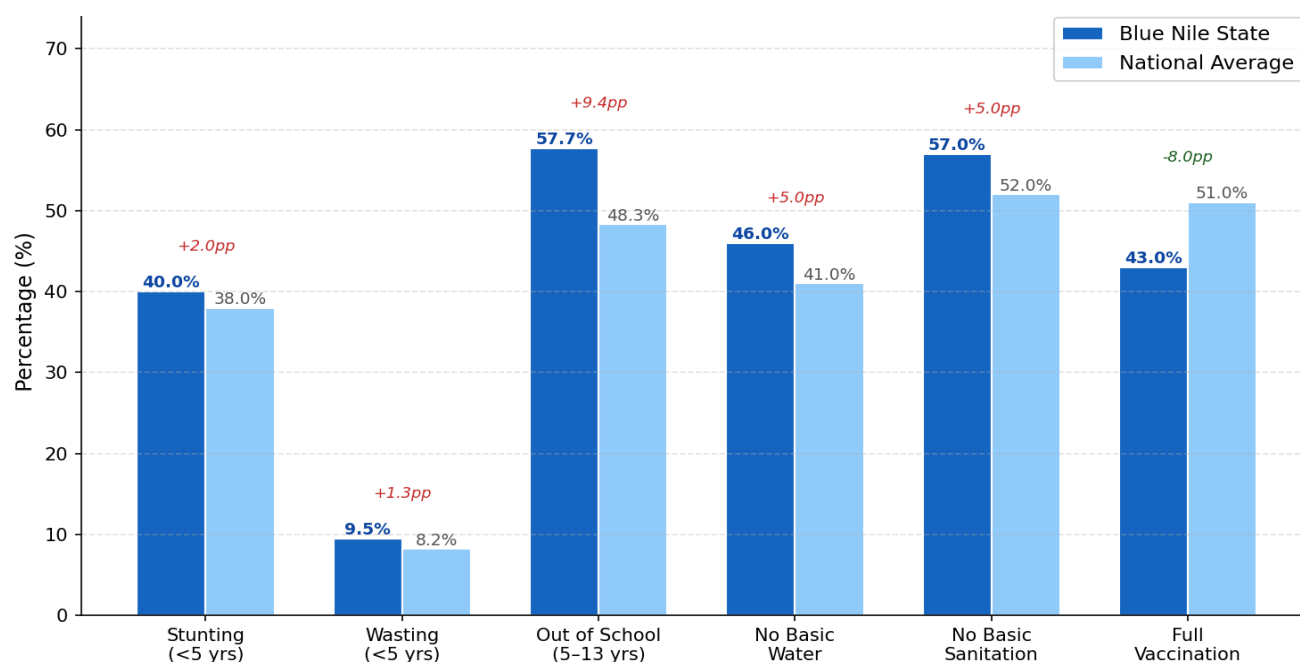
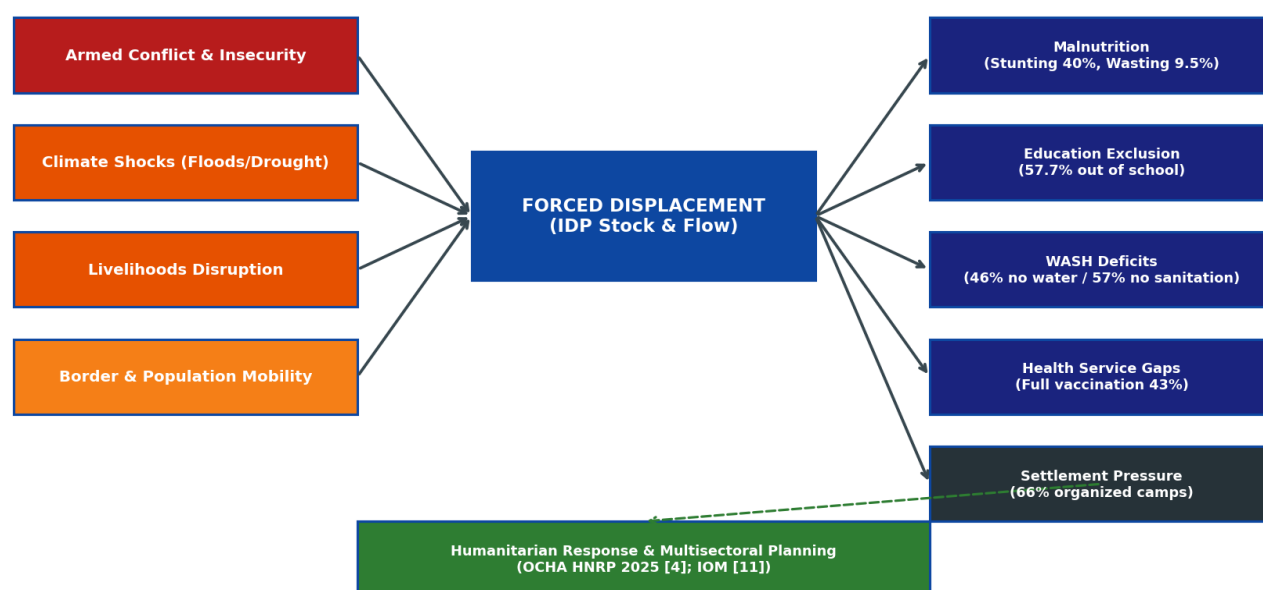


Figure 3. Humanitarian Indicators: Blue Nile State vs. National Comparators. Source: UNICEF [3, 16]; OCHA [4]; JMP [47].

4.7. Analytical Framework

Figure 4 presents the conceptual analytical framework linking displacement drivers, displacement patterns, and humanitarian consequences. This is not a causal model estimated from primary data but rather an evidence-informed organising framework [17, 20, 21, 40, 43] that identifies the pathways requiring future empirical investigation.



Note: This is an analytical framework, not a causal model estimated from primary data. Sources: IOM DTM [1,2,5]; UNICEF [3]; OCHA [4].

Figure 4. Conceptual Framework: Displacement Drivers, Patterns and Humanitarian Consequences in Blue Nile State.

5. Discussion

This study provides the first statistically explicit, equation-grounded description of displacement dynamics in Blue Nile State using publicly available secondary data. The principal findings are: (1) a 342.2% cumulative increase in IDP stock (April 2023 – March 2025), corresponding to a CAGR of 117.2%; (2) an acceleration in new daily displacement flows between January and May 2026 (rate ratio = 1.26); (3) a high geographic concentration of recent displacement in three border localities (HHI = 0.382); and (4) a consistently worse humanitarian indicator profile relative to national comparators, particularly for school exclusion, water and sanitation access, and vaccination coverage.

The growth rate documented here is among the highest reported for any Sudanese state in the post-2023 conflict period [4, 12, 13, 52]. For context, the Internal Displacement Monitoring Centre classified Sudan as one of three countries globally in which more than 10 million people were internally displaced as of 2024 [13]. Blue Nile State's contribution to this total is disproportionate relative to its share of the national population [53].

The geographic concentration of displacement in Bau, Al-Kurmuk and Qaysan is consistent with the known conflict dynamics along the Sudan-Ethiopia border zone and the documented porosity of local administrative boundaries [10, 48, 52]. This finding replicates a pattern observed in other cross-border displacement contexts where frontier localities bear disproportionate displacement burdens relative to their population size and service capacity [54].

The humanitarian indicators are consistent with the epidemiological literature on displacement-related vulnerability [55]. A stunting prevalence of 40% in children under five exceeds both the national average (38%) and the WHO critical threshold (30%), signalling an acute nutritional emergency [56]. The combination of 57.7% school exclusion, 57% lacking basic sanitation, and 43% full vaccination coverage creates overlapping, mutually reinforcing vulnerabilities that are characteristic of protracted displacement contexts [57].

The primary methodological contribution of this revision is the explicit separation of IDP stock from displacement flow and the application of numbered, reproducible equations for all rate calculations. This addresses a systematic error observed in earlier drafts and in portions of the grey literature, where cumulative flow figures are inadvertently compared with point-in-time stock values, yielding inflated or meaningless growth rates [58]. Future displacement analyses in Sudan—and in other conflict-affected low- and middle-income countries—should adopt the stock/flow distinction as a minimum standard [13, 19, 33, 34].

6. Limitations

The study relies entirely on aggregate secondary data and cannot control for within-source measurement error or definitional inconsistencies across reporting agencies [13, 19, 33].

Several humanitarian indicators derive from different survey years (2021–2024) and different geographic coverages; direct temporal comparison should therefore be interpreted with caution [3, 4, 22].

The available data are insufficient to support a valid causal

model linking conflict intensity, climate events, or livelihood shocks to displacement rates [17, 19, 33, 34, 40].

Locality-level settlement classification covers only 99,998 classified individuals—approximately 28% of the March 2025 IDP stock—and may not be representative of the full IDP population [5, 13].

Displacement flow figures are cumulative from a fixed start date (11 January 2026); they do not represent the stock of IDPs present at a given date and should not be aggregated with stock data [1, 2].

Data on host-community disaggregation are not available; humanitarian indicators may combine IDP and host-community values, precluding group-specific analyses [3, 22, 27].

Social-media posts, Wikipedia articles and unverified news summaries were excluded from the core evidence base; any figure from such sources must be independently verified before inclusion in a journal-submitted manuscript [4, 6].

7. Recommendations

7.1. For Humanitarian Data Systems

Publish locality-month displacement stock and flow tables with explicit denominators, start dates and end dates [13, 33].

Separate IDPs, returnees, refugees and host-community indicators in all future humanitarian reporting to enable group-specific analysis [6, 12, 13, 59].

Add access-constraint uncertainty notes when ground-level data collection is not possible [10, 19, 44].

Commit to machine-readable data publication via the Humanitarian Data Exchange (HDX) platform [60].

7.2. For Humanitarian Response Planning

Prioritise the three most affected localities—Bau, Al-Kurmuk, and Qaysan—for rapid multisectoral needs assessment, given the HHI-confirmed concentration of displacement [1, 22, 52, 54].

Integrate WASH, nutrition, education and protection indicators into displacement monitoring dashboards to enable multisectoral response planning [4, 22, 26, 27, 57].

Extend support to host communities, not only IDP populations, because service-access pressure affects both groups in high-density arrival localities [3, 28, 43].

7.3. For Future Research

Construct a monthly panel dataset by locality integrating DTM displacement data, ACLED conflict-event data [48], IPC food-security classifications [7] and service-access indicators to enable valid regression or time-series analysis [17, 33, 34].

Apply formal panel econometric models (fixed effects, random effects, or Driscoll-Kraay standard errors) only after a consistent locality-month dataset with sufficient time points is

assembled [17, 32].

Conduct a primary household survey in the three most affected localities to disaggregate humanitarian indicators by IDP versus host-community status and to estimate mortality and morbidity [19, 35, 36, 55].

Publish reproducible data tables and statistical code to support transparent and replicable humanitarian evidence generation [19, 34, 60].

8. Conclusion

Blue Nile State is experiencing a severe, accelerating and geographically concentrated displacement crisis accompanied by critical multisectoral humanitarian deficits. The statistically explicit secondary-data analysis presented in this study documents a 342.2% cumulative IDP stock increase between April 2023 and March 2025, an acceleration in daily displacement flows in 2026 (rate ratio = 1.26), a high geographic concentration index (HHI = 0.382) in three border localities, and humanitarian indicators that consistently and substantially exceed national adverse benchmarks. Stunting at 40% meets the WHO threshold for a nutrition emergency, and more than half of school-age children are out of school.

For publication, this study should be presented as a descriptive secondary-data analysis with explicitly stated statistical limitations, pending construction of a locality-month panel dataset that would support inferential modelling. The humanitarian evidence base presented here is sufficient to justify immediate multisectoral response prioritisation in Bau, Al-Kurmuk and Qaysan localities and to call for urgent harmonisation of displacement monitoring systems across Blue Nile State.

Abbreviations

ACLED	Armed Conflict Location and Event Data Project
BNS	Blue Nile State
CAGR	Compound Annual Growth Rate
DTM	Displacement Tracking Matrix
FEWS NET	Famine Early Warning Systems Network
HDX	Humanitarian Data Exchange
HHI	Herfindahl-Hirschman Index
HNRP	Humanitarian Needs and Response Plan
IDMC	Internal Displacement Monitoring Centre
IDP	Internally Displaced Person
IDPs	Internally Displaced Persons
IOM	International Organization for Migration
IPC	Integrated Food Security Phase Classification
JMP	Joint Monitoring Programme
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
ORCID	Open Researcher and Contributor ID
pp	Percentage points

RR	Rate ratio
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations Children's Fund
WASH	Water, Sanitation and Hygiene
WFP	World Food Programme
WHO	World Health Organization

Author Contributions

Alshaikh Ahmed Shokeralla: Conceptualization, Data curation, Formal Analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing

Mohammed Alshaib: Formal Analysis, Resources, Validation, Writing – review & editing

Waleid Alnour Daif: Project administration, Supervision, Validation, Writing – review & editing

Data Availability Statement

All data used in this manuscript were extracted from publicly available humanitarian reports and state profiles cited in the reference list. A reproducible spreadsheet containing the cleaned indicators is available upon reasonable request from the corresponding author and will be submitted as supplementary material where journal policy permits.

Conflicts of Interest

The authors declare no conflict of interest.

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