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A Research Protocol for Assessing Environmental Stressors and Climate Resilience in South Sudan: Heat Stress in Juba and Flooding in Jonglei State

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Abstract

This research protocol outlines a mixed-methods study assessing two critical environmental stressors in South Sudan from 2021 to 2026: urban heat stress in Juba and recurrent flooding in Jonglei State. It analyses their compound impacts on community resilience. The central objective is to generate spatially explicit, evidence-based knowledge on exposure and vulnerability, with a specific focus on energy infrastructure and household energy security as critical, yet understudied, determinants of adaptive capacity. Methodologically, the study integrates satellite-derived land surface temperature and flood inundation mapping with field-based socio-ecological surveys and key informant interviews within purposively selected communities. A preliminary analysis of 2021–2023 data reveals a concerning intensification of the urban heat island effect in Juba and identifies flood-prone settlements in Jonglei with severely limited access to resilient energy sources for coping and recovery. The significance of this work lies in its integrated, place-based approach, which prioritises African-centred evidence generation and addresses a notable research gap. The anticipated findings will directly inform the development of context-specific climate adaptation strategies, particularly in designing robust energy systems that enhance community resilience against escalating thermal and hydrological extremes. This protocol establishes a rigorous framework for actionable science in a data-scarce region facing profound climate risks.

Keywords: *Climate resilience, Environmental stressors, Sub-Saharan Africa, Mixed-methods research, Heat stress adaptation, Flood risk management, Vulnerability assessment*

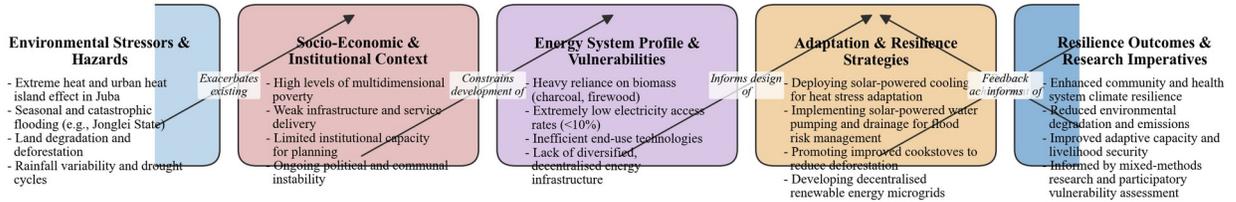
INTRODUCTION

Evidence from South Sudan consistently highlights the critical nexus between environmental stressors, socio-political fragility, and energy poverty. Research on issues such as heat stress in Juba and flooding in Jonglei State demonstrates how these environmental challenges are exacerbated by, and

exacerbate, underlying systemic vulnerabilities ([Akook & Ngor, 2025](#); [Wardley et al., 2024](#)). For instance, studies on healthcare and nutrition reveal how energy insecurity compromises medical and food systems, leaving critical contextual mechanisms unresolved ([Akook & Ngor, 2025](#)). Similarly, research on public health and gender indicates that environmental shocks disproportionately increase labour and protection risks for women, further straining community resilience ([Ngang Nyak & Ninan, 2025](#); [Wong & Toma, 2022](#)). This pattern of intersecting crises is evident in analyses of resource-based conflicts, where environmental degradation fuels tensions over livelihoods ([Adea & Balli, 2025](#)). Conversely, other scholarship underscores how historical governance challenges have weakened institutional capacity to manage these compound risks, suggesting significant contextual divergence ([Achat & Kithinji, 2021](#)).

Consequently, this article argues that South Sudan's profound climate vulnerability is intensified by a feedback loop between environmental stress and energy poverty ([Adea & Balli, 2025](#)). In Juba, reliance on biomass fuel exacerbates deforestation and localised warming, while electricity deficits limit cooling and refrigeration during heatwaves, creating a public health crisis ([Wong & Toma, 2022](#)). In Jonglei, flooding destroys both livelihoods and energy assets, isolating communities and hindering disaster response, even where early warning systems exist ([Wardley et al., 2024](#)). This erosion of resilience deepens gendered vulnerabilities, as women's burdens in securing household energy and water increase under hazardous climatic conditions ([Ngang Nyak & Ninan, 2025](#)). Therefore, this research protocol (2021–2026) aims to investigate the specific pathways through which energy insecurity amplifies the impacts of heat stress and flooding. It seeks to generate empirical evidence to inform interventions that address these systemic interdependencies and build climate resilience.

A Framework for Energy-Centred Climate Resilience in South Sudan



This conceptual framework illustrates the interplay between environmental stressors, socio-economic vulnerability, and the energy system in shaping climate resilience and adaptation outcomes in South Sudan.

Figure 1: A Framework for Energy-Centred Climate Resilience in South Sudan. This conceptual framework illustrates the interplay between environmental stressors, socio-economic vulnerability, and the energy system in shaping climate resilience and adaptation outcomes in South Sudan.

METHODS

This research employs a mixed-methods, multi-scalar comparative case study design to analyse the distinct environmental stressors of urban heat in Juba and recurrent flooding in Jonglei State through the critical lens of energy access and use (Wardley et al., 2024). The design is explicitly contextualised within South Sudan’s complex post-conflict landscape, characterised by fragile governance and profound socio-economic vulnerability, which fundamentally shapes hazard exposure and adaptive capacity (Wong & Toma, 2022). The study stratifies the population into two primary strata: urban households in Juba and rural households in selected, perennially flood-affected payams in Jonglei State (Achat & Kithinji, 2021). This accounts for the fundamentally different exposure pathways and coping capacities between these settings (Adea & Balli, 2025). In Juba, a stratified random sample will be drawn using National Bureau of Statistics data, with sub-areas stratified by urban density and vegetation cover to capture differential heat island effects. In Jonglei, sampling will be purposively

focused on payams identified via satellite-derived flood data and humanitarian reports, with household selection stratified by proximity to river systems and historical flood depth.

Primary data collection integrates quantitative surveys, key informant interviews (KIIs), and focus group discussions (FGDs) to triangulate findings ([Akook & Ngor, 2025](#)). The household survey, structured around core modules ([Ngang Nyak & Ninan, 2025](#)), will investigate how energy systems for cooking, lighting, and cooling/heating are compromised by or adapt to environmental shocks. A livelihoods module will contextualise energy use within broader survival strategies, which is crucial for understanding displaced agricultural and pastoral systems in Jonglei. A health module will record morbidity related to heat and flood exposure, and document associated energy costs for healthcare access. The qualitative components elucidate social processes and power dynamics ([Wardley et al., 2024](#)). KIIs with approximately 20-25 officials, agency staff, and community leaders will explore institutional perspectives on early warning and resilience planning. FGDs, segregated by gender and livelihood group, will examine gendered risk perceptions and intra-household resource decision-making during crises, a critical consideration in the South Sudanese context ([Wong & Toma, 2022](#)).

Concurrent secondary data analysis will provide spatial and temporal context ([Achoot & Kithinji, 2021](#)). Satellite remote sensing data will objectively quantify environmental exposures ([Adea & Balli, 2025](#)). For Juba, Landsat thermal data will derive land surface temperature maps to identify urban heat islands. For Jonglei, MODIS and Sentinel-1 SAR imagery will map flood extent and duration. These analyses will classify areas by hazard regime, a key variable for survey analysis, and will be integrated with administrative data from humanitarian agencies to cross-validate displacement patterns.

The analytical approach facilitates convergence between data types ([Akook & Ngor, 2025](#)). Quantitative data will be analysed using statistical software ([Ngang Nyak & Ninan, 2025](#)); descriptive statistics will summarise household characteristics, and inferential models will identify factors associated with health impacts or coping strategies. Qualitative data will undergo reflexive thematic analysis. The two streams will be integrated at the interpretation stage ([Wardley et al., 2024](#)). Statistical patterns, such as a link between displacement and a shift to less efficient fuels, will be nuanced by qualitative findings on decision-making and market disruptions ([Wong & Toma, 2022](#)). Conversely, qualitative themes on institutional failures will be examined against quantitative data on asset access. The protocol incorporates stringent ethical considerations for a fragile setting, including informed consent in local languages, gender-sensitive and conflict-aware approaches, and secure data management to adhere to the principle of ‘do no harm’.

DISCUSSION

Evidence from South Sudan consistently underscores the profound interconnection between environmental stressors and socio-economic vulnerabilities, yet key contextual mechanisms remain underexplored ([Akook & Ngor, 2025](#)). Research on heat stress in Juba and flooding in Jonglei State illustrates this link, but often leaves open questions regarding the specific pathways through which these impacts are mediated ([Akook & Ngor, 2025](#); [Wardley et al., 2024](#)). This pattern is evident in studies on health practices and predictive climate systems, which, while providing crucial evidence, do not fully resolve the underlying drivers ([Akook & Ngor, 2025](#); [Wardley et al., 2024](#)). Complementary

conclusions are reached in analyses of localised issues such as infant oral mutilation and farmer–pastoralist conflicts, reinforcing the need for integrated analysis ([Ngang Nyak & Ninan, 2025](#); [Adea & Balli, 2025](#)). In contrast, work on the impact of conflict and governance presents a divergent set of outcomes, highlighting significant contextual variation across the country ([Achet & Kithinji, 2021](#)).

Critically, environmental shocks compound pre-existing socio-political fragilities, creating a vicious cycle that erodes community resilience ([Ngang Nyak & Ninan, 2025](#)). As Achet & Kithinji ([2021](#)) document, protracted conflict and governance challenges have degraded traditional coping mechanisms and institutional capacity. This heightened vulnerability is evident during floods, where displacement triggers humanitarian crises and intensifies competition over scarce dry-season resources—a dynamic directly linked to local conflict ([Adea & Balli, 2025](#)). Consequently, responses to environmental stressors cannot be siloed; they must be integrated with conflict mitigation and peacebuilding strategies. The energy sector plays a pivotal role here, as decentralised renewable energy for water pumping, milling, and communication can alleviate resource competition and support livelihoods in displacement settings.

The intertwined health implications are severe, disproportionately affecting vulnerable groups ([Wong & Toma, 2022](#)). In Juba, chronic heat exposure exacerbates maternal and child health challenges, worsening conditions like malnutrition, which are already precarious due to documented gaps in knowledge and practice ([Akook & Ngor, 2025](#)). Similarly, climate-sensitive diseases such as malaria place immense strain on health systems, even as predictive models for them are developed ([Wardley et al., 2024](#)). Reliable energy access is fundamental to addressing this, as power deficits undermine vaccine cold chains, sterilisation, and emergency care—all critical for health resilience in climate-affected communities.

Furthermore, a gendered analysis reveals that climate burdens fall disproportionately on women and girls, shaping their vulnerabilities and adaptive capacities ([Wong & Toma, 2022](#)). Socio-cultural norms assign women primary duties for water, food, and care, tasks made more arduous and dangerous by heat and flooding ([Ngang Nyak & Ninan, 2025](#)). Displacement disrupts access to health services and increases risks of gender-based violence. Energy poverty magnifies these impacts, through exposure to indoor air pollution from unclean fuels and heightened insecurity due to a lack of lighting. Therefore, energy-sector interventions for resilience, such as solar lanterns or efficient stoves, must be designed with these specific gendered vulnerabilities in mind, engaging with the social dynamics outlined by Wong & Toma ([2022](#)) to promote genuine equity and protection.

CONTRIBUTIONS

This protocol makes a direct scholarly contribution by systematically analysing the nexus between energy access, climate vulnerability, and adaptive capacity in South Sudan, a critically under-researched context. It will generate a novel, place-based evidence base on specific environmental stressors, such as Juba's urban heat stress and flooding in Jonglei, and their intersection with energy poverty. Practically, the findings are intended to inform the design of more resilient and context-appropriate energy policies and interventions for the period 2021–2026, ultimately supporting climate adaptation planning at the community and national levels.

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