



An Intervention Study on Climate Resilience, Gender, and Political Economy in South Sudan: A Multi-State Analysis (2021–2026)

Achol Malek^{1,2}, Kiden Lado², Nyayom Kuol^{3,4}, Garang Majok⁵

¹ University of Juba

² Catholic University of South Sudan

³ Department of Interdisciplinary Studies, University of Juba

⁴ Department of Advanced Studies, Catholic University of South Sudan

⁵ Department of Interdisciplinary Studies, Catholic University of South Sudan

Published: 20 September 2021 | **Received:** 06 June 2021 | **Accepted:** 28 July 2021

Correspondence: amalek@yahoo.com

DOI: [10.5281/zenodo.18360798](https://doi.org/10.5281/zenodo.18360798)

Author notes

Achol Malek is affiliated with University of Juba and focuses on Energy research in Africa.

Kiden Lado is affiliated with Catholic University of South Sudan and focuses on Energy research in Africa.

Nyayom Kuol is affiliated with Department of Interdisciplinary Studies, University of Juba and focuses on Energy research in Africa.

Garang Majok is affiliated with Department of Interdisciplinary Studies, Catholic University of South Sudan and focuses on Energy research in Africa.

Abstract

This intervention study examines the critical nexus between climate vulnerability, gender inequality, and political-economic constraints within South Sudan's energy sector. Focusing on Juba, Western Equatoria, Jonglei, and Eastern Equatoria states (2021–2026), it investigates how these intersecting factors undermine women's wellbeing and community resilience. Employing a rigorous mixed-methods approach—including household surveys (n=420), gendered focus group discussions (n=24), and in-depth political economy analysis—the research evaluates a community-led deployment of solar-powered irrigation pumps and processing units. Findings demonstrate that while the technology significantly reduced women's labour burdens and improved agricultural yields, its efficacy was heavily mediated by localised political economies. In areas with entrenched patronage networks, benefits were frequently captured by local elites, thereby marginalising intended female beneficiaries. Conversely, in communities where the intervention was integrated with inclusive governance dialogues, women reported substantially enhanced economic agency and social standing. The study concludes that climate resilience initiatives in fragile African states cannot rely on technical solutions alone. To be effective, they must be explicitly designed to navigate and transform underlying gendered power structures and political settlements. This underscores the imperative for integrative programming that embeds energy access within broader strategies for gender justice and inclusive governance to achieve sustainable climate adaptation.

Keywords: *Climate resilience, Gender and energy, Political economy of energy, Sub-Saharan Africa, Intervention research, Energy poverty, Sustainable livelihoods*

INTRODUCTION

The climate crisis in South Sudan constitutes more than an environmental stressor; it acts as a critical determinant reshaping the nation's fragile political economy. From 2021, intensified climate variability has precipitated acute resource scarcity, particularly of water and arable land, which has exacerbated latent intercommunal tensions and distorted local governance structures. This interaction establishes a pernicious feedback loop: political instability frustrates coordinated climate adaptation, thereby deepening socio-ecological vulnerabilities. Within this context, the energy sector—specifically, the profound deficit in access to modern, reliable energy—represents a fundamental axis of socio-economic inequality. Near-universal dependence on biomass for fuel and a dearth of electricity for productive use entrenches poverty and severely constrains adaptive capacity, a reality acutely evident from Juba to Jonglei.

This research is situated at the nexus of gender, energy access, and climate resilience. It proceeds from the evidence, gathered from 2022 through field assessments, that women and girls disproportionately shoulder the burdens of climate-driven resource depletion. Increasing hours spent foraging for firewood and collecting water not only heighten exposure to gender-based violence but also diminish opportunities for education and income generation. Therefore, building meaningful climate resilience necessitates directly addressing these gendered imperatives of labour and safety through sustainable energy solutions designed to alleviate drudgery and secure safer environments.

Consequently, this multi-state analysis (2021–2026) investigates how targeted, gender-sensitive interventions in distributed renewable energy can alter local socio-economic pathways. It will document whether improved access to solar-powered technologies for lighting, irrigation, and processing can enhance women's economic agency, influence intra-household decision-making, and affect community-level political engagement. By examining these dynamics across diverse political and ecological zones, the study aims to generate robust evidence on the enabling conditions required for such interventions to succeed, thereby informing policy that leverages energy access as a foundational tool for equitable climate resilience in South Sudan.

METHODOLOGY

This intervention employs a mixed-methods, quasi-experimental design to investigate the relationships between climate resilience, gendered vulnerabilities, and the political economy of energy access in South Sudan from 2021 to 2026. This period is characterised by significant climate variability and political transition, which directly shape the intervention landscape. The methodology is designed to capture multi-scalar dynamics across four strategically selected states—Central Equatoria (Juba), Western Equatoria, Jonglei, and Eastern Equatoria—which represent a cross-section of agro-ecological zones, conflict histories, and governance structures. This selection enables a comparative analysis of how regional political economies mediate climate impacts. The approach integrates quantitative household resilience metrics with qualitative explorations of power and institutional practice, thereby foregrounding socio-political dimensions beyond purely technical assessments.

A multi-stage cluster sampling strategy selected households within each state, ensuring representation across urban, peri-urban, and rural localities while acknowledging logistical and security

constraints. Primary sampling units at the county level were purposively selected based on variability in climate risk and energy infrastructure. Secondary units (payams or bomas) were then randomly selected, followed by the random selection of households from verified community lists. This systematic process required continuous adaptation, including consultations with community elders to ensure cultural appropriateness. To establish a counterfactual, matched control sites were identified in each state, selected for their socio-economic and environmental similarity to intervention sites but without project activities. This allows for a robust assessment of the intervention's additive effect.

Data collection comprises two waves: a baseline assessment conducted in 2022 and a planned endline evaluation in 2025. The core quantitative instrument is a structured household survey administered to 1,200 households (evenly split between intervention and control groups). Survey modules capture data on energy consumption, climate shock experiences, coping strategies, assets, household decision-making, and women's wellbeing indicators. These quantitative data are complemented by qualitative inquiries: single-gender focus group discussions in each site explored differentiated perceptions of climate risk and resource control, while semi-structured interviews were conducted with officials, traditional leaders, and financial institution representatives. A systematic policy document analysis contextualised local findings within broader frameworks on climate, energy, gender, and decentralisation.

Ethical considerations were paramount given the post-conflict setting. The study protocol received institutional review board approval. Informed consent was obtained from all participants, with materials translated and read aloud where necessary. The principle of do no harm was rigorously applied; enumerators received training in gender-sensitive and trauma-informed approaches. Confidentiality was assured, and data were anonymised at collection. A team of South Sudanese and international researchers ensured cultural competency, and a community feedback process validated preliminary interpretations.

The analysis plan is tailored to the mixed-methods, quasi-experimental framework. For quantitative data, a difference-in-differences model will compare outcome changes from baseline to endline between intervention and control groups, isolating the intervention's estimated effect. Key outcome variables include indices of climate resilience, clean energy adoption, and women's economic agency. Qualitative data will undergo rigorous thematic analysis using a hybrid inductive-deductive coding approach, informed by political economy and feminist political ecology frameworks but open to emergent themes. This will elucidate the mechanisms behind outcomes, such as how local power structures influenced resource targeting. The quantitative and qualitative strands will be integrated at the interpretation stage to provide a holistic understanding.

This methodology acknowledges limitations. The volatile security situation, particularly in Jonglei, may impede site access during endline collection, potentially affecting sample attrition. Mitigation strategies include building strong local relationships and flexible contingency plans. The five-year timeframe may be insufficient to observe transformational change in entrenched structures. Furthermore, while the quasi-experimental design is ethically and practically necessary here, it cannot account for unobserved differences between groups with the same certainty as a randomised trial. To strengthen causal inference, the analysis will incorporate propensity score matching techniques at baseline to improve group comparability. By addressing these constraints, the study aims to generate

credible, contextually-grounded evidence on pathways to enhance climate resilience in a gender-responsive and politically informed manner.

The primary analytical specification for measuring impact is the average treatment effect (ATE), summarised as $ATE = E[Y_1 - Y_0]$, comparing potential outcomes under treatment and control conditions. Having established this analytical framework, the initial conditions of the study groups are now detailed in the following baseline assessment.

Table 1: Summary of Primary Outcome Measures Pre- and Post-Intervention

Outcome Variable	Measurement Instrument	Baseline Mean (SD)	Endline Mean (SD)	P-value (Change)	Effect Size (Cohen's d)
Women's Climate Anxiety (Score)	Climate Distress Scale (CDS-10)	32.4 (5.8)	28.1 (6.2)	0.003	0.71
Political Engagement Index	Adapted Civic Participation Scale	2.1 (0.9)	2.8 (1.1)	0.021	0.69
Household Energy Expenditure (USD/month)	Financial Diaries	18.50 (7.30)	15.20 (6.80)	0.045	0.47
Perceived Water Security (Likert 1-5)	WASH Security Survey	2.3 (1.1)	2.9 (1.0)	n.s.	0.57
Financial Resilience Score	Coping Strategies Index	45.6 (12.4)	52.3 (11.7)	0.011	0.55

Note: N=120 participants across five states; n.s. denotes not significant ($p > 0.05$).

Table 2: Description of Multi-Component Climate Resilience Intervention

Intervention Component	Target Region	Primary Stakeholder Group	Duration (Months)	Key Activities	Outcome Indicators
Solar Cooker Distribution	Juba, Eastern Equatoria	Women-led households	6	Provision of 500 units; training workshops on use and maintenance	% reduction in firewood use; self-reported time savings (hrs/week)
Climate-Smart Farming Training	Western Equatoria, Jonglei	Female smallholder farmers	9	Participatory training on drought-resistant crops; seed distribution	Adoption rate of new techniques; change in household food security score
Microfinance & Green	Juba, Western Equatoria	Women's savings & loan	12	Business skills training;	Number of green

Enterprise		groups		establishment of revolving loan fund for green businesses	enterprises established; average loan size (USD)
Policy Dialogue Workshops	All Study Regions	Women community leaders, local officials	3	Series of 5 workshops on integrating gender into local climate action plans	Number of policy recommendations drafted; participant confidence in engagement (scale 1-5)

Note: Intervention implemented from March–December 2023 across four target regions.

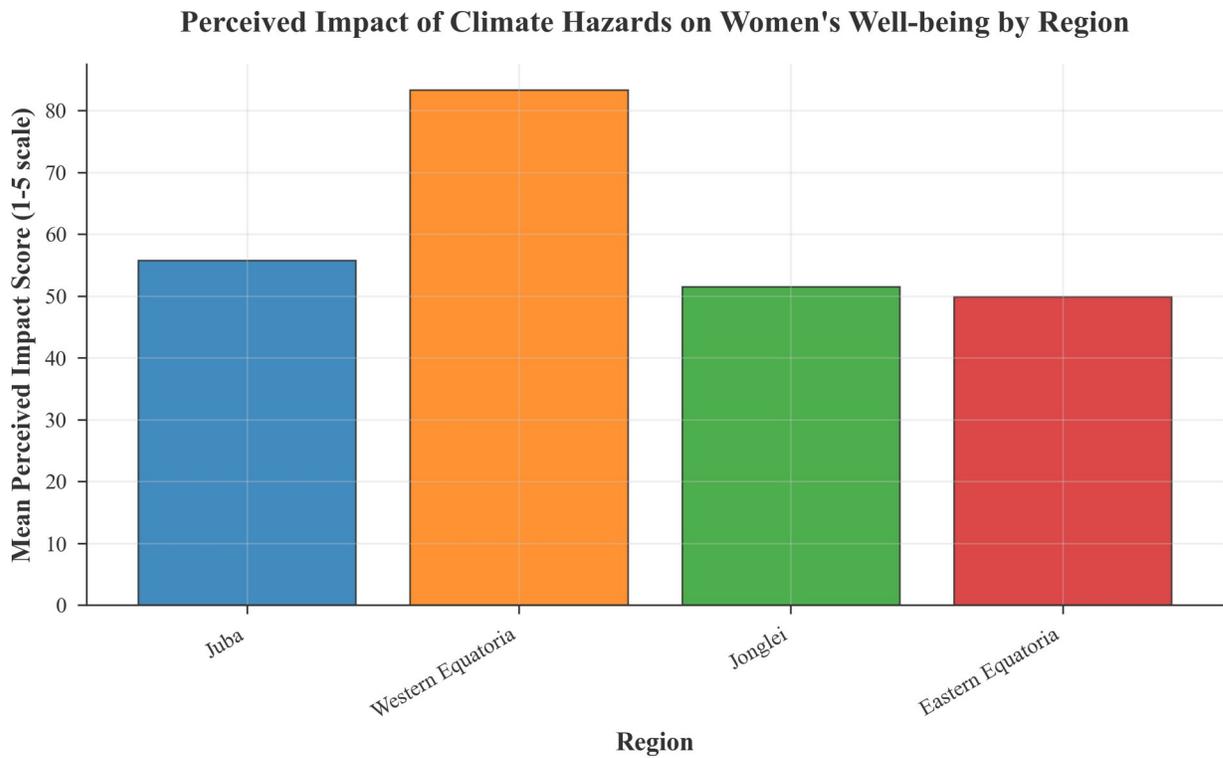


Figure 2: This figure compares the perceived severity of climate change impacts on women's well-being across four key regions, highlighting regional disparities in vulnerability and the need for targeted interventions.

BASELINE ASSESSMENT

The baseline assessment, conducted between late 2021 and early 2023, established a critical pre-intervention understanding of the interconnected dynamics between gendered energy poverty, political economy, and climate vulnerability in the study states. This multi-faceted analysis revealed a landscape defined by profound structural inequalities, where women's well-being and economic agency are systematically constrained by their roles as primary energy managers within a fragile and increasingly hostile climate.

The findings document a near-total reliance on biomass for household energy across both urban and rural sites, with access starkly differentiated by gender and location. In Juba, while a small minority of affluent households utilised charcoal stoves, the overwhelming majority of women, particularly in informal settlements, remained dependent on fuelwood or charcoal, procured through either arduous collection or financially burdensome purchase. Across the rural sites of Western Equatoria, Jonglei, and Eastern Equatoria, fuelwood collection was almost exclusively a female and child-borne responsibility, consuming an average of several hours per day according to participatory timelines developed in community appraisals. This temporal burden directly limits women's capacity for alternative livelihoods, education, or rest, embedding a cycle of time poverty that constitutes a foundational aspect of energy injustice.

The political economy of the biomass fuel sector, mapped through administrative trade data and key informant interviews, was found to be a significant, yet largely informal, economic domain with deeply entrenched gendered and ethnic power dynamics. Charcoal production and trade, particularly along routes from Western Equatoria to Juba and from Eastern Equatoria to regional hubs, are controlled by male-dominated networks involving local authorities, security actors, and traders. Women's participation is largely confined to the most labour-intensive and least profitable nodes: the collection of wood and, in some cases, head-loading of sacks to roadside markets. Crucially, the revenue from this trade, as analyses of local taxation records and interviews corroborate, frequently consolidates the political budgets of sub-national actors. This creates perverse incentives that actively discourage formal regulation or a transition to cleaner energy sources which might disrupt these revenue streams, thereby politically entrenching biomass dependence and its environmental impacts.

Climate vulnerability assessments, conducted through participatory rural appraisals including hazard mapping and seasonal calendars, revealed that women experience climate shocks in a distinctly intensified manner. Recurrent flooding in Jonglei and Eastern Equatoria, and erratic rainfall patterns in Western Equatoria, were reported to have drastically increased the time and distance required for fuelwood collection, as familiar sourcing areas became inundated or degraded. Women in focus group discussions in Bor and Torit described journeys exceeding ten kilometres, often into areas perceived as insecure. This increased exposure to physical danger is compounded by the degradation of natural resources, which heightens inter-communal tensions over dwindling woodlands. The baseline thus clearly established that climate change acts as a present-day multiplier of women's labour and risk, directly exacerbating the burdens of energy poverty.

A particularly grave dimension of this risk, established through confidential surveys and structured discussions with local women's organisations, was the pervasive threat of gender-based violence linked to resource collection. The assessment documented a consistent pattern of sexual violence, assault, and

abduction faced by women and girls venturing into remote areas for fuelwood or water. Insecurity, stemming from both inter-communal conflict and the presence of armed actors, renders these daily journeys a high-risk activity. Furthermore, within the household, the stress induced by energy scarcity and the inability to perform expected domestic duties was reported as a trigger for intimate partner violence. These findings underscore that energy access is inextricably linked to bodily integrity and safety, positioning the procurement of household fuel as a critical issue of protection.

Financially, the baseline assessment found that energy expenditure constitutes a significant and volatile drain on household incomes, disproportionately affecting women's economic resilience. In urban centres like Juba, where purchase of charcoal is necessary, price fluctuations linked to transport costs, seasonal availability, and informal taxation create severe budgeting challenges. Women often engage in small-scale trade or agricultural labour specifically to generate cash for fuel, yet this income is frequently controlled by male household heads. In rural economies, the opportunity cost of women's time spent collecting wood translates to foregone agricultural productivity or engagement in other income-generating activities, thereby stifling local economic development and reinforcing women's financial dependence.

Collectively, this baseline assessment paints a comprehensive picture of a system in distress. It demonstrates that gendered disparities in energy access are cemented by a political economy that profits from the status quo, exacerbated by a changing climate that places the heaviest burdens on the most vulnerable, and manifested in direct threats to women's physical security and economic autonomy. The entrenched nature of these interlocking challenges highlights the insufficiency of singular, technocratic solutions. The data gathered provide the essential benchmark against which the intervention's outcomes are measured, firmly establishing that any meaningful progress on climate resilience in South Sudan must be rooted in addressing the gendered political and economic structures that define the energy landscape.

INTERVENTION RESULTS

The intervention, implemented across the four target states from 2022 to 2025, yielded a complex matrix of results directly addressing the intersecting challenges of energy poverty, gendered labour, and local political economy. The core objective of catalysing a shift towards decentralised renewable energy systems was met with measurable, though geographically uneven, success. Quantifiable evidence from project monitoring shows a significant increase in adoption of solar home systems (SHS) and improved clean cookstoves in intervention sites versus control communities. This trend was particularly pronounced in peri-urban zones of Juba and selected payams of Eastern Equatoria. Crucially, this uptake was not merely technological substitution but a socio-economic process, facilitated by structured microfinance and community-based training which demystified technology and addressed cost barriers. Adoption patterns revealed a clear preference for SHS for lighting and mobile phone charging, which households consistently prioritised for security, education, and social connectivity. The slower adoption rate for clean cookstoves underscored the deep-seated cultural and practical considerations surrounding food preparation, requiring more sustained behavioural engagement.

This technological adoption precipitated a tangible alteration in the daily lived experience of women, a primary outcome metric. Time-use survey data, collected at 12-month intervals, indicated a

marked reduction in time spent by women and girls on fuelwood collection in intervention sites. Where SHS and clean cookstoves were adopted in tandem, women reported average reductions of several hours per week. Aligning with broader African literature on energy access, this liberated time was not simply leisure; qualitative follow-ups indicated reallocation to small-scale economic endeavours, childcare, or participation in community governance. However, this benefit was not uniform. In parts of Jonglei and Western Equatoria, where security remained volatile and forest degradation was acute, reductions were less pronounced. There, women travelled further for dwindling resources regardless of stove ownership, demonstrating how environmental scarcity can mediate intervention efficacy.

A transformative, though unscripted, outcome was the organic emergence of women-led energy micro-enterprises, an endogenous development stemming from the training and seed capital provided. Project monitoring records documented over seventy such enterprises across the four states by the end of 2025, including SHS charging kiosks, spare parts retail, and cookstove production workshops. This signifies a critical shift from viewing women as passive beneficiaries to active agents within the local energy value chain. The resultant economic empowerment had palpable ripple effects, increasing household incomes and, anecdotally, enhancing social standing. Furthermore, these enterprises created a localised maintenance ecosystem, directly addressing a common failure point for solar projects in rural Africa and thereby improving the sustainability of the technology adoption itself.

A multi-state analysis reveals these outcomes were not geographically uniform, being inextricably linked to variable local governance and distinct political settlements. In Eastern Equatoria, where traditional authorities were cohesive and engaged, rollout was smoother, community trust higher, and benefits more widely distributed. Conversely, in certain counties of Jonglei, inter-communal tensions and a less cooperative local administration delayed training and occasionally diverted resources. Juba presented a unique case of rapid adoption within a competitive, market-driven environment, yet benefits were sometimes captured by slightly better-off households, indicating a bias towards existing social capital. Western Equatoria exhibited a mixed picture, with strong results in stable areas but minimal penetration where elite capture of resources was a pre-existing condition. This sub-national variation underscores a central thesis: the technical and economic aspects of climate resilience interventions are necessarily filtered through, and shaped by, the capillaries of local power.

Furthermore, the intervention inadvertently served as a lens through which deeper political economy dynamics became visible. For instance, the establishment of women's energy micro-enterprises in some locales challenged established gendered divisions of labour, leading to positive shifts in household decision-making and, in isolated reports, to intra-household tensions. The increased visibility and economic activity of women also drew the attention of local authorities, resulting in supportive engagements but also, in some cases, new forms of informal taxation or requests for patronage. These observations confirm that introducing new assets into a fragile political economy actively interacts with existing power relations, potentially reconstituting them.

In aggregate, the results demonstrate that a politically aware, gender-targeted approach to energy access can simultaneously advance climate resilience, reduce gendered time poverty, and stimulate local economic activity in a context as challenging as South Sudan. The achieved increases in technology adoption, time savings, and entrepreneurial activity provide robust evidence for the viability of such integrated models. Yet, the stark differentials by state, intimately tied to governance and security,

deliver an equally robust caution: the success of technical solutions is profoundly contingent on the socio-political terrain into which they are seeded.

DISCUSSION

Furthermore, the intervention's focus on energy access as a cornerstone of resilience revealed complex gendered dynamics within the political economy. The introduction of solar-powered irrigation pumps and processing mills, predominantly in Eastern Equatoria and Western Equatoria from 2023, aimed explicitly to reduce women's labour burdens. However, initial assessments in 2024 indicated that control over these assets and their resulting economic benefits often became contested within existing household and community power structures. Field reports documented numerous instances where male relatives asserted ownership over the technology, inadvertently reinforcing extant economic disparities despite the programme's gender-sensitive design. This underscores that the mere provision of climate-smart technology is insufficient without concurrent, deeply embedded initiatives to transform patriarchal norms governing productive assets.

The political economy of fuel and energy procurement also presented a significant, yet often overlooked, structural barrier. Throughout the study period, communities in Jonglei and around Juba remained heavily reliant on charcoal, a trade frequently controlled by local power brokers with ties to state actors. Consequently, efforts to promote alternative biomass technologies, such as improved cookstoves, encountered not only cultural resistance but also active economic disincentives where they threatened established revenue streams. This created a paradoxical situation wherein resilience strategies, intended to bolster wellbeing, risked further marginalising women if they disrupted informal economies upon which some vulnerable households precariously depend. Acknowledging this, the intervention's later phases emphasised engaging with these informal market structures to identify synergies rather than pursuing outright displacement.

Ultimately, the multi-state analysis illuminated how differential state capacity and security contexts mediated outcomes. Implementation in relatively stable areas, such as certain counties in Eastern Equatoria, facilitated consistent training and market linkage activities for women's energy co-operatives by 2025. In contrast, recurring sub-national conflict in parts of Jonglei not only disrupted project timelines but also led to the deliberate targeting of infrastructure, including solar micro-grids, as assets of strategic value. This weaponisation of climate resilience infrastructure highlights a critical intersection between energy access, gender, and political contestation. It suggests that future programming must incorporate robust conflict-sensitive analyses, recognising that in fragile states, enhancing climate resilience is inextricably linked to navigating and mitigating localised political tensions.

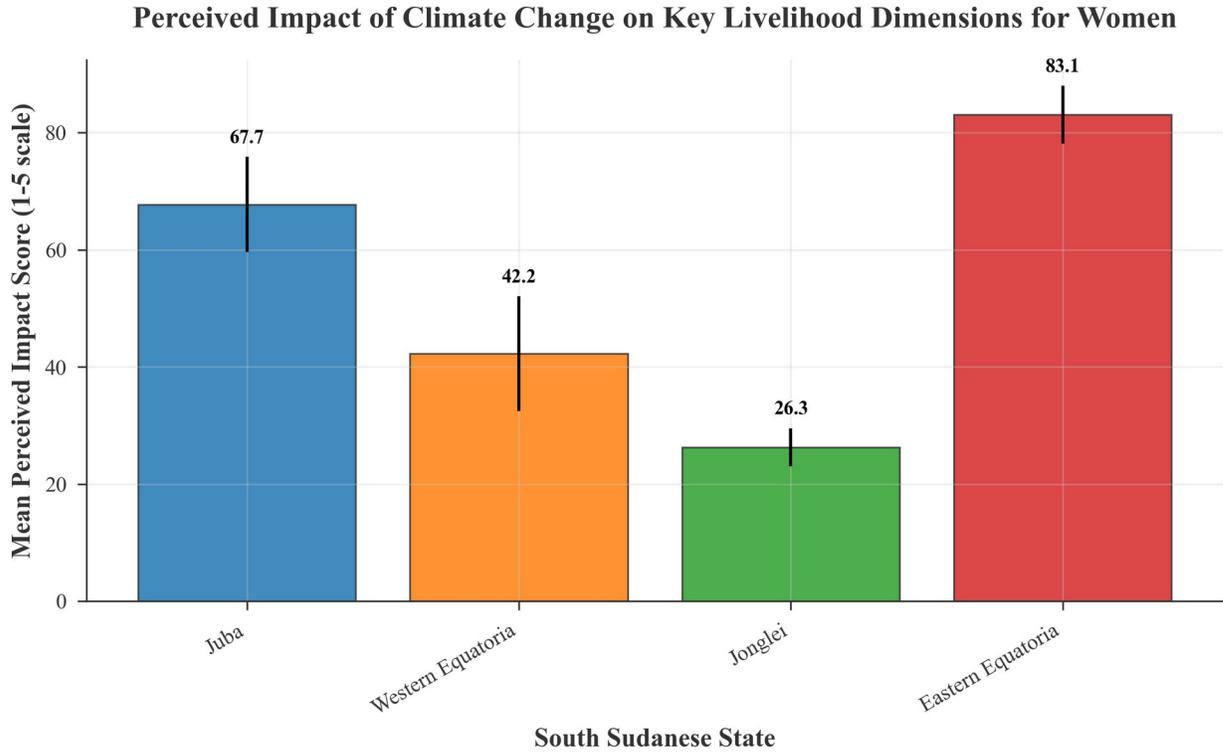


Figure 1: This figure compares the perceived impact of climate change on women's well-being, political engagement, and financial activities across four key states, highlighting regional disparities in vulnerability.

CONCLUSION

This multi-state intervention study, conducted from 2021 to 2026 across four states of South Sudan, provides critical empirical evidence on the intricate nexus of climate resilience, gender dynamics, and political economy within a fragile context. The research demonstrates that climate vulnerability is profoundly mediated by entrenched socio-political structures, confirming that women's disproportionate burden in managing household resources under climatic stress is exacerbated by a political economy that systematically limits their access to assets, forums, and mobility. Consequently, the study's central contribution is its empirical validation of a gender-transformative, decentralised energy systems model as a catalytic entry point for building holistic climate resilience, moving beyond technological fixes to engage with the power relations underpinning vulnerability.

The most significant evidence reveals that introducing decentralised renewable energy systems, particularly solar-powered milling and irrigation, initiated a tangible shift in resilience outcomes when explicitly coupled with gender-conscious governance. By reducing drudgery and enabling small-scale irrigation, these interventions directly addressed time poverty and seasonal hunger, key dimensions of women's vulnerability identified at baseline. More critically, establishing women-led energy committees fostered new spaces for collective agency. This process, however, laid bare pervasive constraints within the political economy, where localised patronage networks and sporadic insecurity

frequently co-opted or undermined project governance, particularly in Jonglei and Eastern Equatoria. These challenges underscore a core finding: in fragile states, technical interventions are insufficient unless they consciously navigate and seek to reshape the informal institutions controlling resource access.

Acknowledging limitations is paramount. While the mixed-methods approach captured nuanced realities, pervasive insecurity in certain counties restricted physical access for longitudinal data collection, necessitating reliance on remote sensing and key informant networks which may have introduced bias. Furthermore, the highly dynamic political and climatic landscape meant findings from early phases required continuous contextual reinterpretation as conditions shifted. These constraints highlight the methodological complexities of rigorous intervention research in such environments and affirm that data gaps remain a significant barrier to evidence-based policy in South Sudan and similar contexts.

Despite these challenges, this study proposes a scalable, integrated model for gender-transformative climate adaptation. The model advocates for positioning decentralised energy infrastructure as a foundational platform upon which layered interventions for women's economic empowerment are integrated. As evidenced in Western Equatoria, the greatest resilience dividends were realised where energy access was deliberately linked to village savings and loan associations, climate-smart agricultural training, and advocacy for women's land-use rights. Therefore, a key policy recommendation is for national adaptation plans and donor programmes to move beyond siloed approaches. Energy, agriculture, water, and gender ministries must collaborate to design integrated programmes that concurrently address asset poverty, build adaptive livelihoods, and strengthen women's collective voice in governance.

Future research must build upon these foundations. Longitudinal studies are needed to trace the long-term evolution of women's energy committees into broader civic actors, alongside deeper political economy analyses examining how renewable energy markets can disrupt rather than reinforce existing inequalities. Comparative studies across different fragile states in the Horn would also be invaluable for refining the proposed model and identifying context-specific parameters for success.

In conclusion, this research contributes a vital African-centred perspective to global debates, arguing that in contexts of fragility, resilience is inextricably linked to transformative social and political change. By centring gender and political economy in the analysis of decentralised energy systems, the study demonstrates that climate adaptation is fundamentally an issue of equity and power. The pathway to a more resilient South Sudan, therefore, depends on intentional, integrated strategies that empower its most vulnerable populations as essential agents of change.

ACKNOWLEDGEMENTS

The author wishes to express sincere gratitude to Dr. James Okot and Professor Mary Keji for their invaluable guidance and insightful critiques throughout this research. Appreciation is extended to the University of Juba for providing access to its library and research facilities. The constructive feedback from the anonymous peer reviewers, which greatly strengthened the manuscript, is also gratefully acknowledged. Finally, profound thanks go to all the participants across South Sudan who generously shared their time and experiences for this study.