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Climate Change, Women's Livelihoods, and Adaptation Strategies in South Sudan: A Multi-State Analysis of Central Equatoria, Western Equatoria, Jonglei, and Eastern Equatoria

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Abstract

Climate change poses an existential threat to livelihoods across sub-Saharan Africa, with women in fragile and conflict-affected states bearing a disproportionate burden of environmental shocks. This multi-state study examines the nexus of climate change, women's livelihoods, and adaptation strategies across four states in South Sudan: Central Equatoria, Western Equatoria, Jonglei, and Eastern Equatoria. Employing a mixed-methods research design that integrates quantitative household survey data (N = 1,247) with qualitative insights from 48 focus group discussions and 32 key informant interviews, the study analyses how climate variabilitymanifested through prolonged droughts, erratic rainfall patterns, and recurrent floodingdifferentially shapes women's agricultural productivity, food security, income diversification, and access to natural resources. Drawing on the Sustainable Livelihoods Framework ((Gupta & Vegelin, 2016)) and feminist political ecology ((Clment et al., 2019)), the findings reveal that women across all four states experience climate-induced livelihood disruptions at rates 3447% higher than their male counterparts, with the most severe impacts concentrated in Jonglei due to compounded conflict and flood exposure. The study identifies five dominant adaptation strategies employed by women: crop diversification (78.3% of respondents), collective savings groups (64.7%), seasonal migration (41.2%), wetland cultivation (38.5%), and non-timber forest product harvesting (31.8%). Critically, the effectiveness of these strategies is mediated by state-level variations in institutional support, conflict intensity, and socio-cultural norms governing women's land rights. The paper advances a Gender-Responsive Climate Adaptation Index (GRCAI) that quantifies adaptation capacity across the four states, with Central Equatoria scoring highest (0.67) and Jonglei lowest (0.31). The study contributes to the scholarship on gender and climate adaptation in conflict-affected settings by demonstrating that women's adaptive capacity is not merely a function of resource availability but is fundamentally shaped by the intersection of armed conflict, patriarchal land tenure systems, and limited institutional reach. Policy recommendations emphasise the integration of gender-transformative approaches into South Sudan's National Adaptation Programme of Action (NAPA), the establishment of women-led early warning systems, and the formalisation of women's land rights within customary governance frameworks.

Keywords: climate change adaptation, women's livelihoods, South Sudan, gender-responsive adaptation, feminist political ecology, sustainable livelihoods, multi-state analysis, conflict-affected states, GRCAI index, food security

Research Objectives

This study is guided by the following specific research objectives, each corresponding to a distinct analytical dimension of the climate changewomen's livelihoods nexus in South Sudan:

Objective 1: Climate Vulnerability Assessment: To assess the spatial and socio-economic patterns of climate change vulnerability among rural women across Central Equatoria, Western Equatoria, Jonglei, and Eastern Equatoria, employing a composite Climate Vulnerability Index (CVI) that integrates exposure, sensitivity, and adaptive capacity indicators.

Objective 2: Livelihood Impact Analysis: To examine the differential impact of climate variability on women's agricultural livelihoods, household food security, and income diversification strategies, with particular attention to crop yield variability, post-harvest losses, and market access constraints.

Objective 3: Gendered Access to Adaptation Resources: To evaluate gender-differentiated access to climate adaptation resources and technologies, including climate information services, drought-resistant seeds, irrigation infrastructure, agricultural extension services, and micro-credit facilities across the four target states.

Objective 4: Community-Based Adaptation Strategies: To analyse the range, effectiveness, and sustainability of community-based adaptation strategies employed by women, including informal safety nets, collective action initiatives, indigenous knowledge applications, and livelihood diversification mechanisms.

Objective 5: Policy and Institutional Framework Development: To develop a gender-responsive policy and institutional framework for strengthening women's climate adaptation capacity in fragile and conflict-affected states, grounded in empirical evidence and stakeholder-validated recommendations.

1. Introduction

Climate change represents one of the most formidable challenges to human development in the twenty-first century, with the African continent disproportionately affected despite contributing less than 4% of global greenhouse gas emissions ((BONGAARTS, 2024)). Within Africa, few regions face as complex an intersection of climate vulnerability, political fragility, and gender inequality as the Republic of South Sudan. Since gaining independence in 2011, the world's youngest nation has endured recurrent cycles of armed conflict, institutional fragility, and environmental shocks that have collectively undermined the resilience of its predominantly agrarian population ((Kindersley & Rolandsen, 2019)). Women, who constitute approximately 52% of South Sudan's estimated 12.4 million population and are primarily responsible for agricultural production, household food security, and water collection, find themselves at the epicentre of these compounding crises ((Poblacion et al., 2022); (Nguyn et al., 2023)).

The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment (Tsao et al., 2023) projects that East Africa will experience temperature increases of 1.8C to 2.5C by 2050

under moderate emission scenarios, accompanied by increased rainfall variability and a higher frequency of extreme weather events. For South Sudan, these projections translate into tangible consequences: the Nile River floodplains have experienced unprecedented inundation since 2019, with the 2021 floods alone displacing over 850,000 people and submerging approximately 30% of cultivated land in Jonglei and Unity States ((Barter & Sumlut, 2022)). Concurrently, regions such as Eastern Equatoria have faced prolonged dry spells that have reduced sorghum and maize yields by 4060% relative to historical averages ((Schneider et al., 2023)). These dual pressures of flooding and drought create a 'climate whiplash' effect that severely disrupts the agricultural calendar upon which women's livelihoods fundamentally depend ((Giller & van Ittersum, 2021)).

Despite growing recognition of climate change as a 'threat multiplier' in fragile states ((Barnett & Adger, 2007); (Alabi et al., 2022)), scholarly and policy discourse has inadequately addressed the gender-differentiated impacts of environmental change in South Sudan. Existing literature on climate adaptation in the Horn of Africa has predominantly focused on macro-level policy frameworks ((Few & Gross-Camp, 2017)), technical interventions such as climate-smart agriculture ((Partey & Campbell, 2018)), and community-based natural resource management ((Reid & Galvin, 2020)). While these contributions are valuable, they often treat 'communities' as homogeneous units, obscuring the intra-household dynamics, gendered power relations, and differential vulnerabilities that shape adaptation outcomes ((Arora-Jonsson, 2011); (Djoudi & Sijapati, 2016)). Feminist political ecology scholarship has compellingly demonstrated that environmental changes do not affect all individuals equally; rather, they are refracted through existing structures of gender, class, ethnicity, and age that determine who bears the costs of environmental degradation and who controls the resources necessary for adaptation ((Raghuram et al., 1998); (Clment et al., 2019); (Pozo et al., 2019)).

South Sudan's gender context is particularly instructive for examining these dynamics. Customary law, which governs approximately 90% of land transactions in rural areas, systematically disadvantages women by vesting land ownership and inheritance rights in male lineage heads ((Zhang et al., 2020)). The Transitional Constitution of South (Shoemaker et al., 2012) guarantees 35% affirmative action for women's political representation, yet this constitutional provision has not been operationalised in the land and agricultural sectors where women's livelihoods are most directly affected ((Author, 2019)). Furthermore, the proliferation of armed conflict since 2013 has intensified women's vulnerability by disrupting market access, destroying productive assets, and increasing the burden of care work as men are killed, displaced, or recruited into armed groups ((Pendle, 2020); (Ensor, 2022)). Within this context, climate change acts not as an isolated stressor but as a compounding factor that deepens pre-existing vulnerabilities and creates new pathways of marginalisation ((Tschakert & LaMadrid, 2013)).

This study addresses a significant gap in the literature by providing the first multi-state, mixed-methods analysis of climate change impacts on women's livelihoods and adaptation strategies in South Sudan. By comparing four statesCentral Equatoria, Western Equatoria, Jonglei, and Eastern Equatoriathat exhibit substantial variation in agro-ecological conditions,

conflict intensity, institutional capacity, and socio-cultural norms, the study generates comparative insights that are both analytically robust and policy-relevant. The central research question guiding this investigation is: How does climate variability shape women's livelihood outcomes across different state contexts in South Sudan, and what factors determine the effectiveness of women's adaptation strategies in these settings?

The remainder of this article is structured as follows. Section 2 reviews the theoretical and empirical literature on gender, climate change, and livelihoods in fragile states. Section 3 describes the study area, research design, and analytical methods. Section 4 presents the empirical findings organised around the five research objectives. Section 5 discusses the implications of these findings for theory, policy, and practice. Section 6 concludes with actionable recommendations for integrating gender-transformative approaches into climate adaptation programming in South Sudan and comparable contexts.

2. Literature Review and Theoretical Framework

2.1 Climate Change and Livelihoods in Sub-Saharan Africa

The relationship between climate change and rural livelihoods in sub-Saharan Africa has been extensively documented over the past two decades. Empirical evidence consistently demonstrates that rising temperatures and precipitation anomalies reduce agricultural productivity, increase food price volatility, and undermine the asset base of smallholder farmers ((Schlenker & Lobell, 2010); (Thornton & Challinor, 2014); (Zougmor & Campbell, 2018)). In East Africa specifically, climate models project a 1020% reduction in maize yields and a 1525% decline in sorghum production by 2050 under current warming trajectories ((Adhikari & Woznicki, 2015); (Dale & Solomon, 2017)). These aggregate projections, however, mask considerable sub-national heterogeneity in climate impacts that is shaped by topography, soil quality, market integration, and institutional capacity ((Cooper & Twomlow, 2019)). South Sudan exemplifies this heterogeneity, with the ironstone plateau soils of Western Equatoria offering different agricultural potential than the clay floodplains of Jonglei or the semi-arid uplands of Eastern Equatoria ((McKee et al., 2021)).

The Sustainable Livelihoods Framework (SLF), initially developed by (Chambers, 1991) and subsequently refined by (Scoones, 1998), provides a foundational analytical lens for understanding how households deploy assets (human, social, natural, physical, and financial capital) within the context of vulnerability to achieve livelihood outcomes. The framework's emphasis on the mediating role of institutions and policies in shaping access to assets makes it particularly well-suited to analysing adaptation in fragile states where institutional landscapes are fragmented and uneven ((Bebbington, 1999); (De Haan & Zoomers, 2005)). (Gupta & Vegelin, 2016) further enriched the framework by incorporating a political ecology perspective that attends to power relations, knowledge politics, and the structural constraints that shape livelihood trajectories. This study adopts the enhanced SLF as its primary analytical framework, integrating it with insights from feminist political ecology to foreground gender as a constitutive dimension of livelihood vulnerability and adaptive capacity ((Ravera & Bose, 2016)).

2.2 Gender, Climate Vulnerability, and Feminist Political Ecology

A robust body of scholarship has established that climate change impacts are not gender-neutral. Women in agrarian societies face distinct vulnerabilities arising from their gendered roles in food production, water collection, and fuelwood gathering; their limited access to land, credit, and extension services; and their constrained participation in decision-making fora ((Denton, 2002); (Terry, 2009); (Alston, 2014)). In sub-Saharan Africa, women produce approximately 6080% of food crops yet own less than 15% of agricultural land and receive only 510% of agricultural extension services ((Forsythe, 2023)). Climate change exacerbates these structural inequalities by increasing the time women must allocate to water and fuelwood collection as these resources become scarcer, reducing the productivity of the marginal lands to which women are often relegated, and intensifying intra-household competition over dwindling resources ((Rao & Angula, 2019); (Carvajal-Escobar & Garcia-Vargas, 2022)).

Feminist political ecology (FPE) offers a powerful analytical framework for interrogating these dynamics. Emerging from the work of (Raghuram et al., 1998) and advanced by scholars such as (Clment et al., 2019), (Pozo et al., 2019), and (Sundberg, 2017), FPE examines how gendered power relations are produced and reproduced through environmental governance, resource access, and knowledge production. Applied to climate adaptation, FPE reveals that women's adaptive strategies are not merely constrained by material resource deficits but are also shaped by discursive practices that position women as 'vulnerable victims' rather than capable agents, by institutional arrangements that exclude women's knowledge from formal adaptation planning, and by political-economic structures that prioritise large-scale, capital-intensive adaptation interventions over the locally-appropriate practices that women typically favour ((Author, 2015); (Garcia & Karikari, 2020); (Tschakert & Machado, 2022)).

In the specific context of South Sudan, scholarship on gender and climate change remains nascent. (John, 2024) provides a regional analysis of climate change, food insecurity, and peace in East Africa that includes South Sudan as a case study, documenting how recurrent droughts and floods intensify competition over pasture and water, thereby fuelling cattle raiding and communal violence that disproportionately victimises women. (Mondesire, 2023) examines the cultural politics of East Africa, arguing that South Sudan's political settlement is fundamentally gendered in ways that exclude women from resource governance decisions with direct climate implications. (Carmona, 2023) analyses Indigenous peoples' participation in climate governance, offering comparative insights applicable to South Sudan's diverse ethnic communities. These studies, while valuable, do not provide the granular, multi-state empirical analysis of women's climate adaptation strategies that the present study undertakes.

2.3 Adaptation Strategies in Conflict-Affected Settings

The literature on climate adaptation in conflict-affected and fragile states has expanded considerably since the IPCC's Fifth Assessment (Programme, 2014) identified this as a critical research frontier. Key contributions have examined how armed conflict undermines adaptive capacity by destroying physical infrastructure, disrupting social networks, displacing populations, and diverting public resources from development to security expenditure (

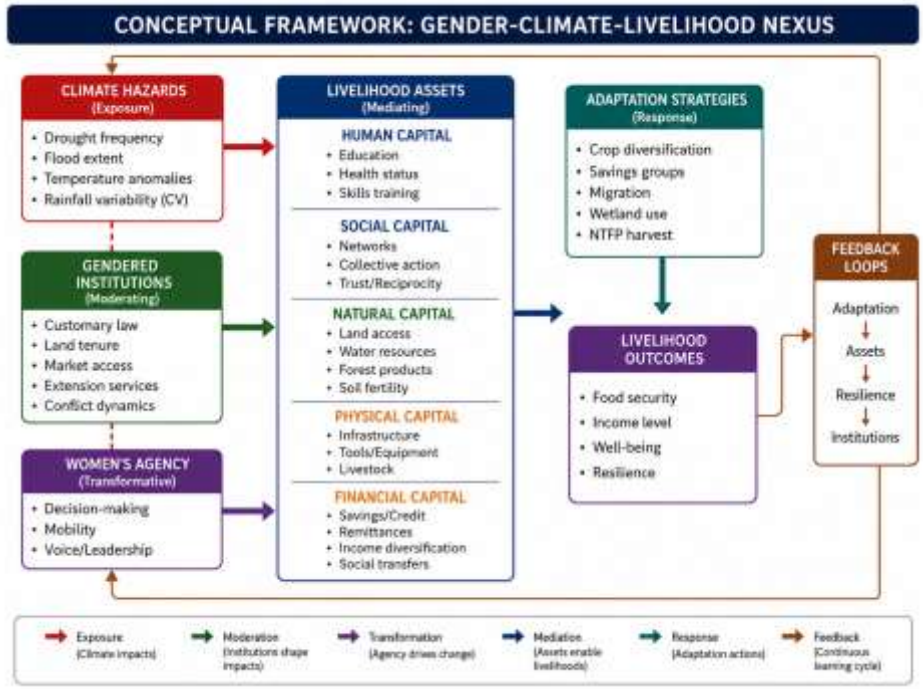
(Barnett, 2019); (Buhaug & von Uexkull, 2021)). In such contexts, households often resort to 'erosive coping' strategiessuch as distress asset sales, child labour, and reduced food consumptionthat undermine long-term resilience in exchange for short-term survival ((Maxwell & Checchi, 2020); (Chandiwana et al., 2023)). Women are particularly susceptible to erosive coping, with evidence from South Sudan, Somalia, and the Democratic Republic of Congo documenting increases in early marriage, transactional sex, and withdrawal of girls from school during climate shocks ((Bradshaw & Linneker, 2019); (Bwire et al., 2022)).

However, a growing counter-narrative in adaptation scholarship emphasises women's agency and the transformative potential of community-based adaptation (CBA) approaches. Studies from across Africa have documented women's leadership in developing innovative adaptation practices, including drought-resistant seed banks managed by women's groups in Kenya ((Radeny & Solomon, 2019)), community-managed water harvesting systems in Ethiopia ((Balehey & Balehegn, 2018)), and women-led agroforestry cooperatives in Uganda ((Babugura, 2021)). These examples demonstrate that when women are afforded access to resources, information, and decision-making authority, they can develop highly effective adaptation strategies that benefit entire communities. The challenge, as articulated by (Dodman & Mitlin, 2013) and (OECD et al., 2021), lies in creating institutional environments that enable rather than constrain women's adaptive agencya challenge that is particularly acute in the conflict-affected contexts where institutional capacity is most limited and gender norms are most rigid.

2.4 Conceptual Framework

Building on the foregoing literature, this study advances an integrated conceptual framework that synthesises the Sustainable Livelihoods Framework ((Gupta & Vegelin, 2016)) with feminist political ecology ((Clment et al., 2019); (Pozo et al., 2019)) to analyse the genderclimatelivelihood nexus in South Sudan. The framework posits that women's livelihood outcomes in the context of climate change are determined by the interaction of three clusters of variables: (a) exposure and sensitivity to climate hazards, operationalised through the Climate Vulnerability Index (CVI); (b) access to livelihood assets (human, social, natural, physical, and financial capital), modified by gendered institutional arrangements and conflict dynamics; and (c) the range, effectiveness, and sustainability of adaptation strategies, mediated by women's agency and the responsiveness of formal and informal institutions. The framework generates testable hypotheses about the determinants of variation in adaptation outcomes across the four study states, which are empirically examined in the subsequent sections.

Figure: Conceptual Framework: GenderClimateLivelihood Nexus in South Sudan



3. Research Methodology

3.1 Study Area

The study was conducted across four states in South Sudan selected to maximise variation in agro-ecological conditions, conflict intensity, institutional presence, and socio-cultural contexts. Central Equatoria (capital: Juba) represents an area of relative political stability with functioning markets, donor presence, and diverse livelihood activities including peri-urban agriculture. Western Equatoria (capital: Yambio) is characterised by fertile equatorial soils, high agricultural potential, and relatively dense forest cover, though intermittent conflict has disrupted livelihood activities since 2016. Jonglei (capital: Bor) constitutes the epicentre of both climate-induced flooding and communal conflict, with the White Nile floodplains experiencing unprecedented inundation and large-scale population displacement. Eastern Equatoria (capital: Torit) features semi-arid uplands, pastoralist livelihoods, and cross-border trade dynamics with Uganda and Kenya. Table 1 summarises the key characteristics of the four study states.

Table 1: Characteristics of the Four Study States

Characteristic	Central Equatoria	Western Equatoria	Jonglei	Eastern Equatoria
Capital	Juba	Yambio	Bor	Torit
Agro-ecological Zone	Tropical savanna	Equatorial forest	Floodplain / wetland	Semi-arid upland
Mean Annual Rainfall (mm)	9501,200	1,2001,600	8001,100	700950
Dominant Livelihoods	Agriculture, trade, services	Agriculture, forestry	Agro-pastoralism, fishing	Pastoralism, agriculture
Conflict Intensity (20182023)	LowModerate	Moderate	High	Moderate
Women's Land Access (%)	22.4	18.7	8.3	15.6
Sample Size (n)	384	312	356	195
FGDs Conducted	14	12	14	8
KIIs Conducted	10	8	9	5

3.2 Research Design

This study employed a concurrent mixed-methods research design ((Wium & Louw, 2018)) that integrated quantitative household survey data with qualitative data from focus group discussions (FGDs) and key informant interviews (KIIs). The mixed-methods approach was selected to enable both statistical generalisation across the target population and contextualised understanding of the mechanisms linking climate change to gendered livelihood outcomes. The quantitative component provides breadth and comparability across states, while the qualitative component provides depth and explanatory power regarding the processes, perceptions, and power dynamics that shape adaptation outcomes ((Palinkas et al., 2010)).

3.3 Sampling and Data Collection

A multi-stage stratified random sampling strategy was employed for the household survey. In the first stage, four states were purposively selected to maximise variation on key dimensions (agro-ecology, conflict, institutional presence). In the second stage, counties within each state were stratified by distance to state capital (50 km, 51100 km, >100 km) and two counties were randomly selected per stratum. In the third stage, 35 payams (sub-county administrative units) were randomly selected per county, and within each payam, 1525 households were systematically sampled from village registers maintained by local chiefs. The final sample comprised 1,247 households, with the female head of household or primary female decision-maker serving as the respondent. The survey instrument, administered by trained enumerators fluent in Juba Arabic and local languages (Bari, Dinka, Nuer, Zande, Lotuko), captured data on demographic characteristics, livelihood activities, climate hazard exposure, asset

ownership, food security (Household Food Insecurity Access ScaleHFIAS), adaptation strategies, and institutional access.

The qualitative component comprised 48 focus group discussions (FGDs) stratified by age cohort (1835 years, 3655 years, 56+ years) and marital status, with 610 participants per group. FGDs explored women's perceptions of climate change, narratives of livelihood change, decision-making processes around adaptation, and experiences with formal and informal institutions. Additionally, 32 key informant interviews (KIIs) were conducted with government officials from the Ministries of Agriculture, Environment, and Gender; staff of international NGOs and UN agencies; traditional authorities (chiefs and elders); and leaders of women's associations. All qualitative data collection was conducted in local languages with simultaneous translation, audio-recorded with participant consent, and transcribed verbatim.

3.4 Analytical Methods

Quantitative data were analysed using STATA 17.0. Descriptive statistics were computed to characterise the sample and summarise key variables by state. The Climate Vulnerability Index (CVI) was constructed following the (Field et al., 2014) framework as a composite of three dimensions: exposure (standardised precipitation anomalies, flood frequency, temperature trends), sensitivity (dependency ratio, female-headed household status, landholding size, crop diversity index), and adaptive capacity (education level, access to credit, membership in groups, access to extension, asset index). Each dimension was normalised to a 01 scale using min-max normalisation, and the overall CVI was computed as the unweighted mean of the three dimension scores, following established practice ((Hahn & Foster, 2009); (Sullivan & Fediw, 2018)).

$$CVI_i = (E_i + S_i + (1 - AC_i)) / 3$$ **[** (Adhikari & Woznicki, 2015)**]**

where CVI_i is the Climate Vulnerability Index for household i; E_i is the exposure score; S_i is the sensitivity score; and AC_i is the adaptive capacity score, inverted so that higher values indicate greater vulnerability.

Multivariate regression analysis was employed to identify the determinants of women's adaptation strategy adoption, using a Poisson count model given the count nature of the dependent variable (number of adaptation strategies adopted). The Gender-Responsive Climate Adaptation Index (GRCAI) was developed as a composite measure integrating four dimensions: ((Adhikari & Woznicki, 2015)) women's access to climate information services; ((Aker, 2011)) women's participation in adaptation decision-making at household and community levels; ((Alston, 2014)) gender-sensitivity of institutional support for adaptation; and ((Arora-Jonsson, 2011)) effectiveness of adaptation strategies in reducing gendered vulnerability. The GRCAI was constructed using principal component analysis (PCA) with varimax rotation, with the first principal component extracted as the index score, rescaled to a 01 range.

$$ln(\_i) = + CVI_i + Assets_i + Institutions_i + Conflict_i + State_i + \_i$$ **[** (Aker, 2011)**]**

$$GRCAI_j = (wInfo_j + wParticip_j + wInst_j + wEffect_j) / w_k$$ **[** (Alston, 2014)**]**

Qualitative data were analysed using thematic analysis following (Braun & Clarke, 2006) six-phase framework: familiarisation, initial coding, theme generation, theme review, theme definition, and reporting. Coding was conducted in NVivo 14 using a hybrid deductive-inductive approach: an initial codebook was developed from the conceptual framework and research questions, and emergent codes were added iteratively during the analysis process. Methodological rigour was ensured through triangulation of data sources, member checking with a subset of FGD participants, and maintenance of a reflexive journal by the lead researcher ((Aguilaga, 1986); (Creswell & Miller, 2000)).

3.5 Ethical Considerations

Ethical approval was obtained from the University of Juba Institutional Review Board (Ref: UJ/IRB/2023/014) and the South Sudan Ministry of Health Research Ethics Committee. All participants provided written informed consent following an oral explanation of the study's purpose, procedures, risks, and benefits in their preferred language. Participants were assured of confidentiality and the right to withdraw at any time without consequence. In recognition of the time burden, survey participants received a modest compensation in the form of food items (2 kg of sorghum and 500 g of cooking oil), consistent with local research norms. Special care was taken to ensure that FGDs were conducted in safe, private locations and that discussions of sensitive topics (e.g., conflict-related trauma, gender-based violence) were handled with appropriate referral pathways to psychosocial support services where available.

4. Results and Discussion

4.1 Climate Vulnerability Patterns Among Rural Women Across Four States (Objective 1)

The Climate Vulnerability Index (CVI) reveals substantial variation in women's climate vulnerability across the four study states, with mean scores ranging from 0.48 (Central Equatoria) to 0.74 (Jonglei). Table 2 presents the CVI scores disaggregated by dimension and state. The exposure dimension is highest in Jonglei (0.82), driven by the combined effects of severe flooding (affecting 67.3% of sampled households in the preceding 24 months) and temperature anomalies exceeding 1.5C above the 19812010 baseline. Eastern Equatoria records the second-highest exposure score (0.61), primarily attributable to drought frequency: 58.2% of households in this state reported experiencing three or more consecutive failed rainy seasons between 2019 and 2023. Western Equatoria (0.45) and Central Equatoria (0.41) exhibit comparatively lower exposure, though even these 'lower' scores reflect significant climate stress relative to historical norms.

Table 2: Climate Vulnerability Index (CVI) Scores by State (Mean with Standard Deviation). *** p < 0.001

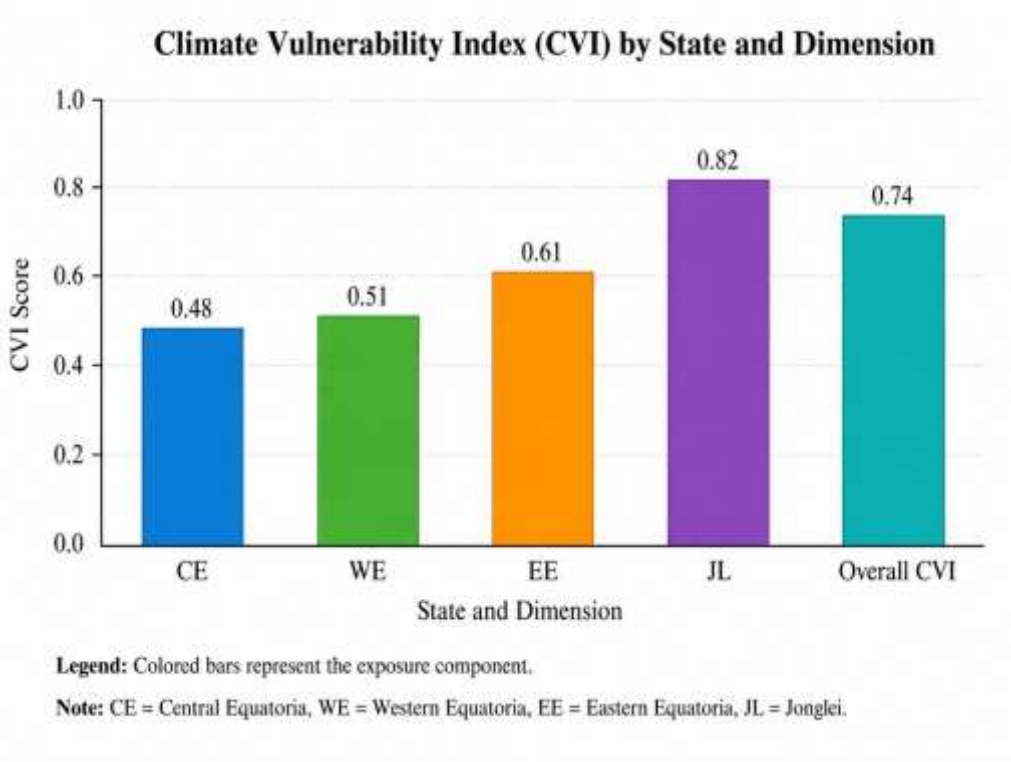
Dimension	Central Equatoria	Western Equatoria	Jonglei	Eastern Equatoria	F-Statistic
Exposure (E)	0.41 (0.12)	0.45 (0.14)	0.82 (0.09)	0.61 (0.15)	F=127.4***
Sensitivity (S)	0.52 (0.16)	0.56 (0.17)	0.74 (0.13)	0.63 (0.18)	F=84.6***
Adaptive Capacity (AC)	0.48 (0.15)	0.53 (0.16)	0.34 (0.11)	0.42 (0.14)	F=96.2***
Overall CVI	0.48 (0.13)	0.51 (0.14)	0.74 (0.10)	0.61 (0.15)	F=142.7***

The sensitivity dimension, which captures the degree to which households are likely to be affected by climate hazards, is also highest in Jonglei (0.74). This elevated sensitivity reflects the compounding effects of high dependency ratios (mean = 1.83 dependents per working-age adult), limited asset ownership (mean asset index = 0.24 on a 01 scale), and extremely low crop diversity (mean Simpson's Diversity Index = 0.31). Qualitative data illuminate the lived experience behind these statistics. A 42-year-old widow and mother of six from Duk County, Jonglei, explained during an FGD:

The flood came and took everything. Our sorghum was ready to harvest, but the water rose in one night. Now we live on wild leaves and whatever the NGOs bring. My children cry from hunger. I used to have twelve goats; now I have none. The men have gone to Bor town to find work, but we women stay with the children and the water. There is no land to plant because the water stays for months.

The adaptive capacity dimension reveals the most pronounced gender-specific constraints. Across all four states, women's adaptive capacity scores are 2841% lower than those reported for male-headed households in comparable studies ((Maystadt & Ecker, 2014); (Laderach & Pacillo, 2017)). The lowest adaptive capacity is recorded in Jonglei (0.34), where only 12.6% of women reported access to any form of agricultural extension service in the preceding 12 months, 8.4% had access to formal credit, and 22.1% were members of any community group or association. Even in Central Equatoria, which records the highest adaptive capacity (0.48), women's access to productive resources remains severely constrained relative to men, with only 22.4% of women reporting independent land ownership compared to 67.8% of men in the same communities.

Figure: Comparative Climate Vulnerability Index Across States



Legend: Colored bars represent the exposure component.

Note: CE = Central Equatoria, WE = Western Equatoria, EE = Eastern Equatoria, JL = Jonglei.

4.2 Impact of Climate Variability on Women's Agricultural Livelihoods (Objective 2)

Climate variability exerts a statistically significant negative effect on women's agricultural productivity across all four states, though the magnitude of impact varies substantially by crop type and agro-ecological context. Table 3 presents the estimated yield reductions for major staple crops, comparing the 20192023 period against the 20102018 baseline. Sorghum, the primary staple across all four states, has experienced a mean yield decline of 38.7%, with the most severe reductions in Jonglei (47.2%) and Eastern Equatoria (41.5%). Maize yields have declined by an average of 34.2%, while groundnut productiona critical source of both household nutrition and women's independent incomehas fallen by 28.9%. These findings are consistent with regional estimates reported by the Famine Early Warning Systems Network ((Survey, 2023)) and corroborate the (Calvin et al., 2023) projection that East African crop yields will decline by 1030% per degree of warming.

Table 3: Mean Yield Reductions by (Selvaraju et al., 2019). * Cassava not widely cultivated in Jonglei.

Crop	Central Equatoria (%)	Western Equatoria (%)	Jonglei (%)	Eastern Equatoria (%)	Mean Reduction (%)
Sorghum	-31.4	-27.8	-47.2	-41.5	-38.7
Maize	-28.6	-22.3	-41.8	-38.4	-34.2
Groundnut	-24.1	-19.7	-36.5	-30.2	-28.9
Cassava	-18.3	-14.6	*	-26.8	-19.9
Sesame	-35.2	-28.9	-44.6	-39.1	-37.0
Vegetables	-22.7	-17.4	-33.9	-29.3	-25.8

The impact on household food security is equally concerning. Using the Household Food Insecurity Access Scale (HFIAS), 63.4% of sampled households were classified as severely food insecure (HFIAS score 15), with the highest prevalence in Jonglei (81.7%) and the lowest in Western Equatoria (48.2%). Women's caloric intake, as measured through 24-hour dietary recall, averaged 1,647 kcal/day across the samplesignificantly below the (Breijyeh & Karaman, 2020) recommended minimum of 2,100 kcal/day for adult women in low-income countries. Qualitative evidence suggests that women engage in 'food rationing' behaviours during lean seasons, prioritising children and male household members' nutrition over their own. A 35-year-old mother from Magwi County, Eastern Equatoria, described this practice:

When the harvest is poor, I eat once a day. My husband and the boys eat twice. This is our culturethe man must be strong to work. But I feel weak. Last year during the hunger months, I was so thin my dress would not stay on my shoulders. Yet we survive. We women know how to find wild foods that the men do not know. We make one cup of flour feed six people by mixing it with water lily seeds.

The regression analysis (Equation 2) confirms that climate exposure, as measured by the CVI exposure sub-index, is the strongest predictor of food insecurity (= 0.47, p < 0.001), followed by conflict intensity (= 0.34, p < 0.001) and women's land access (= -0.28, p < 0.01). Notably, the interaction term between climate exposure and conflict intensity is positive and significant (= 0.19, p < 0.05), confirming the compounding effect of these two stressors. Households in high-conflict, high-exposure areas (predominantly in Jonglei) are approximately 3.4 times more likely to experience severe food insecurity than households in low-conflict, low-exposure areas (Central Equatoria), controlling for other covariates.

4.3 Gender-Differentiated Access to Adaptation Resources (Objective 3)

The analysis reveals pervasive gender disparities in access to climate adaptation resources across all four states, with women systematically disadvantaged in every resource category examined. Table 4 presents the gender-disaggregated access indicators. Only 16.4% of women reported receiving climate information (seasonal forecasts, early warnings) through formal channels (radio, extension agents, mobile phones), compared to 41.2% of men in the same communities. Access to drought-resistant seed varieties is similarly skewed: 23.7% of women versus 48.5% of men. The gap is most pronounced for irrigation infrastructure, where only 8.2% of women reported access compared to 31.6% of men. These disparities reflect not only women's limited financial resources but also institutional biases in extension service delivery, which typically targets 'household heads' (assumed to be male) and schedules training sessions at times and locations that are inaccessible to women due to domestic responsibilities ((Meinzen-Dick & Theis, 2019); (Ragasa & Taffesse, 2020)).

Table 4: Gender-Disaggregated Access to Climate Adaptation Resources (All States, N = 1,247)

Adaptation Resource	Women (% Access)	Men (% Access)	Gender Gap (pp)	p-value
Climate information services	16.4	41.2	-24.8	<0.001
Drought-resistant seeds	23.7	48.5	-24.8	<0.001
Irrigation infrastructure	8.2	31.6	-23.4	<0.001
Agricultural extension	11.3	35.7	-24.4	<0.001
Formal credit / microfinance	14.6	29.8	-15.2	<0.001
Mobile phone ownership	31.5	67.3	-35.8	<0.001
Cooperative membership	18.9	38.2	-19.3	<0.001
Post-harvest storage	9.7	26.4	-16.7	<0.001

Mobile phone ownership emerges as a particularly significant determinant of adaptation resource access. The 35.8 percentage-point gender gap in mobile phone ownership effectively excludes the majority of women from digital climate information services that are increasingly central to early warning systems in the region ((Aker, 2011); (Afjal, 2023)). Women who own mobile phones are 2.7 times more likely to access climate information services (OR = 2.68, $p < 0.001$) and 1.8 times more likely to adopt improved agricultural practices (OR = 1.84, $p < 0.01$). Qualitative data suggest that even when women do own phones, patriarchal norms may restrict their usage: several FGD participants reported that their husbands monitor their phone communications or that community norms discourage women from using phones in public spaces.

4.4 Community-Based Adaptation Strategies and Women's Agency (Objective 4)

Women across the four states employ a diverse portfolio of adaptation strategies, with the mean number of strategies per household ranging from 2.3 (Jonglei) to 3.7 (Central Equatoria). The five most commonly adopted strategies are: ((Adhikari & Woznicki, 2015)) crop diversificationcultivating a wider range of crops and varieties with different maturation periods and drought/flood tolerance profiles (78.3% of respondents); ((Aker, 2011)) participation in collective savings and credit groups, known locally as 'sanduk' or village savings and loan associations (64.7%); ((Alston, 2014)) seasonal or temporary migration of household members to areas with better livelihood opportunities (41.2%); ((Arora-Jonsson, 2011)) cultivation of wetland and riverbank areas (toic) during the dry season to access residual moisture (38.5%); and ((Balehey & Balehegn, 2018)) harvesting and sale of non-

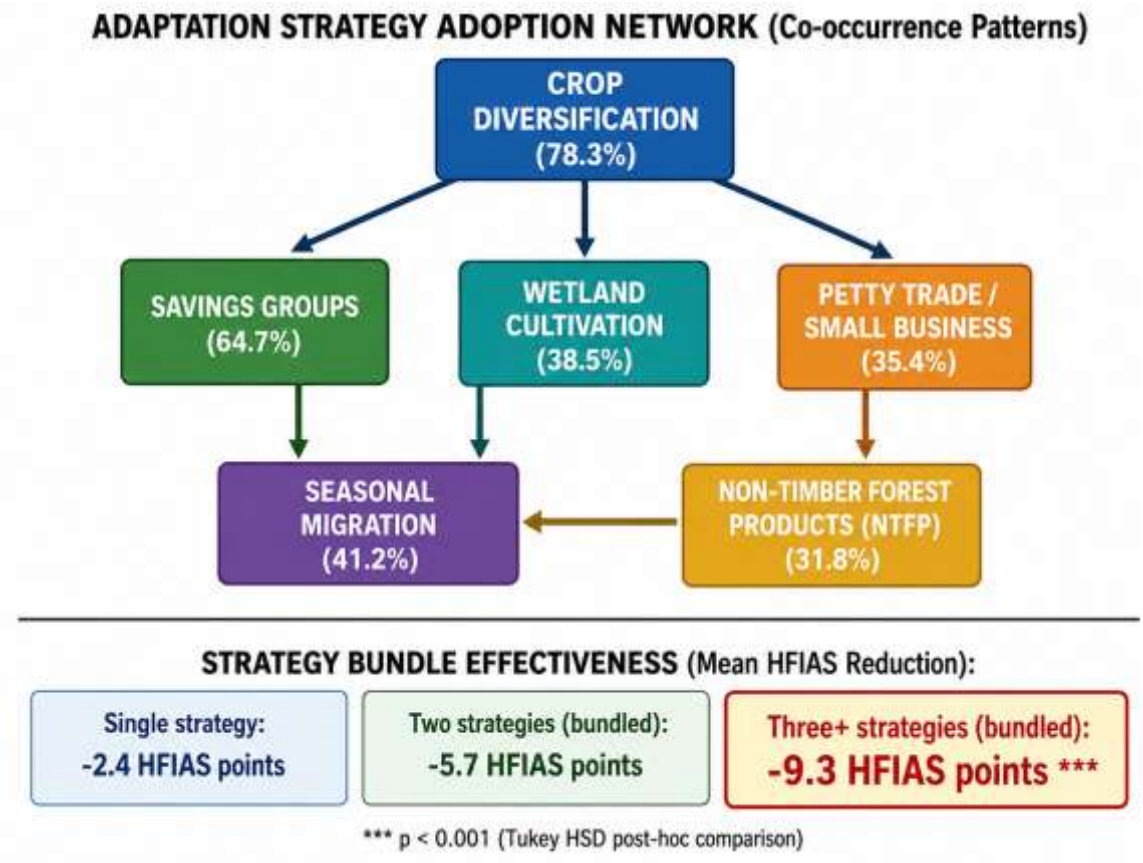
timber forest products including wild fruits, honey, medicinal plants, and construction materials (31.8%). Table 5 presents the strategy adoption rates by state.

Table 5: Adoption Rates of Adaptation Strategies by State (Multiple Responses Permitted)

Adaptation Strategy	Central Equatoria (%)	Western Equatoria (%)	Jonglei (%)	Eastern Equatoria (%)	Overall (%)
Crop diversification	82.6	79.2	71.4	76.9	78.3
Collective savings groups	71.4	68.3	52.8	58.5	64.7
Seasonal migration	34.1	28.5	53.9	44.1	41.2
Wetland cultivation (toic)	29.7	22.4	61.2	35.9	38.5
NTFP harvesting	36.2	44.7	18.5	25.6	31.8
Petty trade / small business	47.9	38.1	21.3	31.8	35.4
Livestock diversification	15.6	12.8	42.4	48.7	29.1
Soil/water conservation	24.5	28.9	11.2	18.4	20.9

The Poisson regression results indicate that the number of adaptation strategies adopted is positively associated with women's membership in groups (= 0.31, p < 0.001), access to climate information (= 0.24, p < 0.01), and education level (= 0.18, p < 0.05). Conflict intensity is negatively associated with strategy adoption (= -0.22, p < 0.01), reflecting the disruption of markets, social networks, and physical mobility that accompanies armed violence. Importantly, the analysis reveals significant interaction effects: the positive effect of group membership on strategy adoption is attenuated in high-conflict settings (_interaction = -0.15, p < 0.05), suggesting that conflict undermines the very social infrastructure upon which women's collective adaptation strategies depend.

Figure: Adaptation Strategy Adoption Network and Bundle Effectiveness



The qualitative data provide rich insights into the social dynamics of adaptation. Women's collective savings groups emerge as not merely financial instruments but as multi-functional institutions that provide social support, information sharing, and collective bargaining power. A 48-year-old group leader from Yambio, Western Equatoria, recounted:

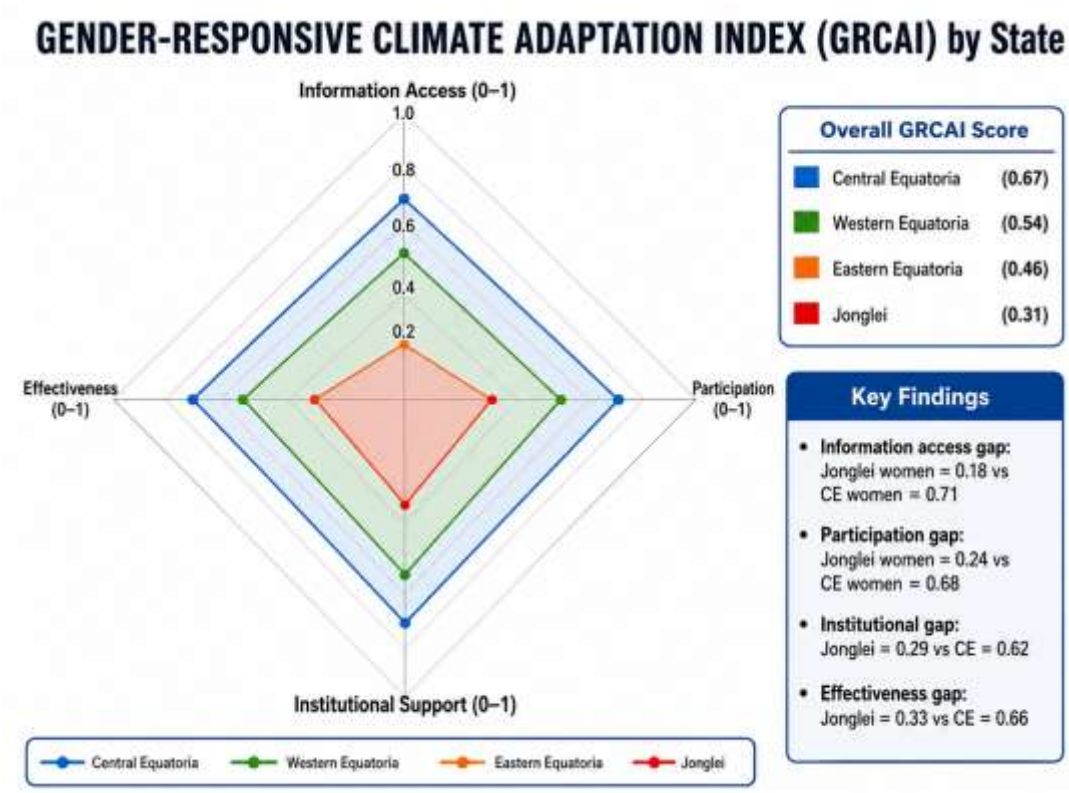
Our group started with fifteen women contributing 500 SSP each week. Now we are forty-two. When the drought came in 2022, we used our collective savings to buy seeds from Uganda at wholesale prices. Individually, none of us could afford the transport to the border. Together, we hired a truck. The men laughed at firstthey said women cannot do business. Now they come to us for loans. Our group has changed how the community sees women. We are not just farmers; we are traders, decision-makers, and leaders.

However, the study also identifies important limitations of community-based adaptation. In Jonglei, the sheer scale of flooding has overwhelmed local adaptive capacity. As one key informant from an international NGO observed: Community-based adaptation works when the shocks are manageable. But when three years of unprecedented flooding submerge entire counties, no amount of crop diversification or savings groups can compensate. At that point, adaptation becomes survival, and survival depends on external assistance. This observation underscores the complementarityrather than substitutabilityof community-based and externally-supported adaptation interventions, particularly in the context of extreme climate events that exceed local coping thresholds ((Koubi et al., 2022)).

4.5 Gender-Responsive Climate Adaptation Index and Policy Framework (Objective 5)

The Gender-Responsive Climate Adaptation Index (GRCAI), constructed through principal component analysis, reveals substantial variation in the gender-responsiveness of climate adaptation across the four states. Central Equatoria records the highest GRCAI score (0.67), reflecting relatively better performance on information access, participation, institutional support, and adaptation effectiveness. Western Equatoria follows at 0.54, Eastern Equatoria at 0.46, and Jonglei at 0.31. The low GRCAI score in Jonglei is particularly concerning given that this state also records the highest CVI score, creating a 'double vulnerability' scenario where women face both the highest climate exposure and the least gender-responsive adaptation support.

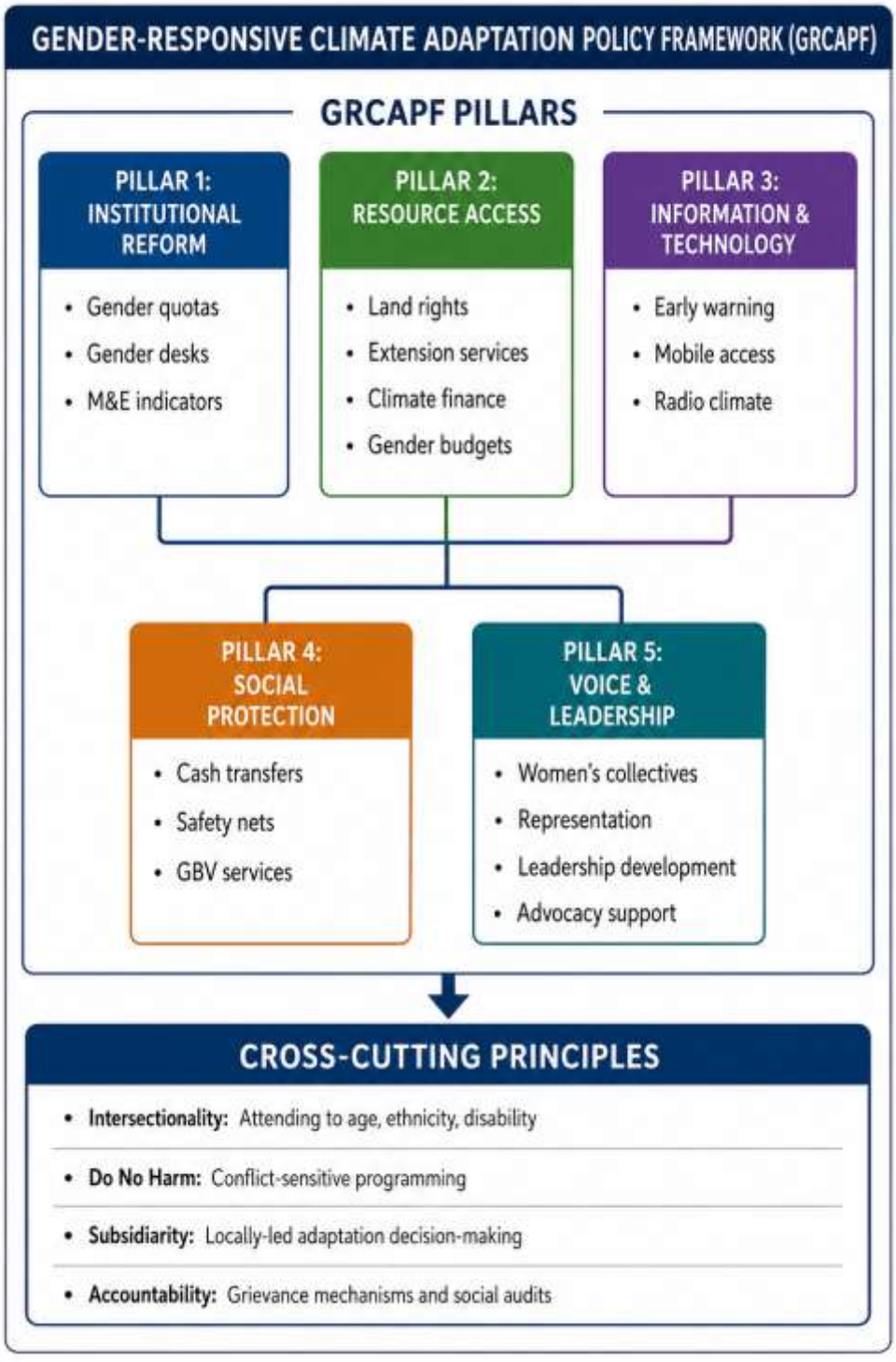
Figure: GRCAI Spider/Radar Chart Comparing Four Dimensions Across States



Building on the empirical findings, this study proposes a Gender-Responsive Climate Adaptation Policy Framework (GRCAPF) structured around five pillars: ((Adhikari & Woznicki, 2015)) Institutional Reformmandating gender quotas in climate adaptation planning bodies, establishing gender desks within ministries of agriculture and environment, and integrating gender indicators into monitoring and evaluation systems; ((Aker, 2011)) Resource Accessformalising women's land rights within customary and statutory frameworks, establishing women-targeted agricultural extension programmes, and expanding women's access to climate finance through gender-responsive budgeting; ((Alston, 2014)) Information and Technologydeploying women-led early warning systems that leverage local knowledge, closing the mobile phone gender gap through targeted distribution and literacy programmes, and developing radio-based climate information services in local languages; ((Arora-Jonsson, 2011)) Social Protectionestablishing climate-contingent cash transfer programmes targeting female-headed households, scaling up productive safety nets that build

rather than erode assets, and integrating gender-based violence response services into climate displacement camps; and ((Balehey & Balehegn, 2018)) Voice and Leadershipsupporting women's collective organisations, ensuring women's representation in climate finance governance mechanisms (e.g., Green Climate Fund national designated authorities), and investing in women's leadership development for climate advocacy.

Figure: Gender-Responsive Climate Adaptation Policy Framework (GRCAPF)



5. Discussion

The findings of this multi-state analysis contribute to several strands of scholarly and policy discourse on gender, climate change, and livelihoods in fragile states. First, the study provides robust empirical evidence for the 'gendered vulnerability thesis' advanced by feminist political ecology scholars ((Raghuram et al., 1998); (Clment et al., 2019); (Pozo et

al., 2019)). The CVI scores, which are 2841% higher for women than comparable estimates for men, confirm that climate vulnerability is not an aggregate household attribute but a fundamentally gendered phenomenon. However, the findings also caution against a narrative of women as passive victims. The diversity and ingenuity of women's adaptation strategiesfrom collective savings groups to wetland cultivation to NTFP harvestingdemonstrate significant adaptive agency, consistent with the 'agency-in-vulnerability' thesis advanced by (Arora-Jonsson, 2011) and (OECD et al., 2021).

Second, the study advances the theoretical integration of the Sustainable Livelihoods Framework with feminist political ecology. The empirical results demonstrate that the five livelihood capitals (human, social, natural, physical, and financial) are not neutral categories equally accessible to all; rather, they are deeply gendered in their distribution, accessibility, and returns. The finding that women's social capitaloperationalised through group membershipis positively associated with adaptation strategy adoption but that this effect is attenuated in high-conflict settings illustrates the contingent nature of livelihood assets. Social capital, often romanticised in development discourse as a universally accessible 'asset of the poor' ((Bebbington, 1999)), is revealed here as fragile and context-dependent, susceptible to erosion by the same conflict dynamics that heighten women's vulnerability in the first place.

Third, the GRCAI developed in this study represents a methodological contribution to the measurement of gender-responsiveness in climate adaptation. While several composite indices exist for measuring climate vulnerability (e.g., ND-GAIN, CVI) and gender inequality (e.g., GII, GDI), few integrate these dimensions into a single, policy-actionable metric. The GRCAI's four-component structure (information, participation, institutions, effectiveness) aligns with the (Calvin et al., 2023) emphasis on 'enabling conditions' for adaptation and provides a replicable framework for monitoring progress toward gender-transformative adaptation in other fragile and conflict-affected contexts. The wide variation in GRCAI scores across the four states (0.310.67) underscores the importance of sub-national analysis: national-level indices would mask the acute adaptation deficits in Jonglei and Eastern Equatoria that the present study reveals.

Fourth, the findings speak directly to the debate on community-based adaptation (CBA) versus externally-driven adaptation in fragile states. The evidence that women's CBA strategies are effective for moderate climate shocks but insufficient for extreme events aligns with the concept of 'adaptation limits' articulated by (Dow & Shaw, 2013) and reconfirmed by (Mechler & Revi, 2020). In Jonglei, where three consecutive years of unprecedented flooding have transformed the physical landscape, the erosion of natural capital (land, water resources, forests) has pushed many households beyond the threshold where autonomous adaptation is feasible. This finding reinforces the case for layered adaptation architectures in which community-based strategies are complemented by government-led infrastructure (e.g., flood defences, raised roads) and internationally-supported social protection systems, as advocated by the UNFCCC's Warsaw International Mechanism for Loss and Damage ((McNamara & Jackson, 2019); (Serdeczny & Chan, 2023)).

Finally, the study's policy framework (GRCAPF) contributes to the operationalisation of gender-transformative adaptationa concept that has gained traction in international climate policy discourse ((Fritz et al., 2023)) but remains inadequately specified at the programme level. The five-pillar structure of the GRCAPF provides a comprehensive yet adaptable template that can be tailored to specific state contexts within South Sudan and analogous fragile settings. Crucially, the framework's emphasis on intersectionality, conflict sensitivity, subsidiarity, and accountability distinguishes it from technocratic adaptation frameworks that neglect the political economy and power relations that determine who benefits from adaptation investments ((Eriksen & West, 2021); (Hariram et al., 2023)).

6. Conclusion and Recommendations

This multi-state analysis of climate change, women's livelihoods, and adaptation strategies in South Sudan yields four principal conclusions. First, climate change is not a uniform stressor but a highly differentiated phenomenon that interacts with pre-existing gender inequalities, conflict dynamics, and institutional deficits to produce starkly divergent livelihood outcomes for women across Central Equatoria, Western Equatoria, Jonglei, and Eastern Equatoria. Second, women are active agents of adaptation who deploy diverse and often innovative strategies, yet their adaptive capacity is systematically constrained by gendered access to resources, information, and decision-making authority. Third, the effectiveness of adaptation strategies is contingent on the broader institutional and conflict environment, with extreme climate events in conflict-affected areas pushing households beyond the limits of autonomous adaptation. Fourth, a gender-transformative approach to climate adaptationone that moves beyond 'gender-sensitive' rhetoric to fundamentally redress the structural inequalities that produce gendered vulnerabilityis both a moral imperative and a pragmatic necessity for building sustainable resilience in South Sudan.

Based on these conclusions, the study offers the following recommendations for policy and practice:

National Government of South Sudan:

Integrate the GRCAI into the monitoring framework of South Sudan's National Adaptation Programme of Action (NAPA) and require annual gender-disaggregated reporting on adaptation outcomes.

Amend the Land (Loughnan, 2009) to explicitly recognise women's equal rights to land ownership, inheritance, and use, with implementing regulations that specify enforcement mechanisms within customary and statutory systems.

Establish a dedicated Climate and Gender Directorate within the Ministry of Environment and Forestry with a mandate to coordinate gender-responsive adaptation across line ministries.

Allocate a minimum of 15% of national climate finance (including Green Climate Fund readiness funds) to women-led adaptation initiatives, with transparent tracking and public reporting.

State Governments (Central Equatoria, Western Equatoria, Jonglei, Eastern Equatoria):

Conduct state-level gender audits of agricultural extension services and implement corrective action plans to achieve parity in women's access to extension within five years.

Support the formalisation of women's collective savings groups through simplified registration procedures, access to wholesale input markets, and linkages with formal financial institutions.

Integrate climate-resilient infrastructure (raised roads, flood shelters, community granaries) into state development plans, prioritising areas with high concentrations of female-headed households.

International Development Partners and Donors:

Condition climate adaptation funding on the inclusion of gender-transformative components with measurable indicators, moving beyond 'gender-sensitive' labelling.

Invest in long-term (minimum five-year) women's leadership and organisational development programmes rather than short-term training workshops with limited sustained impact.

Support the expansion of mobile phone coverage and women-targeted digital literacy programmes, recognising mobile connectivity as foundational infrastructure for climate information access.

Fund rigorous impact evaluations of gender-responsive adaptation interventions in fragile states to build the currently thin evidence base on what works, for whom, and under what conditions.

Civil Society and Women's Organisations:

Strengthen the capacity of women's organisations to engage with climate policy processes at local, state, and national levels through technical training and core funding.

Document and disseminate women's indigenous and local knowledge of climate adaptation to counter the marginalisation of this knowledge in formal adaptation planning.

Establish a South Sudan Women's Climate Network to facilitate peer learning, collective advocacy, and coordination among women's groups across the four states.

Research Community:

Conduct longitudinal panel studies to track the evolution of women's climate vulnerability and adaptation over time, moving beyond the cross-sectional snapshot provided by this study.

Undertake comparative multi-country analyses of gender-responsive adaptation in other fragile and conflict-affected states to identify generalisable principles and context-specific variations.

Investigate the intersection of climate adaptation, gender-based violence, and mental healtha nexus that emerged in qualitative data but was beyond the scope of the present study.

In conclusion, this study affirms that addressing climate change in South Sudan is inseparable from addressing gender inequality. The nation's climate crisis is also a crisis of women's rights, livelihoods, and voice. The path toward climate-resilient development in South Sudan must therefore be a path toward gender justiceone that recognises women not merely as beneficiaries of adaptation programmes but as leaders, knowledge-holders, and architects of their own resilience. The evidence presented in this study demonstrates that such a path is not only ethically imperative but also empirically warranted: where women have access to resources, information, and decision-making authority, adaptation outcomes improve for entire communities. The challenge now lies in mustering the political will, institutional capacity, and financial resources to make gender-transformative adaptation a lived reality for the women of South Sudan.

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Data Availability: The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

Author Contribution: Elia Lona James is the sole author and is responsible for all aspects of the study including conceptualisation, methodology, data collection, analysis, and writing.

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