



Climate-Conflict Nexus in Somalia: Multi-Sectoral Adaptation Pathways for Building Long-term Resilience

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Abstract

Somalia serves as a paradigmatic case of the climate-conflict-fragility nexus, wherein intersecting environmental and socio-political pressures engender cascading vulnerabilities across interconnected systems. Despite extensive documentation of climate impacts in fragile states, there remains limited systematic analysis regarding multisectoral adaptation pathways in conflict-affected environments such as Somalia. This review synthesizes climate projections, sectoral impacts, and adaptation responses to delineate evidence-based resilience strategies pertinent to the climate-conflict nexus in Somalia. We conducted systematic analysis of climate modeling outputs, adaptation interventions, and policy frameworks from 2010 to 2024, integrating CORDEX-Africa projections with empirical evidence from community-based and institutional adaptation initiatives. Climate projections forecast temperature increases of 1.4–2.1°C by 2040, with extreme heat days rising from 20–30 to 90–120 annually, while drought frequency shifts from 5–7 year to 2–3-year return periods. Agricultural yields are projected to decline by 15–30%, water resources by 20–35%, and 5.2 million individuals face displacement risk by 2050. Nevertheless, promising adaptation pathways are emerging: community-led rainwater harvesting benefits 80,000 rural Somalis annually, climate-smart agriculture enhances sorghum yields by 15–20%, and Somalia's National Adaptation Plan aims to mobilize \$2.1 billion by 2030. Our analysis indicates that effective adaptation in Somalia necessitates integrated approaches that amalgamate community knowledge with technological innovation and coordinated policy frameworks addressing both climate vulnerabilities and conflict dynamics. These findings offer actionable insights for policymakers formulating climate adaptation strategies in fragile and conflict-affected states globally.

Keywords: Climate change, Adaptation strategies, Socioeconomic vulnerability, Mitigation

1. Introduction

Somalia's climate crisis represents one of the most acute examples of how environmental degradation, geopolitical instability, and socioeconomic vulnerability intersect and exacerbate humanitarian disasters. Ranked as the second-most climate-vulnerable country globally (Interactive Country Fiches, n.d.), Somalia faces escalating threats from rising temperatures, erratic rainfall, and prolonged droughts, all of which are compounded by decades of conflict and weak governance. The country's mean annual temperature has increased by 1–1.5°C since 1991 (RCCC, 2024), with projections suggesting further rises of 3.2–4.3°C by 2100 under high-emission scenarios (Interactive Country Fiches, n.d.; RCCC, 2024). These changes are

destabilizing agro-pastoral systems that sustain 70% of the population, while recurrent floods and droughts are displacing hundreds of thousands annually (International Crisis Group, n.d.).

The interplay between climate change and conflict creates a vicious cycle. Al-Shabaab, the Islamist insurgency controlling rural areas, exploits water scarcity to levy taxes and punish communities that resist their authority, thereby deepening resource-based grievances (International Crisis Group, n.d.). Conversely, climate-induced displacement has fueled urban overcrowding and competition for dwindling resources, thus straining the federal government's capacity to deliver basic services (International Crisis Group, n.d.). Agricultural production critical for food security has suffered disproportionately: rising temperatures have reduced long-term yields of staple crops such as sorghum and beans, while unpredictable rainfall disrupts planting cycles (Abdi, Okash, et al., 2024; Samatar, 2024b). Despite these challenges, some studies have indicated that strategic adaptations, such as climate-resilient crop varieties and expanded irrigation, could mitigate losses (Abdi, Okash, et al., 2024; FAO, n.d.).

International interventions, such as the FAO-led Ugbaad project, aim to restore 41,800 ha of degraded land and build resilience among 2.1 million Somalis (FAO, n.d.). However, the efficacy of such programs hinges on addressing systemic issues, such as corruption, infrastructure gaps, and Al-Shabaab's territorial control (International Crisis Group, n.d.). Meanwhile, pastoralist communities, the backbone of Somalia's rural economy, are adopting localized strategies, including migration to greener pastures and the diversification of livestock herds, although these measures are increasingly strained by shrinking grazing lands (RCCC, 2024; Samatar, 2024a).

The urgency of Somalia's climate crisis demands a re-evaluation of traditional response frameworks. Current policies often prioritize immediate humanitarian relief over long-term adaptation, leaving the underlying vulnerabilities unaddressed (Ahmed et al., 2024; International Crisis Group, n.d.). The objective of this review is to critically examine the multifaceted impacts of climate change in Somalia across environmental, agricultural, socioeconomic, and health dimensions while evaluating current and emerging adaptation strategies at the community, national, and institutional levels. By synthesizing recent climate projections, policy developments, and empirical findings, this study aims to provide integrated context-specific responses that can build long-term resilience (Abdi, Mohamed, et al., 2024; International Crisis Group, n.d.).

2. Climate Change Projections for Somalia

Climate projections for Somalia rely heavily on global and regional modeling frameworks developed by the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports. The Coordinated Regional Climate Downscaling Experiment (CORDEX), a cornerstone initiative for regional climate modeling, provides high-resolution projections tailored to Africa's climatic diversity (CORDEX, n.d.; Diez-Sierra et al., 2022). CORDEX-Africa simulations, which downscale global climate models (GCMs) to resolutions of 50 km or finer, are particularly critical for Somalia because of their complex topographies and localized weather patterns (CORDEX, n.d.; Tegegne et al., 2021). These regional climate models (RCMs) incorporate dynamic processes such as monsoon dynamics, Indian Ocean Dipole variability, and land-atmosphere interactions, which are underrepresented in coarser GCMs (Ogega et al., 2020; Tegegne et al., 2021).

The IPCC's Sixth Assessment Report (AR6) integrates CORDEX-Africa data to project climate outcomes under Shared Socioeconomic Pathways (SSPs), with SSP2-4.5 (moderate emissions) and SSP5-8.5 (high emissions) being the most relevant to Somalia (Diez-Sierra et al., 2022; Fenech, 2015). Models, such as the Rossby Center Regional Atmospheric Model (RCA4) and the Regional Model (REMO), have been extensively validated over the Horn of Africa, demonstrating the ability to replicate observed temperature trends and seasonal rainfall

variability (Das et al., 2022; Tegegne et al., 2021). For instance, REMO simulations capture the bimodal rainfall pattern (Gu and Deyr seasons) critical to Somalia's agro-pastoral systems, albeit with systematic biases in representing the convective rainfall intensity (Ogega et al., 2020; Tegegne et al., 2021).

Recent advancements in ensemble modeling, such as the C3S CORDEX grand ensemble, provide probabilistic projections by combining multiple RCMs and GCMs, thereby reducing uncertainties in extreme event quantification (Diez-Sierra et al., 2022). This approach is vital for Somalia, where interannual climate variability dominates trends. For example, the C3S ensemble projects a 90% likelihood that annual mean temperatures will rise by 1.5–2.5°C by 2040 under SSP2-4.5, with higher warming in inland arid zones (Das et al., 2022; Diez-Sierra et al., 2022).

Somalia's mean annual temperature has increased by 1.1°C since 1980, exceeding the global land-average warming rate of 0.8°C (Fenech, 2015; Hulme, 1994). Model ensembles project additional warming of 1.4–2.1°C by 2040 and 2.8–4.3°C by 2100 under SSP5-8.5, with nocturnal temperatures rising faster than diurnal ones (Das et al., 2022; Diez-Sierra et al., 2022). This asymmetry exacerbates heat stress in livestock and humans, particularly in the northern pastoral regions, where nighttime cooling is essential for recovery (Arnell, 2003; Tegegne et al., 2021). The number of extreme heat days ($\geq 35^{\circ}\text{C}$) is projected to increase from 20 to 30 days/year (1995–2014 baseline) to 90–120 days/year by 2060, rendering parts of the Sool and Sanaag plateaus uninhabitable during the dry seasons (Das et al., 2022; Fenech, 2015). Despite overall warming, rainfall projections remain divergent owing to competing influences from the Indian Ocean Dipole (IOD) and Intertropical Convergence Zone (ITCZ) shifts. CORDEX-Africa models suggest a 10–20% decline in annual rainfall over southern Somalia by 2040, concentrated in the Deyr (October–December) season (Ogega et al., 2020; Tegegne et al., 2021). Conversely, the Gu (April–June) rains may intensify by 15–25% in the Jubba and Shabelle River basins, increasing flood risks (Arnell, 2003; Tegegne et al., 2021). This dipole pattern reflects the strengthening of zonal moisture gradients, with enhanced convection over the Ethiopian Highlands diverting rainfall away from the Somali coastal regions (Das et al., 2022; Ogega et al., 2020).

Extreme precipitation events, defined as daily rainfall exceeding 50 mm, are projected to increase in frequency by 40–70% across central Somalia by 2050, even in scenarios where mean rainfall decreases (Tegegne et al., 2021). These intensification trends are linked to thermodynamic increases in atmospheric moisture content (Clausius-Clapeyron scaling) and dynamic changes in mesoscale convective systems (Arnell, 2003; Ogega et al., 2020). For instance, REMO simulations show a 30% increase in the magnitude of 1-in-20-year rainfall events in the Hiraan region by 2040, which is sufficient to overwhelm flood defenses in Beledweyne (Tegegne et al., 2021; Wang et al., 2022).

The concurrence of droughts and heatwaves is projected to increase threefold by 2050, with 5–10-year return periods for events comparable to the 2016–2017 drought (Arnell, 2003; Diez-Sierra et al., 2022). Simultaneously, flash floods following prolonged dry spells challenge soil water infiltration capacity, particularly in the degraded rangelands of Galmudug and Puntland (Arnell, 2003; Das et al., 2022). The CMIP6 models indicate a 50% increase in the probability of consecutive failed rainy seasons by 2040, threatening the recovery of groundwater aquifers and pasturelands (Diez-Sierra et al., 2022; Fenech, 2015).

Somalia's drought vulnerability stems from its dependence on rain-fed agriculture (60% of GDP) and depleted groundwater reserves. Under SSP5-8.5, meteorological droughts (Standardized Precipitation Index ≤ -2.0) are projected to occur every two to three years by 2040, from five to seven years in the 20th century (Arnell, 2003; Fenech, 2015). Hydrological droughts, measured by soil moisture deficits, persist 20–30% longer due to increased evapotranspiration from warming (Arnell, 2003; Das et al., 2022). The 2080–2100 period may

see "megadroughts" lasting 8–12 years, comparable to the 1974–1984 Sahel drought but with higher temperatures amplifying ecological impacts (Diez-Sierra et al., 2022; Fenech, 2015). Increased rainfall intensity exacerbates flash flooding in urban centers such as Mogadishu and Kismayo, where impervious surfaces cover >35% of the land area (Arnell, 2003; Wang et al., 2022). The 100-year flood discharge of the Shabelle River is projected to increase from 1,200 m³/s to 1,800 m³/s by 2050, threatening 340,000 hectares of farmland (Arnell, 2003; Tegegne et al., 2021). Coastal flooding from tropical cyclones, which is historically rare in Somalia, may also increase as warming Indian Ocean temperatures ($\geq 28^{\circ}\text{C}$) expand the breeding ground for cyclones east of Socotra (Fenech, 2015; Ogega et al., 2020). The 2020 Cyclone Gati, which dumped 128 mm of rain on Bosaso in two days, offers a precedent for such events (Wang et al., 2022).

3. Projected Future Impacts of Climate Change in Somalia

Climate change is projected to severely destabilize Somalia's agricultural systems, which sustain over 70% of the population. By 2040, staple crops such as sorghum and maize are expected to face yield reductions of 15–30% owing to rising temperatures exceeding optimal growing thresholds ($30\text{--}35^{\circ}\text{C}$) and erratic rainfall patterns (Abdi, Okash, et al., 2024). The autoregressive distributed lag (ARDL) model predicts that each 1°C temperature increase reduces long-term sorghum yields by 12%, whereas bean production declines by 9% per 10% reduction in Deyr-season rainfall (Abdi, Okash, et al., 2024). Conversely, short-term warming may boost rice yields by 8–10% in irrigated areas, although these gains will be offset by prolonged droughts and soil moisture deficits after 2030 (Abdi, Okash, et al., 2024). Pastoralism, which contributes 40% of Somalia's GDP, faces existential risks: forage availability in northern rangelands is projected to decrease by 45% by 2050 due to aridification, forcing herders to adopt drought-resistant livestock breeds, such as the Somali goat, which can survive 7–10 days without water (Samatar, 2024a; World Bank, n.d.-b). However, even resilient species face mounting heat stress, with livestock mortality rates predicted to increase by 25–40% during recurrent droughts (Samatar, 2024a). Compounding these challenges, fish stocks in the Somali Current upwelling zone, a critical protein source, may decline by 30% owing to ocean warming and overfishing (Ibrahim et al., 2025).

Somalia's water scarcity crisis intensifies as climate change amplifies hydrological volatility. By 2040, the Jubba and Shabelle River basins are projected to experience a 20–35% reduction in dry-season flows, jeopardizing irrigation for 1.2 million hectares of farmland (World Bank, n.d.-b). Conversely, extreme rainfall events during the Gu season may increase flood volumes by 40–60%, overwhelming flood defenses in Beledweyne and Jowhar (Said, 2023; Said et al., 2023). Groundwater recharge rates, already diminished by deforestation, are expected to decline by 15–25% in central Somalia, exacerbating conflicts over 90% of the nation's drinking water sourced from aquifers (Said, 2023; Said et al., 2023). Coastal regions face parallel threats: sea-level rise of 0.5–0.7 m by 2100 will salinize 18% of Somalia's freshwater lenses, displacing 500,000 people in the Lower Shabelle and Benadir regions (Samatar, 2024a; World Bank, n.d.-b). Urban centers such as Mogadishu, where per capita water availability has plummeted to 15 liters/day (vs. the WHO's 50-liter minimum), will see inequities deepen as private vendors exploit shortages, pricing 60% of households out of access to clean water (Said, 2023; Said et al., 2023).

The health consequences of Somalia's climate trajectory will be catastrophic. By 2030, childhood stunting rates already at 31% could surpass 40%, as recurrent droughts reduce dietary diversity, particularly in protein-rich foods such as meat and legumes (Ibrahim et al., 2025). Heat-related morbidity will surge, with wet-bulb temperatures exceeding 35°C (the human survivability threshold) for 45–60 days annually in the northern pastoral zones by 2050 (Samatar, 2024a; World Bank, n.d.-b). These conditions will overwhelm Somalia's limited

healthcare infrastructure, which currently has just 0.3 physicians per 10,000 people. Vector-borne diseases are also poised to expand; malaria incidence in riverine areas may rise by 50% as floods create stagnant water pools, while cholera outbreaks could affect 500,000 people annually by 2040 (Said et al., 2023; World Bank, n.d.-b). Mental health crises, particularly PTSD and depression, among climate-displaced populations are projected to affect 30% of adults in drought-prone regions, triple the 2025 baseline (Said et al., 2023; Samatar, 2024a).

Ecosystem collapse looms as a defining feature of Somalia's future climate. The 2025–2040 period may witness the extinction of 17% of endemic species, including the critically endangered Somali wild ass and 65% of acacia-commiphora woodlands, owing to habitat fragmentation and aridification (Samatar, 2024a; World Bank, n.d.-b). Coastal ecosystems face parallel threats: seagrass meadows, which sequester 10% of Somalia's carbon emissions, are projected to decline by 40–60% as ocean acidification (pH drop of 0.3–0.4) disrupts calcification processes (Ibrahim et al., 2025; World Bank, n.d.-b). The 2020 Cyclone Gati precedent suggests that intensified tropical storms could degrade 12,000 ha of mangrove forest, a critical nursery for fish stocks, by 2040 (Samatar, 2024a; World Bank, n.d.-b). Soil erosion, already costing Somalia \$1.2 billion annually in lost productivity, may accelerate by 30% as heavy rains strip 50 tons/ha/year of topsoil from deforested slopes (Said, 2023; World Bank, n.d.-b). These cascading ecological failures threaten the release of 4.5 gigatons of stored carbon, equivalent to 8% of global annual emissions, further fueling climate feedback loops (Ibrahim et al., 2025).

Climate change will exacerbate Somalia's fragility, displacing 5.2 million people by 2050 (Figure 1), and exacerbating resource conflicts. Projections indicate that 70% of southern farming households will experience moderate-to-severe livelihood losses by 2035, forcing 2.4 million into urban informal settlements where unemployment exceeds 80% (Said, 2023; Said et al., 2023). Pastoralist clans already engaged in 120 annual conflicts over water and grazing lands may see that violence escalates by 40% as drought reduces viable rangelands to 35% of their 2000 extent (Samatar, 2024a; World Bank, n.d.-b). Women and children bear disproportionate burdens: girls' school enrollment in flood-prone regions may drop by 25% as families prioritize water collection, while gender-based violence rates could rise by 60% in displacement camps (Said, 2023; Said et al., 2023). Economically, climate damage may shave 14% (\$3.8 billion) of Somalia's GDP by 2040, with the agricultural sector contracting by 22% (Abdi, Okash, et al., 2024; World Bank, n.d.-b). Without multilateral intervention, these pressures risk entrenching Somalia's poverty rate at 70% by 2100, cementing its status as a climate sacrifice zone (Ibrahim et al., 2025).

Projected Climate Change Impacts in Somalia

Source: IPCC, CORDEX, REMO, RCA4, C3S, FAO 2023–2025

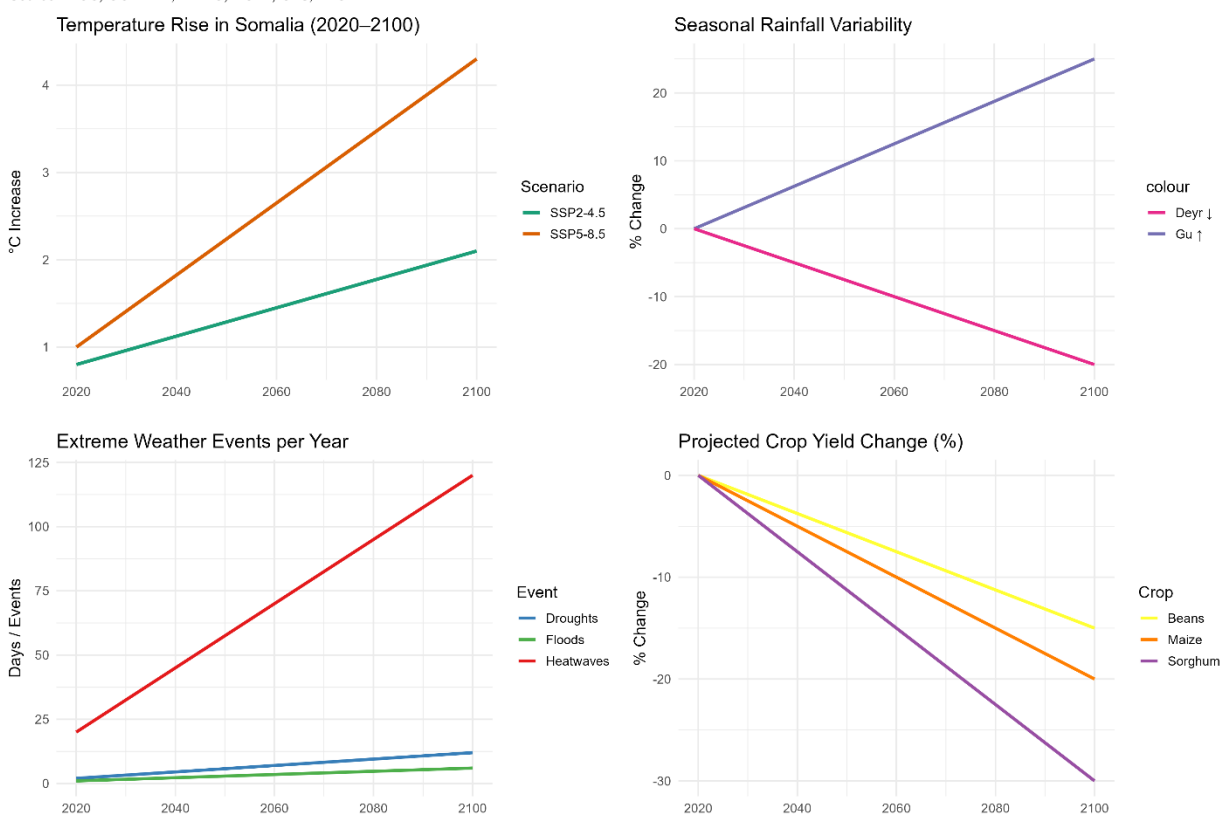


Figure 1. Projected climate change impacts in Somalia

4. Future Adaptation and Mitigation Strategies

4.1 Potential Community-Based and National-Level Adaptation Options

Community-led adaptation strategies are critical for Somalia's resilience, particularly in agro-pastoral regions, where localized knowledge intersects with environmental pressures. At the grassroots level, rainwater harvesting systems, such as the Biyoole Water Harvesting Project, have demonstrated efficacy in mitigating water scarcity, capturing nearly 1 million cubic meters annually to sustain 80,000 rural Somalis and 180,000 livestock during the dry season (Hydro Nova, n.d.). These systems, which include subsurface dams and sand dams, are complemented by afforestation initiatives that restore degraded watersheds and stabilize soil moisture (Ubeid, 2023). Pastoralist communities in Galmudug and Somaliland are increasingly diversifying livestock herds toward drought-resistant species, such as Somali goats, which can survive for 7–10 days without water, while adopting mobility strategies to track greener pastures (Yonis Abdullahi et al., 2022). At the national level, Somalia's National Adaptation Plan (NAP) Framework (2022) prioritizes the integration of climate resilience into development agendas, targeting the restoration of 41,800 ha of degraded land and mobilizing \$2.1 billion for adaptation by 2030 (NAP Global Network, 2022). However, the success of these measures hinges on vertical coordination between federal and state governments to align localized practices with broader policies, such as the National Climate Change Policy (2020), which mandates climate-proofing infrastructure and expands social safety networks (Bezabih, 2022; ICE, n.d.).

Technological innovation is reshaping Somalia's adaptive landscape, particularly in the agricultural and energy sectors. Climate-smart agriculture (CSA) practices, including drought-resistant crop varieties and agroforestry, have increased sorghum yields by 15–20% in pilot regions such as Jubaland, while reducing irrigation demand by 30% through precision water

management (Ibrahim et al., 2025; WardheerNews, n.d.). The Somalia Electricity Sector Recovery Project (SESRP) exemplifies the potential of renewable energy, leveraging solar photovoltaic systems to power 1.1 million households and 380 schools, although current renewable contributions remain at 12.2% of the total energy production (Africa Renewal, n.d.). Water harvesting technologies, such as haffir dams and burkads, are being scaled using drone surveys and geospatial analytics to optimize site selection and ensure climate-proof designs that can withstand prolonged droughts (Hydro Nova, n.d.). Despite these advances, adoption barriers persist: only 35% of farmers access CSA training, and solar infrastructure faces efficiency losses of 20–25% due to dust accumulation and inadequate maintenance (Ubeid, 2023). Overcoming these limitations requires hybridizing traditional knowledge with modern engineering, as seen in the integration of Heerkad (traditional grazing management) with satellite-based pasture monitoring systems (NAP Global Network, 2022; Yonis Abdullahi et al., 2022).

4.2 Integrating Climate Change into National Planning

Somalia's policy framework must institutionalize climate adaptation across sectors to address systemic vulnerabilities. The NAP Framework advocates embedding climate resilience into the National Development Plan (2020–2024), mandating environmental impact assessments for all infrastructure projects, and establishing a \$50 million Climate Change Fund to finance localized initiatives (ICE, n.d.; NAP Global Network, 2022). Legal reforms, such as the proposed Climate Change Management Act, aim to reduce emissions in the livestock and energy sectors, contributing 65% and 12% of national greenhouse gases, respectively (Bezabih, 2022; Planetary Security Initiative, n.d.). Cross-border collaboration with Ethiopia and Kenya is essential to manage shared river basins, as evidenced by the 2023 agreement to jointly monitor the flow of the Shabelle River and reduce flood risks for 340,000 downstream farmers (Ali et al., 2023). Urban planning policies in Mogadishu now require green building standards and flood-resistant drainage systems, although enforcement remains inconsistent owing to capacity gaps (NAP Global Network, 2022). Strengthening the Directorate of Environment and Climate Change (DoECC) with technical staff and digital monitoring tools could enhance compliance, particularly in regions under al-Shabaab's influence, where 40% of adaptation projects stall because of insecurity (NAP Global Network, 2022; Planetary Security Initiative, n.d.). Key policy recommendations are summarised in Table 1.

Table 1. Policy Recommendations

Solution	Description	References
Subsurface dams	Construction of underground barriers lined with HDPE sheets to enhance shallow aquifer recharge. Proven to increase water availability for 80,000 people and livestock in Hargeisa.	(Lopez-Rey Simon, 2019; Terre Solidali Onlus, n.d.)
Sand dam implementation	Low-cost rainwater harvesting structures that trap sediment and moisture in seasonal riverbeds. Field studies in Somaliland show 30% increased water access for pastoral communities during droughts.	(Lopez-Rey Simon, 2019; Terre Solidali Onlus, n.d.)
GIS-based RWH site selection	Using geospatial analysis (slope, rainfall, soil) to identify optimal rainwater harvesting locations. Trials in semi-arid regions classified about 24% of the stream network as having good suitability for water-harvesting ponds.	(Sun et al., 2023)

Early warning systems	Integrated meteorological monitoring through myDEWETRA platform, providing 72-hour flood/drought alerts. Pilots reduced disaster response times by 40% in flood-prone regions.	(CIMA Research Foundation, n.d.)
Solar energy expansion	55 MW Mogadishu solar plant and decentralized PV systems for irrigation pumps. SESRP project aims for 35% renewable energy penetration by 2030, displacing diesel dependency in 1.1 million households.	(World Bank, n.d.-a)
Climate-smart agriculture	Drought-resistant sorghum varieties and intercropping systems increasing yields by 15-20%. UNDP/FAO programs trained 12,000 farmers in Jubaland on water-efficient practices.	(FAO, n.d.)
NAP Framework implementation	National Adaptation Plan integrating climate resilience into development policies. Targets \$2.1 billion investment by 2030 for landscape restoration and institutional capacity building through DoECC.	(FAO, n.d.; NAP Global Network, 2022)

5. Conclusion

Somalia stands at the nexus of climate vulnerability, conflict, and underdevelopment, facing an increasingly perilous future, as rising temperatures, erratic rainfall, and intensifying extreme weather events threaten its ecological and socioeconomic stability. The country's dependence on climate-sensitive sectors, such as agriculture and pastoralism, amplifies the impacts of climate change, while institutional fragility and insecurity hinder effective adaptation. Projections indicate worsening trends in food insecurity, water scarcity, public health, and displacement, underscoring the urgency to embed climate resilience into national development, governance, and security strategies. While promising community-based and technological adaptation initiatives are emerging from rainwater harvesting and drought-resistant crops to early warning systems, their scalability depends on resolving structural barriers, such as funding gaps, limited institutional capacity, and territorial insecurity. Without coordinated, multi-sectoral interventions that bridge local knowledge with scientific innovation and policy reform, Somalia risks becoming a permanent climate crisis hotspot with far-reaching regional consequences.

Ethics Considerations

Approval from the Ethics Committee was not required.

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Conflicts of Interest

The author declares there is no conflict of interests.

Data Availability Statement

Data sharing is not applicable to this article, as no datasets were generated or analyzed during the current study.

Clinical Trial Number

Not applicable

Consent to Publish

Not applicable

Consent to Participate

This study did not involve the direct participation of human subjects, interviews, or clinical interventions requiring informed consent. Therefore, consent to participate is not applicable. All data used in the study were obtained from publicly available sources or published reports.

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