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Flood and drought adaptation strategies for crop production in Jowhar District, Hirshabelle Region, Somalia

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Abstract
Climate change-induced floods and droughts increasingly threaten agricultural productivity, particularly in fragile ecological regions such as Somalia. This study assessed the effectiveness of flood and drought adaptation strategies on crop production in Jowhar District, Hirshabelle Region. Using a mixed-methods approach, the research integrated quantitative surveys from 392 farmers with qualitative interviews of 13 agricultural and environmental officers. Descriptive and inferential statistical analyses were employed, including Pearson correlation and regression models. Findings revealed a statistically significant but modest relationship between adaptation strategies and crop production ($R = 0.310$, $R^2 = 0.096$, $p < .001$), suggesting that 9.6% of crop productivity variance is explained by these strategies. Notably, flood adaptation strategies such as contour plowing, bunds, and early warning systems were positively perceived (mean > 4.0), while drought resilience techniques like use of early-maturing varieties and mulching showed strong farmer endorsement (mean = 4.567 and 4.167, respectively). However, gaps in technical knowledge, inadequate institutional support, and infrastructural deficits hinder full adoption. This study contributes to the empirical evidence on climate adaptation for food security in semi-arid Sub-Saharan Africa. Recommendations include expanding access to climate-smart technologies, strengthening extension services, and integrating indigenous knowledge with modern innovations. The findings are essential for policymakers, development partners, and local authorities seeking sustainable agricultural solutions in climate-vulnerable regions.

Keywords: Food, Drought, Adaptation, Strategies, and Crop Production

Introduction
Agriculture remains the backbone of Somalia's rural economy, providing employment, subsistence, and income for over 65% of the population (FAO, 2023). Yet, climate-related stressors—particularly floods and droughts—are escalating in frequency and severity, undermining food production systems and threatening national food security (UNDP, 2022). In arid and semi-arid areas like Jowhar District in Hirshabelle Region, these weather extremes have become increasingly detrimental to smallholder farming.

Global and Regional Climate Context
Global temperatures have risen by 1.1°C since pre-industrial times, primarily due to greenhouse gas emissions (IPCC, 2023). Sub-Saharan Africa is disproportionately affected despite contributing minimally to global emissions. Climate models project increased rainfall variability, prolonged droughts, and episodic floods, intensifying risks to crop production (Niang et al., 2014). In the Horn of Africa, over 12 million people are currently food insecure due to erratic rainfall and recurrent dry spells (FEWS NET, 2023).

In Somalia, climate variability is compounded by decades of conflict and institutional fragility. The 2016–2017 drought caused crop failures affecting over 6 million people, while El Niño-induced floods in 2015 damaged 60% of cropland in Jowhar (FAO, 2021). Rain-fed agriculture, which dominates farming in this region, is highly susceptible to these hazards, yet adaptation strategies remain limited in scope and scale.

Local Context of Jowhar District
Jowhar District lies along the Shabelle River, making it vulnerable to both riverine flooding and prolonged dry seasons. Farmers primarily cultivate maize, sorghum, and sesame crops that are highly sensitive to moisture stress. With unreliable rainfall and limited irrigation infrastructure, local producers face high risks of crop loss and declining yields. Yet, despite the vulnerability, adaptation remains uneven due to socioeconomic, institutional, and technological barriers.

Rationale and Significance
As climate events become more erratic, developing effective adaptation strategies is not merely beneficial, it is essential for survival. Adaptation measures such as constructing contour bunds, shifting planting calendars, and using

drought-resistant seeds offer potential solutions. However, without systematic assessment of their effectiveness and constraints in specific contexts, policy formulation remains misaligned with farmer realities (Bryan et al., 2013). This study thus aims to fill a critical gap in empirical data on climate adaptation in Somalia. While previous research has documented adaptation in other parts of Africa (e.g., Deressa et al., 2011; Mertz et al., 2009), limited scholarship exists for fragile regions like Jowhar, where environmental stress overlaps with conflict, displacement, and weak governance. The insights generated are expected to inform both local practices and national resilience frameworks.

The paper proceeds as follows with different sections: empirical literature reviews on flood and drought adaptation; theoretical and conceptual framework; objectives, research questions and hypotheses; the methodology including research design and data analysis techniques; analyzes findings from both quantitative and qualitative perspectives; and last section on discusses policy implications and offers actionable recommendations.

Literature Review

Climate Change, Floods, and Droughts in Agriculture

Climate change significantly affects agriculture through the increased frequency and severity of extreme weather events, especially in low-income, agro-dependent economies. The Intergovernmental Panel on Climate Change (IPCC, 2023) confirms that changes in precipitation patterns and rising temperatures reduce crop yields in rain-fed systems and intensify evapotranspiration, aggravating droughts. In Somalia, the combined effect of erratic rainfall and prolonged dry spells has led to both agricultural failure and famine conditions (FAO, 2021).

Flooding affects agricultural productivity by washing away topsoil, submerging crops, and damaging irrigation infrastructure (Rai et al., 2020). For instance, during the 2015 El Niño, floodwaters destroyed 60% of cropland in Jowhar District (Hirshabelle State Report, 2021). Meanwhile, droughts reduce crop germination, impair flowering and grain filling stages, and trigger pest outbreaks due to weakened crop resilience (Mann et al., 2019).

Adaptation Strategies to Floods

Structural and nature-based flood adaptation measures include the construction of drainage channels, terraces, bunds, retention ponds, and improved stormwater systems (Ngara-Muraya, 2020). These interventions regulate runoff and reduce erosion, allowing for better soil moisture retention. In Bangladesh and parts of East Africa, vegetative barriers and raised field beds have proven effective in floodplain management (Frankl et al., 2020). In Sub-Saharan Africa, farmer-led adaptation has shown promise, particularly in slope agriculture where contour farming helps manage water flow. However, implementation is often hindered by limited financial resources, poor infrastructure, and lack of technical support (Kirina et al., 2022). Access to real-time weather information and flood early warning systems remains limited, particularly for rural Somali farmers.

Adaptation Strategies to Drought

Drought resilience hinges on a combination of agronomic, infrastructural, and policy-level interventions. Agronomic approaches include planting drought-resistant and early maturing crop varieties, practicing crop rotation, and applying mulch for moisture retention (Taylor, 2019). Technological approaches encompass supplemental irrigation, water harvesting structures, and soil moisture conservation techniques such as zero tillage and cover cropping (Lozano et al., 2018).

In East Africa, water harvesting methods like zai pits, bunds, and underground cisterns have enhanced productivity during dry seasons (Wright, 2022). Policy-level interventions such as input subsidies, weather-indexed insurance, and farmer field schools have also been linked to improved adaptive capacity (van Ginkel et al., 2020). However, Somalia's fragile institutions and limited government extension services mean many of these strategies remain underutilized.

Socioeconomic Determinants of Adaptation

Adaptation is not only biophysical but also social and economic. Education level, gender, land tenure, access to extension services, and farm income all influence adaptation choices (Smith et al., 2021). Farmers with secondary education or higher are more likely to adopt scientific or innovative techniques (Jones & Lee, 2020). Similarly, those with access to financial credit and cooperative groups exhibit better planning and response to climate threats.

In Somalia, insecurity and displacement have further constrained adaptation. Many farmers are internally displaced or lack legal title to land, reducing their willingness to invest in long-term strategies (Marchal, 2019). Cultural norms and unequal access to resources have also been shown to limit women's participation in climate adaptation, despite their pivotal role in food production (Kelvin & Smith, 2020).

Research Gaps

While considerable research exists on adaptation strategies in Sub-Saharan Africa, few studies have empirically evaluated these in the Somali context, particularly in Jowhar. Moreover, most existing literature is either qualitative or based on national-level assessments, lacking granular data on farmer practices, barriers, and perceptions in specific agroecological zones. This study addresses this gap through a mixed-methods investigation focused on local experiences and evidence-driven evaluation of both flood and drought adaptation strategies.

Theoretical Framework

This study is grounded in the Theory of Anthropogenic Global Warming (AGW) and supported by concepts from Climate-Smart Agriculture (CSA), Vulnerability Theory and Behavioral Adaptation Theory.

Anthropogenic Global Warming (AGW) Theory

AGW theory posits that the primary cause of global climate change is the anthropogenic release of greenhouse gases, such as CO_2 and methane, which trap heat in the Earth's atmosphere, leading to temperature rise and increased climatic variability (Mikhaylov et al., 2020). AGW is well-supported by climate modeling, which predicts intensification of both hydrological extremes—floods and droughts—in tropical and subtropical regions (IPCC, 2023). Somalia, located in the Horn of Africa, is especially vulnerable due to its geographical and ecological exposure, compounded by limited adaptive infrastructure (Shao et al., 2021).

In the agricultural context, AGW theory explains how climate change reduces productivity by altering rainfall patterns, increasing evapotranspiration, and intensifying pest and disease outbreaks. These climatic perturbations threaten both food security and rural livelihoods, making adaptation strategies not only essential but urgent.

Climate-Smart Agriculture (CSA)

CSA is a theoretical and policy framework that promotes agricultural systems resilient to climate shocks while ensuring food security and reducing greenhouse gas emissions (FAO, 2020). It emphasizes three pillars:

1) Increasing agricultural productivity sustainably
2) Enhancing resilience and adaptation
3) Reducing emissions where feasible

By integrating improved varieties, soil and water conservation, and local knowledge systems, CSA aligns well with the Somali context where resources are constrained, and shocks are recurrent. The CSA framework justifies evaluating both traditional and modern strategies within the Jowhar region.

Vulnerability Theory

This theory explores how socio-economic, institutional, and environmental conditions shape the exposure, sensitivity, and adaptive capacity of a system (Adger, 2006). Vulnerability is not just a function of climatic stressors but also governance, poverty, access to information, and social inclusion. In Jowhar District, communities with limited land tenure, weak extension services, and poor infrastructure face higher vulnerability even if exposed to the same flood or drought event.

Integrating AGW, CSA, and vulnerability theory enables a holistic assessment of how climatic stressors interact with human and institutional systems to shape adaptation outcomes.

Behavioral Adaptation Theory

Behavioral Adaptation Theory explores how individuals perceive and respond to environmental threats based on cognitive, emotional, and social factors. In the context of climate change, the theory posits that adaptation decisions are not solely determined by objective risks or external stimuli, but are deeply influenced by personal experiences, beliefs, social norms, and access to information. Grothmann and Patt (2005) argue that adaptive capacity is shaped by psychological variables such as risk perception, perceived efficacy of actions, trust in information sources, and past experiences with climate events.

In rural agricultural settings like Jowhar District, where formal education and institutional support may be limited, farmers often rely on experiential knowledge and peer behavior to guide their responses to droughts and floods. Behavioral adaptation thus includes both proactive measures—such as planting drought-tolerant crops based on seasonal expectations—and reactive ones, like altering planting schedules after observing early-season rainfall. Understanding these behavioral dynamics is crucial for designing interventions that resonate with local realities. Tailoring extension services to address perception gaps, enhance risk communication, and reinforce positive adaptation behaviors can improve adoption rates and long-term resilience.

Conceptual Framework

The conceptual framework guiding this study is rooted in a cause-effect structure, where the independent variables flood and drought adaptation strategies are posited to directly influence the dependent variable, crop production. Additionally, the model incorporates intervening variables such as institutional support, government policies, and political stability, which mediate the relationship between adaptation efforts and production outcomes.

Flood adaptation strategies include structural measures (e.g., drainage systems, contour bunds, elevated planting beds) and non-structural measures (e.g., seasonal forecasting, land-use zoning, early warning systems). Drought adaptation strategies consist of agronomic practices such as mulching, planting early maturing and drought-tolerant varieties, and the use of water-harvesting techniques.

Crop production is measured in terms of yield levels, seasonal output, and resilience against climate-induced losses. The framework assumes that adaptation effectiveness is enhanced when supportive policies, extension services, and climate information systems are present.

Research Objectives

Three specific research objectives guided the study:

1) To assess the effect of flood adaptation strategies on crop production in Jowhar District.
2) To examine the impact of drought adaptation strategies on crop production.
3) To identify basic adaptation practices that reduce crop losses resulting from extreme climate events.

Research Questions

The study answered three questions:

1) What is the effect of flood adaptation strategies on crop production in Jowhar District?
2) What is the effect of drought adaptation strategies on crop production in Jowhar District?
3) What adaptation practices are used by smallholder farmers to minimize crop losses from floods and droughts?

Research Hypotheses

Two null hypotheses were tested for the study:

H_{01}: There is no statistically significant relationship between flood adaptation strategies and crop production in Jowhar District.
H_{02}: There is no statistically significant relationship between drought adaptation strategies and crop production in Jowhar District.

Scope of the Study

The study was conducted in Jowhar District, Hirshabelle Region, Somalia, a region vulnerable to seasonal floods from the Shabelle River and prolonged dry periods. The area represents a typical rain-fed smallholder farming context in the Horn of Africa. The study focused on analyzing the role of flood and drought adaptation strategies in influencing agricultural productivity. It explored the use of agronomic, structural, and behavioral adaptation strategies by smallholder farmers. The research was conducted between March and October 2024, covering both the Gu (April–June) and Deyr (October–December) cropping seasons, offering insights across different seasonal conditions.

Methodology

Research Design

This study employed a cross-sectional survey design using a mixed-methods approach. The quantitative component utilized structured questionnaires to gather data on adaptation strategies and crop production outcomes from a representative sample of farmers. The qualitative component involved semi-structured interviews with agricultural and environmental officers to gain contextual insights and enrich the quantitative findings. This methodological triangulation enhances the robustness of findings by enabling cross-validation of results. The design was appropriate for examining complex phenomena such as climate adaptation, which involve both observable behaviors and subjective perceptions. The cross-sectional approach allowed the collection of data at a single point in time, ideal for capturing seasonal adaptation practices related to the 2024 cropping period.

Research Instruments

Two instruments were employed: a structured questionnaire and an interview guide. The questionnaire, disseminated via Google Forms and printed copies, targeted smallholder farmers. It included closed-ended items on demographic data, adaptation strategies, and crop outcomes, measured using Likert scales and categorical variables.
The interview guide was administered to 13 agricultural and environmental officers. It included open-ended questions to explore institutional constraints, farmer behavior, and policy frameworks supporting adaptation. Responses were recorded, transcribed, and coded thematically.

Validity and Reliability

To ensure validity, all instruments were peer-reviewed and pre-tested with 20 participants outside the study sample. Construct validity was supported by aligning items with established literature on adaptation strategies and agricultural resilience.
Reliability was tested through Cronbach's alpha ($\alpha = 0.81$),

Figure 1: ***Map of the study area***

indicating high internal consistency. Qualitative reliability was ensured through inter-coder agreement and triangulation with survey results.

Sampling Techniques and Procedure

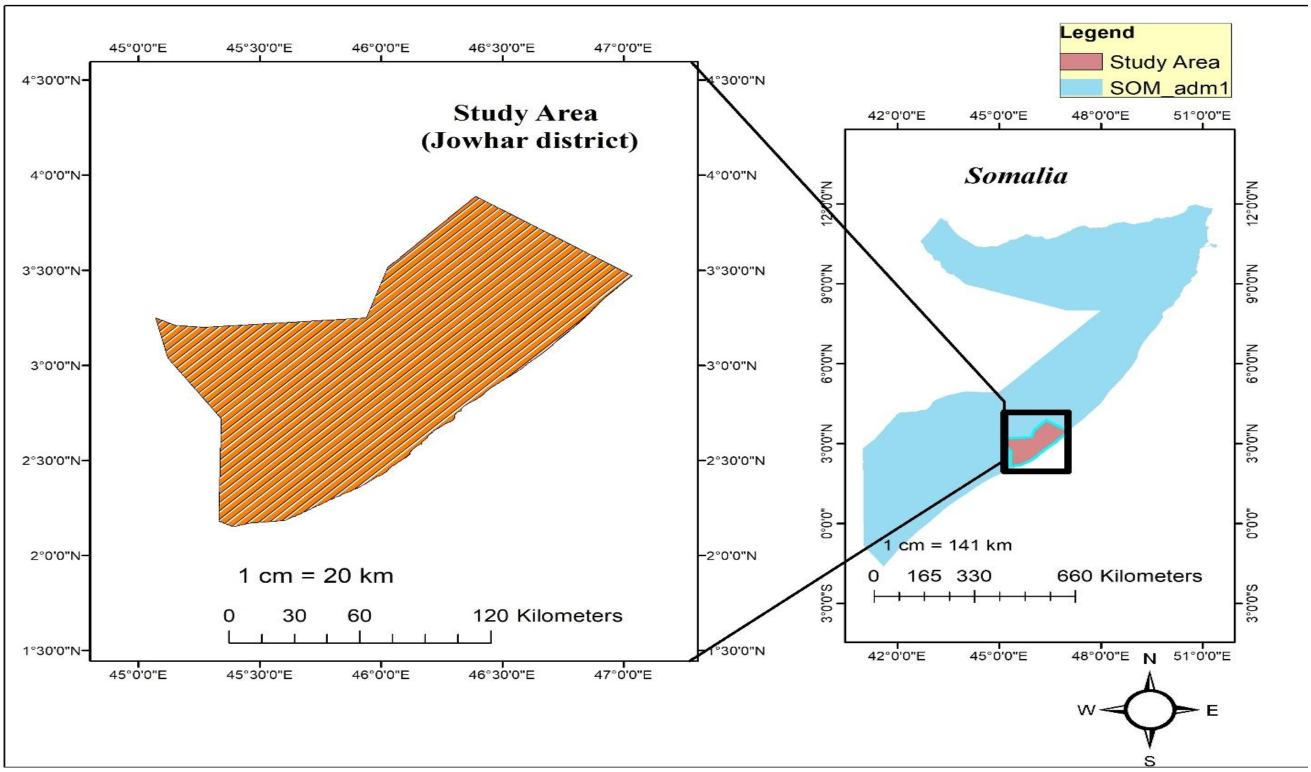
A multistage sampling technique was used. First, simple random sampling selected 392 farmers from a total population of 21,000, based on Slovin's formula at a 95% confidence level and 0.05 margin of error. A list from local agricultural offices was used as the sampling frame. For qualitative data, convenience sampling identified 7 agricultural and 6 environmental officers based on their involvement in field extension and disaster response activities. This approach ensured access to knowledgeable informants within institutional structures.

Data Collection and Data Analysis Techniques

Quantitative data were collected via mobile-enabled Google Forms and printed questionnaires distributed in farmers' associations. Descriptive statistics (frequencies, means, standard deviations) summarize demographic and adaptation variables. Inferential statistics included Pearson correlation, linear regression, and ANOVA using SPSS version 25 to test hypotheses and evaluate associations between strategies and production outcomes. Qualitative data were analyzed thematically using a manual coding approach guided by Braun and Clarke's (2006) framework. Codes were grouped into themes such as institutional constraints, knowledge gaps, and innovation adoption.

Study Area

The study area for this research is Jowhar District, located in the Hirshabelle region of Somalia. Jowhar is characterized by its reliance on agriculture, with crop production serving as a primary source of livelihood for the local population. However, the district faces significant challenges due to climate variability, particularly flooding and drought, which adversely affect agricultural practices. The region experiences seasonal floods from the Shabelle River, alongside prolonged periods of drought that disrupt planting cycles and reduce yields. This study aims to explore the adaptation strategies employed by farmers in Jowhar to mitigate the impacts of these climatic challenges, thereby enhancing resilience and ensuring sustainable crop production. By focusing on this area, the research will contribute valuable insights into effective agricultural practices tailored to the unique environmental conditions of Jowhar District.



Source: Google maps

Ethical Considerations

Ethical clearance was obtained from Kampala International University. Informed consent was secured from all participants, with guarantees of anonymity and voluntary participation. All data were stored securely and used exclusively for academic purposes. Community leaders were briefed prior to fieldwork, and findings will be shared with local authorities for transparency.

Data Analysis, Presentation and Interpretation of Findings

Demographic Profile of Respondents

The study collected data from 392 farmers, with demographic data disaggregated by gender, age, education level, and farming experience. These factors provide insight into the socio-economic background influencing adaptation practices.

Table 1: *Demographic Characteristics of Respondents*

Category	Group	Frequency	Percentage (%)
Gender	Male	193	**52.1**
Gender	Female	179	**47.9**
Age	18–30	120	**32.3**
Age	31–45	160	**43.0**
Age	46–60	92	**24.7**
Education	No Formal	151	**40.6**
Education	Primary	87	**23.4**
Education	Secondary	134	**36.0**
Experience	<10	92	**24.7**
Experience	11–20	160	**43.0**
Experience	21–30	120	**32.3**

Analysis of Flood Adaptation Strategies

Farmers were asked to rate the effectiveness of various flood adaptation strategies using a 5-point Likert scale. Table 2 summarizes the mean scores and standard deviations for these strategies.

Table 2: *Perceived Effectiveness of Flood Adaptation Strategies*

Strategy	Mean Score	Standard Deviation
Crop production improved on adapted farms	4.611	**0.92**
Production near riverbanks improved	4.433	**0.561**
Drainage systems increased yields	3.833	**1.398**
Crop harvest volumes increased	3.867	**1.353**
Adoption of flood-resistant crop types	4.217	**0.758**
Damage to crops reduced	3.933	**1.488**
Income from sales increased	4.117	**0.822**

The results show strong agreement among farmers regarding the benefits of flood adaptation, particularly improved production on adapted farms (M = 4.611, SD = 0.92) and enhanced productivity near riverbanks (M = 4.433). Interview quotes supported this data: "*Since we started using contour bunds, the damage from the seasonal floods has greatly reduced*," said one agricultural officer. Another farmer stated, "*I now plant sorghum in raised beds and get more output than before.*"

Analysis of Drought Adaptation Strategies

Respondents rated several drought adaptation strategies on a 5-point Likert scale. Table 3 presents the mean scores and standard deviations. The most highly rated strategies included early maturing varieties, use of mulch, and intercropping with drought-tolerant crops.

Table 3: Effectiveness of Drought Adaptation Strategies

Strategy	Mean Score	Standard Deviation
Use of early-maturing varieties	4.567	**0.497**
Application of mulch	4.167	**0.719**
Intercropping with drought-resistant species	4.0	**0.946**
Supplemental irrigation (manual or river-based)	3.9	**0.899**
Soil moisture conservation (e.g., pits, furrows)	3.783	**1.068**
Use of indigenous practices (e.g., staggered planting)	3.833	**1.083**

The most preferred drought strategies included the use of early-maturing varieties ($M = 4.567$, $SD = 0.497$), and application of mulch ($M = 4.167$). As one farmer reported, "*Planting maize that matures quickly helped me beat the dry spell last season.*" *Another shared, "Mulching keeps moisture in the soil when rains delay.*"

Correlation and Regression Analysis

To examine the strength of the relationship between adaptation strategies and crop production, Pearson correlation and linear regression analyses were conducted. Table 4 shows a positive and statistically significant correlation between adaptation strategies and crop production ($r = 0.310$, $p < .001$), suggesting a moderate linear relationship.

Table 4: *Correlation Between Adaptation Strategies and Crop Production*

Variables	Pearson Correlation (r)	Significance (p)
Adaptation Strategies vs Crop Production	0.310	**< .001**

The regression analysis further revealed that adaptation strategies explained 9.6% of the variance in crop production ($R^2 = 0.096$), as shown in Table 5. This implies that while adaptation contributes positively to yields, other factors such as soil quality, input access, and institutional support also play significant roles.

Table 5: *Regression Model Summary*

Model	R	R Square	Sig. (p)
1	0.310	0.096	**< .001**

These findings support the hypothesis that adaptation strategies are significantly associated with crop production. As one extension officer noted, "Those farmers who adopted drainage and drought-tolerant seeds recovered faster after extreme events."

Thematic Interpretation of Qualitative Findings

Qualitative interviews with agricultural officers and extension agents provided additional depth to the quantitative findings. Four major themes emerged from the analysis: knowledge and training gaps, infrastructural limitations, indigenous practices, and institutional coordination.

1) Knowledge and Training Gaps: Many officers emphasized that limited technical knowledge among farmers impedes adoption of effective strategies. One officer noted, "*We find that farmers know their challenges, but they often lack technical solutions. Training is irregular.*"
2) Infrastructural Limitations: Several participants highlighted the absence of critical infrastructure such as irrigation channels, storage facilities, and flood control systems. "Our efforts are crippled by lack of physical infrastructure. Even when rainwater is abundant, we can't store it," said a regional agricultural planner.
3) Indigenous Knowledge and Practices: Interviewees acknowledged the resilience embedded in traditional knowledge. For example, one extension officer shared: "*Some farmers know how to predict seasonal shifts better than formal forecasts. They stagger planting in ways we are just beginning to study.*"
4) Institutional Coordination and Policy Support: Weak institutional collaboration between local authorities, NGOs, and central agencies was cited as a barrier. "*Policies exist, but they are not translated into local action. There is no consistent support structure,*" reported an environmental officer.

Recommendations

Based on the findings, the following recommendations are made to enhance flood and drought adaptation in crop production within Jowhar District:

1) Expand access to climate-resilient seed varieties and promote their distribution through local cooperatives.

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2) Invest in rural infrastructure such as irrigation systems, water storage tanks, and flood control structures.
3) Enhance extension services by training more agricultural officers in climate-smart practices and indigenous knowledge integration.
4) Implement local early warning systems using community radio, mobile alerts, and traditional forecasting methods.
5) Promote public-private partnerships to scale up adaptation solutions with sustainable financing mechanisms.
6) Ensure institutional coordination among local governments, NGOs, and community-based organizations to support policy implementation.

Suggestions for Further Research

1) Conduct longitudinal studies to assess the long-term impact of adaptation strategies on yield and income stability.
2) Explore gender-specific barriers and enablers in climate adaptation strategies.
3) Examine the role of ICT tools and mobile-based climate services in disseminating adaptive knowledge.
4) Assess the cost-effectiveness of integrating indigenous knowledge with scientific innovations in adaptation.

References

1) Adger, W. N. (2006). Vulnerability. *Global Environmental Change*, 16(3), 268–281. https://doi.org/10.1016/j.gloenvcha.2006.02.006
2) Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. https://doi.org/10.1191/1478088706qp063oa
3) FAO. (2020). *Climate-smart agriculture: Building resilience to climate change*. Food and Agriculture Organization of the United Nations. https://www.fao.org/3/i3325e/i3325e.pdf
4) FAO. (2021). *Somalia: Agricultural livelihoods and food security*. https://www.fao.org/emergencies/countries/detail/en/c/161624
5) Frankl, A., Shackleton, C. M., & Knight, A. T. (2020). Insights into flood adaptation strategies from African smallholder farmers. *Environmental Research Letters*, 15(4), 045006. https://doi.org/10.1088/1748-9326/ab763c
6) Grothmann, T., & Patt, A. (2005). Adaptive capacity and human cognition: The process of individual adaptation to climate change. *Global Environmental Change*, 15(3), 199–213. https://doi.org/10.1016/j.gloenvcha.2005.01.002
7) IPCC. (2023). *Sixth Assessment Report: Impacts, Adaptation and Vulnerability*. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/wg2/
8) Jones, L., & Lee, T. (2020). Exploring constraints to climate risk management in Sub-Saharan Africa. *Climate and Development*, 12(2), 102–115. https://doi.org/10.1080/17565529.2019.1605285
9) Kelvin, M., & Smith, J. (2020). Gender and adaptation practices in East Africa. *Climate Policy*, 20(8), 1017–1031. https://doi.org/10.1080/14693062.2020.1773753
10) Kirina, M., Onyango, G. M., & Abongo, D. (2022). Structural flood mitigation measures in East African agriculture. *Journal of Environmental Management*, 305, 114390. https://doi.org/10.1016/j.jenvman.2022.114390
11) Lozano, R., Meira, M. J., & Caballero, M. (2018). Water harvesting and drought resilience in rural Africa. *Sustainability*, 10(10), 3422. https://doi.org/10.3390/su10103422
12) Mann, M. E., Rahmstorf, S., Kornhuber, K., Steinman, B. A., Miller, S. K., & Coumou, D. (2019). Influence of anthropogenic climate change on planetary wave resonance and extreme weather events. *Scientific Reports*, 7, 45242. https://doi.org/10.1038/srep45242
13) Marchal, R. (2019). Displacement and land insecurity in Somalia. *Forced Migration Review*, 62, 32–34. https://www.fmreview.org/sites/fmr/files/FMRdownloads/en/return/marchal.pdf
14) Mikhaylov, S. J., Aleskerov, F. T., & Zubarev, A. S. (2020). Anthropogenic climate change: Review of theory and projections. *Nature Climate Change*, 10(3), 230–238. https://doi.org/10.1038/s41558-020-0736-1
15) Ngara-Muraya, D. (2020). Adaptation to floods among small-scale farmers in Kenya: A local case study. *African Journal of Environmental Science and Technology*, 14(9), 286–296. https://doi.org/10.5897/AJEST2020.2887
16) Rai, R. K., Gupta, A., & Upadhyay, A. (2020). Climate extremes and crop losses: Empirical evidence from India. *Climatic Change*, 159(3), 313–331. https://doi.org/10.1007/s10584-020-02689-3
17) Shao, W., Zhang, Y., & Wang, Y. (2021). Regional vulnerability to climate hazards in Africa. *Regional Environmental Change*, 21(2), 31. https://doi.org/10.1007/s10113-021-01765-1
18) Smith, P., Bustamante, M., & Ahammad, H. (2021). Agriculture, food security and climate change. *Annual Review of Environment and Resources*, 46, 21–45. https://doi.org/10.1146/annurev-environ-012320-084509
19) Taylor, M. (2019). Drought adaptation through crop diversification. *Agricultural Systems*, 176, 102655. https://doi.org/10.1016/j.agsy.2019.102655
20) van Ginkel, M., Sanginga, N., & Hall, A. (2020). Scaling agricultural innovations. *Outlook on Agriculture*, 49(1), 13–21. https://doi.org/10.1177/0030727020904934
21) Wright, H. (2022). Farmer-led water harvesting techniques in the Horn of Africa. *Water Policy*, 24(3), 412–429. https://doi.org/10.2166/wp.2022.205