

Toward Climate-Resilient Agriculture in Somalia: A Review of Impacts, Challenges, and Adaptation Pathways

Mohamed Dahir Aden

Faculty of Agriculture, Benadir University, Mogadishu, Somalia

Email: Mdahir775@gmail.com

Abstract

Climate change is a defining threat to agricultural production and food security in Somalia, a country whose economy and rural livelihoods depend heavily on rain-fed cropping and pastoralism. This review synthesizes evidence published between 2010 and 2024 on the relationship between climate change and agricultural production in Somalia, drawing on a structured literature search of Google and Google Scholar that identified 177 candidate documents, of which 35 met the relevance criteria for narrative synthesis. The review addresses three objectives: evaluating the association between climate change and agricultural production, identifying gaps in knowledge, policy, and institutional capacity, and outlining pathways toward more climate-resilient agriculture. The synthesized evidence shows that rising temperatures and increasingly erratic rainfall have reduced yields of staple cereals such as maize and sorghum, with a one to two degree Celsius temperature rise associated with three to five percent lower cereal productivity in the studies reviewed, while findings on carbon dioxide fertilization effects remain contested. Livestock production is similarly exposed, with heat stress, pasture degradation, and disease risk threatening a sector that underpins nomadic pastoral livelihoods. Three structural gaps recur across the literature: an absence of agricultural climate risk provisions in national policy, limited institutional coordination capacity, and constrained access to climate data and early warning infrastructure. Addressing these gaps will require integrated policy development, strengthened meteorological and early warning services, wider adoption of climate-smart agricultural practices, and sustained investment in collaborative research capable of resolving the contested evidence identified in this review.

Keywords: Climate change; Agricultural production; Somalia; Adaptation; Food security; Horn of Africa

1. Introduction

Climate change poses growing risks to food production and security worldwide. According to assessments by the Intergovernmental Panel on Climate Change, crop yields have been negatively affected globally by increasing temperatures, changing precipitation patterns, and more frequent extreme weather events, and these impacts are projected to further reduce global crop production in the coming decades (Pörtner et al., 2022). The multifaceted effects of climate change on food systems manifest as crop losses, reduced yields, and fluctuating food prices, contributing to hunger, malnutrition, and food insecurity (Semeraro et al., 2023). As the Intergovernmental Panel on Climate Change emphasises, addressing the influence of climate change on agriculture and implementing adaptive measures are essential to global food security both now and in the future (Pörtner et al., 2022; Bedeke, 2023).

While climate impacts on agriculture are expected across the globe, Sub-Saharan Africa has been identified as an exceptionally vulnerable region in assessments of food security risk under climate change (Alasow et al., 2024c; Omotoso et al., 2023). Agricultural production constitutes roughly one third of gross domestic product across Sub-Saharan African nations (Erdaw, 2023), and with heavy reliance on smallholder rain-fed farming, crops and livestock are highly exposed to shifts in precipitation and rising temperatures (Omotoso et al., 2023). Countries across the Horn of Africa face acute sensitivity given existing water scarcity, governance challenges in adaptation planning, and limited resources to respond to further shocks (Krampe et al., 2020). Drought events in the region are becoming more frequent and intense as a result of rising temperatures and rainfall variability (Alasow et al., 2024b, 2024c), leading to significant damage to livestock, crop losses, and acute food security crises (Bedasa & Deksis, 2024; Seife, 2021). These changes are expected to have severe impacts on countries that rely on small-scale agricultural systems, particularly Ethiopia and Somalia (Demem, 2023).

Climate-related hazards in Somalia, such as increased drought frequency, have already led to livestock losses and substantially heightened food insecurity for farming communities in recent decades (Warsame et al., 2022). The impact of climate change on food security in the country has been significant, with changes in precipitation and temperature contributing to land degradation, water shortages, and the degradation of crops and livestock (Omar et al., 2024; Rady et al., 2025). Somalia has also experienced prolonged civil conflict, weak rule of law, and limited institutional capacity, which have compounded poverty and constrained service delivery (Abdirizak, 2022). These factors interact to heighten the vulnerability of Somalia's food supply and agricultural livelihoods, deepening the threats of food insecurity, asset loss, and livelihood deterioration (Omer, 2024).

Despite the importance of understanding how climate change affects agricultural production in Somalia, a clear gap remains in the literature. Somalia experiences frequent droughts and extreme weather, yet the effects of these events on the country's agricultural sector are not comprehensively synthesised in one place. This review addresses that gap by examining the relationship between climate change and agricultural production in Somalia, identifying shortfalls in current understanding, policy, and institutional capacity, and outlining directions for future research and practice that can assist policymakers, planners, and stakeholders in strengthening the climate resilience and productivity of Somalia's agricultural system. The review pursues three objectives: to evaluate the association between climate change and agricultural production in Somalia, to identify gaps in knowledge, policy, and institutions relevant to climate change and agriculture, and to outline a way forward for climate-resilient agricultural production in Somalia.

2. Study Area

Somalia, located in the Horn of Africa (Figure 1), is characterised by an arid and semi-arid climate with limited and erratic rainfall. The country's geographical position makes it highly susceptible to the adverse effects of climate change, including rising temperatures, prolonged droughts, and unpredictable rainfall (Alasow et al., 2024d). Somalia's economy is predominantly agrarian, with agriculture contributing significantly to gross domestic product and employing a large share of the population, and the agricultural sector is primarily rain-fed, making it highly vulnerable to climate variability and extreme weather events (Mohamed et al., 2024). The country spans several agro-ecological zones, including a coastal zone, a central plateau, and northern highlands, each with distinct climatic conditions and agricultural practices; the coastal zone is influenced by the Indian Ocean and experiences relatively higher humidity and rainfall, while the central plateau and northern highlands are more arid and prone

to drought (Boitt et al., 2018). These varying conditions across regions complicate the agricultural landscape, as farmers and pastoralists must adapt to localised climate impacts.

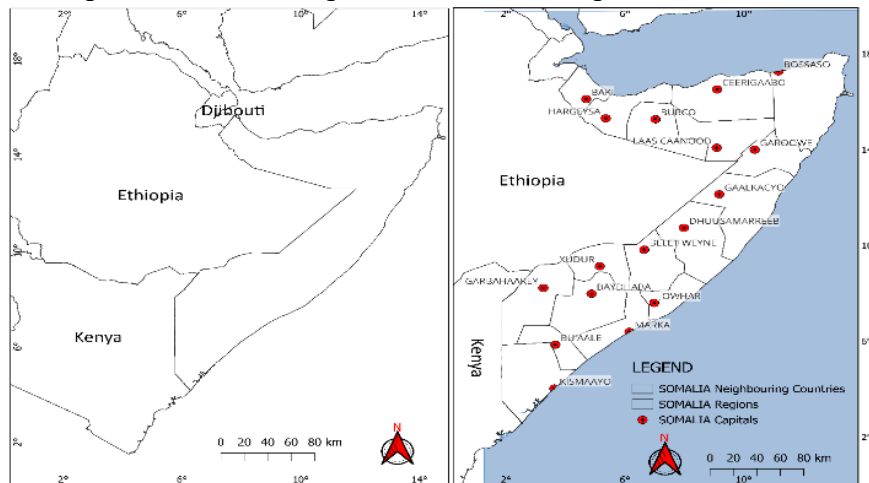


Figure 1. Location of Somalia within the Horn of Africa and its administrative regions.

Somalia's agricultural production is dominated by staple crops such as maize, sorghum, and other cereals, which are essential for food security, while nomadic pastoralism remains a critical component of the agricultural sector and a source of livelihood for a significant share of the population (Mohamed, 2022). Both crop production and livestock farming are under severe threat from climate change: rising temperatures and changing rainfall patterns have led to reduced crop yields, degraded pastures, and increased livestock mortality (Hassan et al., 2014). Prolonged civil unrest, weak governance, and limited institutional capacity have further compounded the challenges posed by climate change, and the lack of effective policies and coordination mechanisms for climate adaptation and mitigation has left many communities vulnerable to climate-induced shocks (Gure, 2021; Pape & Wollburg, 2019). Limited access to climate data, early warning systems, and technological resources has further hindered the ability of farmers and pastoralists to adapt to changing conditions (Citaristi, 2022; Tesfay, 2024). Somalia's geographical and climatic conditions, combined with its socio-economic challenges, make it a critical case study for understanding the impacts of climate change on agricultural production, and its heavy reliance on rain-fed agriculture and pastoralism underscores the urgent need for comprehensive climate adaptation strategies to safeguard food security and rural livelihoods (Omer, 2024).

Somalia's diverse agroecological zones significantly influence agricultural practices across the country (Omar et al., 2024). The coastal zone, with its higher humidity and rainfall influenced by the Indian Ocean, primarily supports rain-fed farming of crops such as maize and sesame, alongside small-scale fishing communities (Mohamed et al., 2024). The central plateau, characterised by semi-arid conditions, is predominantly used for pastoral activities and drought-resistant crop varieties such as sorghum (Mohamed, 2022). The northern highlands, despite their aridity, provide crucial seasonal grazing land for nomadic pastoralists and support limited cereal cultivation where rainfall is adequate (Hassan et al., 2014). Each zone faces distinct climate change challenges: coastal areas are vulnerable to flooding and saltwater intrusion, the central regions experience intensifying drought cycles that disrupt pastoral movements, and the highlands face increased soil erosion and reduced water availability for traditional farming practices (Alasow et al., 2024a).

3. Materials and Methods

This review used document analysis and a structured assessment of relevant publications as its principal data collection method (Kusangaya et al., 2014). The review searched for published articles, books, book chapters, and institutional reports relating to climate variability, climate change, agricultural production, and climate impacts on agriculture between 2010 and 2024. Searches were conducted using Google and Google Scholar, focusing on literature concerning the Horn of Africa and Somalia specifically, with key search terms comprising climate change, climate variability, agricultural production, food security, Horn of Africa, and Somalia. The literature search was carried out between December 2023 and March 2024 and yielded 177 candidate documents. Following title and abstract screening, 142 records were excluded as irrelevant to the review's scope, duplicated, or failing to meet the inclusion criteria, leaving 35 documents that were assessed in full text and retained for synthesis (Figure 2). This review synthesises concepts and evidence on the effects of climate change and variability on agricultural production in the Horn of Africa and Somalia, and identifies knowledge, policy, and institutional gaps relevant to climate resilience and food security. Narrative synthesis was used to analyse the included studies, with figures and tables used to summarise and present the results. A small number of more recent publications were consulted during manuscript preparation to provide contextual background in the Introduction and Study Area sections; these were not part of the screened evidence base.

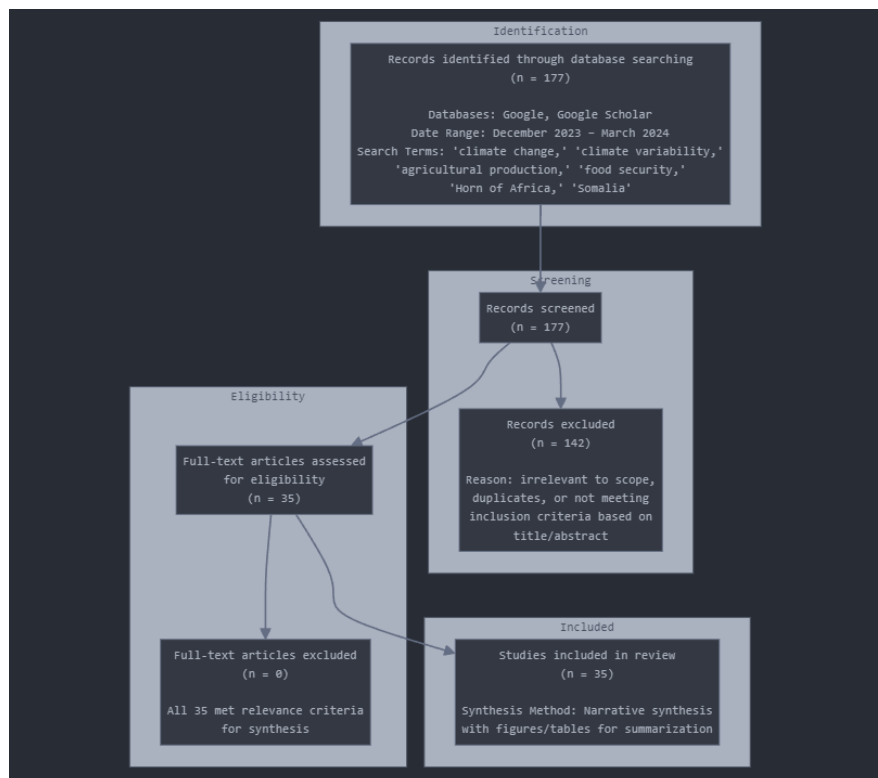


Figure 2. PRISMA-style flowchart of the literature identification, screening, and inclusion process.

4. Results and Discussion

4.1 The Impact of Climate Change on Crop Production in Somalia

Rising temperatures, declining and erratic rainfall, and an increased frequency of climate extremes such as droughts and floods have significantly reduced crop yields over the past few decades in Somalia (Ali et al., 2023; Said & Bashir, 2023; Warsame et al., 2021; Warsame, Sheik-Ali, Jama, et al., 2022). Key staple crops such as maize, sorghum, and other cereals have experienced substantial production declines; findings from multiple studies

suggest that a one to two degree Celsius temperature rise has been associated with three to five percent lower cereal crop productivity (Ali et al., 2023; Mohamed & Nageye, 2021; Warsame et al., 2021), while increased climate variability, including monthly rainfall fluctuations of 50 millimetres, has been linked to four to tenfold decreases in crop output in some localities (Thalheimer et al., 2023b).

While several studies demonstrate negative impacts of climate change on crop yields, findings regarding the effects of carbon dioxide emissions on agricultural production in Somalia are more contested. Warsame and Abdi (2023) found that carbon dioxide emissions positively influenced crop production in both the short and long term, potentially through carbon dioxide fertilisation effects on plant growth, whereas Ali et al. (2023) caution that these apparent benefits may be offset by the long-term negative effects of environmental degradation and rising temperatures. This complexity highlights the need for more nuanced research examining the interaction between different climate factors and their combined effects on agricultural systems, rather than treating emissions, temperature, and rainfall as independent influences.

Both the short-term and long-term impacts of warming temperatures are notable across the reviewed evidence. Higher temperatures have repeatedly been shown to negatively affect yields of staple cereals such as maize and sorghum in Somalia (Ali et al., 2023; Warsame et al., 2021; Warsame, Sheik-Ali, Jama, et al., 2022), likely operating through reduced water availability and soil moisture that increase crop water stress. The relationship between rainfall and crop production appears more nuanced: while most reviewed studies indicate that precipitation increases can support yield, excessive rainfall has also caused damaging floods that destroy existing farmland and crops (Said & Bashir, 2023; Warsame et al., 2021).

The decline in crop production documented across this literature has compounded existing food insecurity challenges. Recurrent droughts and prolonged dry seasons are considered the primary driver of hunger in Somalia (Said & Bashir, 2023; Thalheimer et al., 2023a), and climate change adds a further stress on top of this baseline vulnerability by diminishing crop yields directly. The situation is further exacerbated by unsustainable land use practices that degrade the quality of arable land available for cultivation (Mohamed & Nageye, 2021; Said & Bashir, 2023). With agriculture central to livelihoods and the broader Somali economy, the reviewed evidence points to an urgent need for investment and policy attention directed at climate adaptation and resilient crop production systems.

Adaptation measures such as expanding water storage infrastructure and irrigation access have been proposed in the literature but have not been implemented at scale, largely due to continued political instability (Boitt et al., 2018; Said & Bashir, 2023; Warsame et al., 2023b). The reviewed studies converge on the need for further research paired with global and local partnerships to mitigate environmental degradation and support farmers with climate-resilient solutions, given that Somalia's growing population depends on continued improvements in agricultural productivity for future food security. It is also notable that studies examining the association between climate factors such as carbon dioxide emissions and crop productivity report cross-sectional dependence and heterogeneity across Somali regions, indicating a need for specialised econometric modelling approaches rather than pooled national estimates (Abdi et al., 2023). Table 1 summarises the methods and key findings of the principal empirical studies reviewed on this topic.

Table 1. Summary of Reviewed Studies on Climate Change and Crop Production in Somalia

Study	Focus	Method	Key Finding
Said & Bashir (2023)	Climate change impacts on food security	Mixed methods; 80 participants; SPSS analysis	Precipitation and temperature changes drove water shortages,

Study	Focus	Method	Key Finding
			crop and livestock degradation, and food insecurity
Thalheimer et al. (2023b)	Weather and conflict effects on displacement	Two-way fixed effects panel regression, 2016-2018 displacement data	Extreme weather drives displacement, interacting with conflict dynamics
Warsame, Sheik-Ali, Jama et al. (2022)	Climate change, instability, and sorghum production	Cointegration analysis; FMOLS; Granger causality	Temperature and political instability reduce long-run sorghum production; rainfall enhances it
Mohamed & Nageye (2021)	Land degradation and agricultural production	Cobb-Douglas production function; structural break tests, 1962-2017	One hectare of land loss reduces output by 5%; a 1°C rise reduces output by 3%
Boitt et al. (2018)	Geospatial agro-climatic potential	GIS overlay and multi-clustering analysis	Identifies substantial under-used agricultural potential across Somalia
Ali et al. (2023)	Climatic and non-climatic determinants of cereal production	ARDL bounds testing	Land use and rural population outweigh climatic factors as drivers of cereal production
Warsame et al. (2021)	Climate change and crop production nexus	ARDL; Johansen cointegration; DOLS, 1985-2016	CO2 boosts output; temperature and rainfall reduce long-term productivity
Warsame et al. (2023b)	Climate change, instability, and maize production	ARDL bounds test; DOLS	1% temperature rise associated with an 11.67% long-term decline in maize production
Abdi et al. (2023)	Climate impacts on cereal production, East Africa	Panel cointegration (PMG, DOLS, FMOLS); Dumitrescu-Hurlin causality	Rainfall increases and temperature reduces cereal production across the panel
Warsame & Abdi (2023)	Environmental pollution and crop production	ARDL bounds test; Granger causality; FMOLS	CO2 and methane emissions raise short and long-term output; degradation lowers it long-term
Alasow et al. (2024c)	Drought variability and affected croplands	SPEI at 3, 6, 12-month scales, 1901-2020	Cropland affected by drought nearly doubled between 1981-2020 versus 1901-1940

Study	Focus	Method	Key Finding
Alasow et al. (2024a)	Soil moisture drought	ERA5 reanalysis; SPEI, 1951-2020	Soil moisture declined sharply since 1986, most severely in Somalia and Djibouti
Omar et al. (2024)	Agricultural drought severity in Somaliland	MODIS VCI; CHIRPS rainfall, 2005-2023	Severe drought 2015-2018, most acute in Sool and Togdheer regions

4.2 The Impact of Climate Change on Livestock

The livestock sector plays a vital role in Somalia's agricultural production and economy, with nomadic pastoralism the predominant mode of animal husbandry (Mohamud et al., 2022), and this sector is particularly vulnerable to the impacts of climate change. Reviewed studies show that climatic factors such as rainfall and temperature have significant effects on livestock production in Somalia: increased rainfall tends to have a positive effect, while rising temperatures are associated with substantial declines in output (Warsame et al., 2022). Climate change is also projected to influence pasture growth and feed availability, which are crucial for livestock productivity; under high emissions scenarios, pasture growth rates are projected to increase in some assessments, potentially reducing supplementary feed requirements in most regions (Hussein et al., 2023), although overgrazing and soil erosion remain pressing concerns that could offset these gains through pasture degradation (Mohamud et al., 2022).

The effects of climate change on the livestock sector extend beyond production levels and feed availability. Animal health and welfare are also at risk from heat stress and the potential spread of disease and parasites (Rojas-Downing et al., 2017), and the profitability of livestock enterprises in Somalia is consequently likely to be affected by climate change. While some projections suggest increased profits under certain scenarios (Hussein et al., 2023), these estimates should be interpreted cautiously given the risks posed by extreme weather events, resource availability, and market dynamics (Thalheimer et al., 2023b). Addressing these challenges will require a multifaceted approach, including promoting climate-smart livestock practices, improving animal health services, and enhancing feed and water resource management (Rojas-Downing et al., 2017).

The livestock sector's own contribution to environmental degradation in Somalia is also a concern raised in the reviewed literature. Agricultural activities, particularly livestock production and crop cultivation, have been linked to increased carbon dioxide emissions and environmental pollution (Warsame et al., 2023a), and traditional livestock rearing practices and the expansion of grazing land across diverse zones can harm the environment, underscoring the need for sustainable livestock management practices and environmentally sound policy. Achieving sustainable agricultural development in Somalia will require addressing the environmental impact of livestock production alongside strategies to enhance the sector's resilience to climate change.

4.3 Knowledge, Policy, and Institutional Gaps

Climate change poses a significant threat to agricultural production in Somalia, a country heavily dependent on rain-fed agriculture and pastoralism, and despite the urgency of these challenges, the reviewed literature identifies critical policy and institutional gaps that hinder effective climate adaptation and mitigation. One major gap is the inadequacy of existing policies and strategies in addressing climate risk reduction, adaptation, and community resilience; Somalia's National Development Plan, for instance, has been found not to comprehensively integrate these issues (Gure, 2021; Pape & Wollburg, 2019), and many

countries in the region, including Somalia, lack coherent policy frameworks that address the multifaceted nature of climate change impacts on the agricultural sector (Kuate, 2022). Somalia's institutions also face significant capacity constraints and lack effective coordination mechanisms to implement adaptation and mitigation strategies; assessments associated with the World Bank (Pape, 2017) and the United Nations Development Programme (UNDP, 2018) note that the country lacks a comprehensive and decentralised system for disaster risk reduction, with gaps and weaknesses in policy and early warning frameworks. This institutional weakness hampers the translation of policy into action on the ground, leaving communities poorly prepared to cope with climate-induced shocks.

A further gap identified across the reviewed studies is limited access to technology and information, which impedes information sharing, learning, innovation, and collaboration among stakeholders. Assessments associated with the Intergovernmental Authority on Development (Citaristi, 2022) highlight the importance of access to information and communication technologies in facilitating effective climate change adaptation and resilience building; without these resources, communities and decision-makers in Somalia struggle to access and use climate data, early warning systems, and documented best practices, further compounding their vulnerability. Addressing these policy and institutional gaps will require comprehensive and integrated policies that prioritise climate risk reduction, adaptation, and community resilience, developed through a participatory process that involves government agencies, civil society organisations, and local communities (Jama et al., 2020; Nzuma et al., 2014), alongside strengthened institutional capacity and coordination mechanisms achieved through capacity-building initiatives, resource allocation, and dedicated coordination platforms. Investment in information and communication technologies is similarly pivotal for enhancing access to climate data, early warning systems, and knowledge-sharing platforms, which can be facilitated through partnerships with international organisations, research institutions, and technology providers. The contradictory findings regarding carbon dioxide emissions and agricultural productivity discussed in Section 4.1 illustrate a broader knowledge gap in understanding the complex interactions between climate variables in Somalia's specific context, and this scientific uncertainty complicates policymaking and underscores the need for more comprehensive, long-term studies that consider multiple climate factors simultaneously rather than in isolation.

4.4 Pathways for Sustainable Agriculture

Enhancing the resilience of crop and livestock production systems in Somalia against climate change impacts requires a multi-pronged approach grounded in the gaps identified above. Developing comprehensive policies that integrate climate change adaptation and resilience-building strategies for the agricultural sector is a central priority, encompassing climate-smart practices, improved water management, measures to boost livestock productivity, and support for smallholder farmer adaptation through multi-stakeholder involvement (Nzuma et al., 2014). Strengthening the technical capacity of relevant institutions and establishing functioning coordination mechanisms can facilitate inter-agency collaboration, knowledge sharing, and harmonised adaptation efforts across government and civil society (UNDP, 2018).

Investment in robust meteorological monitoring, data analysis, and early warning systems is important for providing timely climate information and risk alerts to farmers and pastoralists through accessible channels (Gure, 2021). Promoting climate-smart agricultural techniques, including drought-tolerant crop varieties, efficient irrigation, agroforestry, integrated pest management, sustainable pasture management, feed supplementation, and resilient animal breeds, is central to improving both productivity and resilience (Adenle et al., 2017; Rojas-Downing et al., 2017). Enhancing collaborative research between local

institutions, international organisations, and development partners is important for assessing impacts, testing adaptation strategies, and developing innovative, context-specific solutions, with knowledge-sharing platforms helping to disseminate findings and best practices among practitioners (Adenle et al., 2017).

Implementing sustainable land, water, and environmental management practices is essential for the long-term sustainability of Somali agriculture. Combating land degradation, desertification, deforestation, and inefficient water use through rainwater harvesting, soil conservation, and the integration of traditional ecological knowledge into natural resource management is a recurring recommendation across the reviewed literature. Taken together, this multi-faceted approach offers a route by which Somalia can build resilience in its agricultural systems, safeguarding food security, rural livelihoods, and sustainable development in the face of a changing climate.

5. Conclusion

Climate change poses a severe threat to agricultural production and food security in Somalia. Rising temperatures, changing rainfall patterns, and an increased frequency of extreme weather events such as droughts and floods have already contributed to substantial declines in crop yields and livestock productivity across the studies reviewed here. Key staple crops such as maize, sorghum, and other cereals have experienced reduced output linked to climate impacts, and the pastoral livestock sector is similarly exposed, with climate change influencing pasture growth, feed availability, and animal health. Despite this urgency, critical gaps remain in the policies, institutions, knowledge, and climate information infrastructure needed for effective adaptation planning. Somalia currently lacks comprehensive climate-resilient policies and strategies that prioritise risk reduction and adaptation in the agricultural sector, and institutional capacity constraints together with weak coordination mechanisms continue to impede policy implementation, while limited access to climate data, early warning systems, and knowledge-sharing platforms further compounds these challenges.

Addressing these issues and enhancing the resilience of Somali agriculture will require sustained attention across several complementary fronts identified throughout this review. Comprehensive and integrated policies that prioritise climate change adaptation, resilience building, and sustainable agricultural practices should be developed through a participatory process that involves the full range of relevant stakeholders. Institutional capacities need strengthening, alongside effective coordination mechanisms that support inter-agency collaboration and harmonised adaptation efforts. Investment in robust meteorological monitoring, data analysis, and early warning systems is needed to deliver timely climate information and risk alerts to farmers and pastoralists through channels they can readily access, while climate-smart agricultural techniques, including drought-tolerant crop varieties, efficient irrigation, agroforestry, integrated pest management, sustainable pasture management, feed supplementation, and resilient animal breeds, warrant wider promotion. Collaborative research between local institutions, international organisations, and development partners should be expanded to assess impacts, test adaptation strategies, and develop context-specific solutions, supported by sustainable land, water, and environmental management practices that combat land degradation, desertification, deforestation, and inefficient water use, and by knowledge-sharing platforms that disseminate research findings and best practice among the stakeholders who need them. Pursued together, through coordinated collaboration, sound policy, sustainable practice, and strategic investment, these measures can help Somalia build a more resilient agricultural system and safeguard food security, rural livelihoods, and sustainable development amid a changing climate.

Acknowledgements

None

Conflict of Interest Statement

The author declares no conflict of interest.

Data Availability Statement

As a literature review, this study did not generate new primary data. The full list of documents synthesized is available from the corresponding author upon reasonable request.

References

- Abdi, A. H., Warsame, A. A., & Sheik-Ali, I. A. (2023). Modelling the impacts of climate change on cereal crop production in East Africa: Evidence from heterogeneous panel cointegration analysis. *Environmental Science and Pollution Research*, 30(12), 35246-35257.
- Abdirizak, A. E. (2022). Development aid and post civil war reconstruction in Mogadishu, Somalia. Kampala International University, College of Humanities and Social Science.
- Adenle, A. A., Ford, J. D., Morton, J., Twomlow, S., Alverson, K., Cattaneo, A., Cervigni, R., Kurukulasuriya, P., Huq, S., & Helfgott, A. (2017). Managing climate change risks in Africa: A global perspective. *Ecological Economics*, 141, 190-201.
- Alasow, A. A., Hamed, M. M., Rady, M., Arab, M. A., Muhammad, M. K. I., & Shahid, S. (2024a). Spatiotemporal analysis of soil moisture drought in the Horn of Africa. *Theoretical and Applied Climatology*, 1-12.
- Alasow, A. A., Hamed, M. M., Rady, M., & Shahid, S. (2024b). Spatiotemporal analysis of compound droughts and heat waves in the Horn of Africa. *International Journal of Climatology*.
- Alasow, A. A., Hamed, M. M., & Shahid, S. (2024c). Spatiotemporal variability of drought and affected croplands in the Horn of Africa. *Stochastic Environmental Research and Risk Assessment*, 38(1), 281-296.
- Alasow, A. A., Hersi, A. A., Nadarajah, S., Omar, A. O., Ashaari, Z. H., & Warsame, A. A. (2024d). Long-term air temperature trends in Somalia from 1901 to 2021. *Earth Systems and Environment*, 1-14.
- Ali, D. A., Dahir, A. M., & Yusuf, S. M. (2023). Autoregressive distributed lag modeling of climate and non-climatic determinants affecting cereal production: Empirical evidence from Somalia. *International Journal of Energy Economics and Policy*, 13(5), 577-584.
- Bedasa, Y., & Deksisa, K. (2024). Food insecurity in East Africa: An integrated strategy to address climate change impact and violent conflict. *Journal of Agriculture and Food Research*, 100978.
- Bedeke, S. B. (2023). Climate change vulnerability and adaptation of crop producers in sub-Saharan Africa: A review on concepts, approaches and methods. *Environment, Development and Sustainability*, 25(2), 1017-1051.
- Boitt, M. K., Langat, F. C., & Kapoi, J. K. (2018). Geospatial agro-climatic characterization for assessment of potential agricultural areas in Somalia, Africa. *Journal of Agricultural Informatics*, 9(3).
- Citaristi, I. (2022). Intergovernmental Authority on Development, IGAD. In *The Europa directory of international organizations 2022* (pp. 623-628). Routledge.
- Demem, M. S. (2023). Impact and adaptation of climate variability and change on smallholders and agriculture in Ethiopia: A review. *Heliyon*.
- Erdaw, M. M. (2023). Contribution, prospects and trends of livestock production in sub-Saharan Africa: A review. *International Journal of Agricultural Sustainability*, 21(1), 2247776.

- Gure, A. (2021). The role of climate information and early warning systems in supporting disaster risk reduction in Somalia. WASH Cluster Somalia.
- Hassan, B. A., Glover, E. K., Luukkanen, O., Jamnadass, R., & Chikamai, B. (2014). An assessment of the socio-economic and ecological impacts of environmental changes on rural livelihood: A study across Addado, Buhodle and northern Galkaayo of central and northern Somalia. *Agriculture, Forestry and Fisheries*, 3(4), 279-291.
- Hussein, J. A., Bilotto, F., Ferreira, C. S. S., Liu, K., Omondi, P., Sircely, J., Wachira-Mbui, D. N., & Harrison, M. T. (2023). From crisis to opportunity: Climate change benefits livestock production in Somalia. *Authorea Preprints*.
- Jama, O. M., Liu, G., Diriye, A. W., Yousaf, B., Basiru, I., & Abdi, A. M. (2020). Participation of civil society in decisions to mitigate environmental degradation in post-conflict societies: Evidence from Somalia. *Journal of Environmental Planning and Management*, 63(9), 1695-1715.
- Krampe, F., Van De Goor, L., Barnhoorn, A., Smith, E., & Smith, D. (2020). Water security and governance in the Horn of Africa. Stockholm International Peace Research Institute.
- Kuete, S. A. (2022). Macroeconomic and social developments in Eastern Africa 2022: What next?
- Kusangaya, S., Warburton, M. L., Van Garderen, E. A., & Jewitt, G. P. W. (2014). Impacts of climate change on water resources in southern Africa: A review. *Physics and Chemistry of the Earth, Parts A/B/C*, 67, 47-54.
- Mohamed, A. A., & Nageye, A. I. (2021). Measuring the effect of land degradation and environmental changes on agricultural production in Somalia with two structural breaks. *Management of Environmental Quality*, 32(2), 160-174.
- Mohamed, M. (2022). The agricultural output-economic growth nexus in Somalia. University of Nairobi.
- Mohamed, M. H., Ombati, J. M., & Ahmed, A. F. (2024). Influence of selected extension support services on sesame production among smallholder farmers in Bal'ad District, Somalia. *International Journal of Agricultural Extension and Rural Development Studies*, 11(1), 46-60.
- Mohamud, A. H., Mat, B., & Çevrimli, M. B. (2022). Economic development opportunities and general structure of livestock production in Somalia. *Antakya Veteriner Bilimleri Dergisi*, 1(1), 23-32.
- Nzuma, J. M., Radeny, M. A. O., Kinyangi, J., & Cramer, L. (2014). A review of agricultural, food security, food systems and climate change adaptation policies, institutions and actors in East Africa. CCAFS Working Paper.
- Omar, A. O., Alasow, A. A., Farah, A. A., & Shahid, S. (2024). Spatiotemporal analysis of agricultural drought severity and hotspots in Somaliland. *International Journal of Sustainable Development and Planning*, 19(11).
- Omer, M. A. (2024). Climate variability and livelihood in Somaliland: A review of the impacts, gaps, and ways forward. *Cogent Social Sciences*, 10(1), 2299108.
- Omotoso, A. B., Letsoalo, S., Olagunju, K. O., Tshwene, C. S., & Omotayo, A. O. (2023). Climate change and variability in sub-Saharan Africa: A systematic review of trends and impacts on agriculture. *Journal of Cleaner Production*, 137487.
- Pape, U. J. (2017). Somali poverty profile: Findings from wave 1 of the Somali high-frequency survey. World Bank.
- Pape, U. J., & Wollburg, P. R. (2019). Impact of drought on poverty in Somalia (World Bank Policy Research Working Paper No. 8698). World Bank.

- Pörtner, H. O., Roberts, D. C., Adams, H., Adler, C., Aldunce, P., Ali, E., Begum, R. A., Betts, R., Kerr, R. B., & Biesbroek, R. (2022). Climate change 2022: Impacts, adaptation and vulnerability. IPCC.
- Rady, M., Alasow, A. A., & Hersi, A. A. (2025). Bibliometric analysis of climate research in East Africa: The rise and progress. *Sustainable Environment*, 11(1), 2454746.
- Rojas-Downing, M. M., Nejadhashemi, A. P., Harrigan, T., & Woznicki, S. A. (2017). Climate change and livestock: Impacts, adaptation, and mitigation. *Climate Risk Management*, 16, 145-163.
- Said, M., & Bashir, A. (2023). Analysis of climate change impacts on food security in Somalia.
- Seife, T. K. (2021). The impact of climate change on agriculture and food security in the greater Horn of Africa. *Politikon*, 48(1), 98-114.
- Semeraro, T., Scarano, A., Leggieri, A., Calisi, A., & De Caroli, M. (2023). Impact of climate change on agroecosystems and potential adaptation strategies. *Land*, 12(6), 1117.
- Tesfay, S. (2024). What are the impacts of climate change on sustainable food production, food demand, and population numbers in Sub-Saharan Africa? A systematic review. *Food Journal*, 2(2).
- Thalheimer, L., Gaupp, F., & Webersik, C. (2023a). Systemic risk and compound vulnerability impact pathways of food insecurity in Somalia. *Climate Risk Management*, 42, 100570.
- Thalheimer, L., Schwarz, M. P., & Pretis, F. (2023b). Large weather and conflict effects on internal displacement in Somalia with little evidence of feedback onto conflict. *Global Environmental Change*, 79, 102641.
- UNDP. (2018). Somali drought impact and needs assessment report. United Nations Development Programme.
- Warsame, A. A., & Abdi, A. H. (2023). Towards sustainable crop production in Somalia: Examining the role of environmental pollution and degradation. *Cogent Food & Agriculture*, 9(1), 2161776.
- Warsame, A. A., Mohamed, J., & Mohamed, A. A. (2023a). The relationship between environmental degradation, agricultural crops, and livestock production in Somalia. *Environmental Science and Pollution Research*, 30(3), 7825-7835.
- Warsame, A. A., Sheik-Ali, I. A., Ali, A. O., & Sarkodie, S. A. (2021). Climate change and crop production nexus in Somalia: An empirical evidence from ARDL technique. *Environmental Science and Pollution Research*, 28(16), 19838-19850.
- Warsame, A. A., Sheik-Ali, I. A., Barre, G. M., & Ahmed, A. (2023b). Examining the effects of climate change and political instability on maize production in Somalia. *Environmental Science and Pollution Research*, 30(2), 3293-3306.
- Warsame, A. A., Sheik-Ali, I. A., Hassan, A. A., & Sarkodie, S. A. (2022). Extreme climatic effects hamper livestock production in Somalia. *Environmental Science and Pollution Research*, 29(27), 40755-40767.
- Warsame, A. A., Sheik-Ali, I. A., Jama, O. M., Hassan, A. A., & Barre, G. M. (2022). Assessing the effects of climate change and political instability on sorghum production: Empirical evidence from Somalia. *Journal of Cleaner Production*, 360, 131893.