

Research Article

The Effects of Climate Change in Ethiopia: A Review

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Abstract

Ethiopia's strong dependence on climate-sensitive sectors, combined with limited adaptive capacity, makes climate change one of the most significant threats to the country's socioeconomic development. This review synthesizes current knowledge on observed climate trends, future climate projections, and the diverse impacts of climate change across Ethiopia's regions and key sectors. Evidence consistently indicates rising temperatures, increasing rainfall variability, and a growing frequency and intensity of extreme events such as droughts and floods. These changes profoundly affect agriculture and food security, water resources and hydropower generation, pastoral livelihoods, human health, ecosystems, and rapidly expanding urban systems. Marked regional differences are evident: highland areas face soil degradation, shifting agroecological zones, and declining crop productivity, while lowland and pastoral regions experience increasing aridity, rangeland degradation, and livelihood insecurity. The review further examines cross-cutting issues, including gendered vulnerability, technological innovation, economic impacts, migration, and climate finance, highlighting the interconnected nature of climate risks. National policy frameworks, governance mechanisms, and documented case studies illustrate pathways for enhancing resilience, while also revealing persistent implementation and capacity gaps. Key research priorities include the need for high-resolution climate projections, long-term monitoring of climate impacts, and improved understanding of urban climate risks. Strengthening institutional capacity, scaling up climate-smart practices, and enhancing international cooperation are essential to support Ethiopia's transition toward climate-resilient and sustainable development.

Keywords

Climate Change, Adaptation, Food Security, Water Resources, Urban Resilience, Policy, Ethiopia

1. Introduction

Climate change is widely recognized as one of the defining challenges of the twenty-first century, with particularly severe consequences for developing countries whose economies and livelihoods are closely linked to natural resources and climate-sensitive sectors. Ethiopia is among the most vulnerable countries in Sub-Saharan Africa due to its heavy reliance on rain-fed agriculture, rapid population growth, widespread poverty, and limited institutional and technolog-

ical capacity for adaptation [8, 15]. Climate variability and long-term climate change already exert significant pressure on food production systems, water availability, ecosystem services, and socioeconomic stability across the country.

Agriculture employs the majority of Ethiopia's population and contributes substantially to national gross domestic product, export earnings, and food security. As a result, fluctuations in temperature and rainfall directly translate into changes in crop

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yields, livestock productivity, and household income [13, 19]. Warming trends, erratic rainfall patterns, and increasing frequencies of droughts and floods have heightened vulnerability, particularly among smallholder farmers and pastoral communities who depend on natural rainfall and rangeland resources [5, 10]. Climate-related shocks not only undermine agricultural productivity but also exacerbate poverty, inequality, and food insecurity in both rural and urban areas [1, 17].

Urbanization adds a further layer of complexity to Ethiopia's climate challenge. Rapid expansion of cities such as Addis Ababa, Adama, Hawassa, and Mekelle has increased exposure to heat stress, flooding, and infrastructure strain [7]. Informal settlements are particularly vulnerable due to inadequate drainage, limited access to basic services, and weak urban planning. Climate extremes also disrupt education systems and public health, affecting children's learning outcomes, nutrition, and long-term human capital development [22].

Over the past two decades, a growing body of research has examined climate trends, impacts, and adaptation strategies in Ethiopia. However, much of this literature remains fragmented across sectors and regions, making it difficult to derive an integrated understanding of climate risks and response options. Existing reviews often focus on single sectors—such as agriculture or water resources—or specific regions, while cross-cutting issues such as gender, migration, governance, and finance receive comparatively less attention.

This review addresses these gaps by providing a comprehensive synthesis of observed and projected climate change in Ethiopia and its multifaceted impacts across regions and sectors. The objectives of this paper are to: (i) summarize current evidence on climate trends and projections in Ethiopia; (ii) assess sectoral and regional impacts of climate change; (iii) examine cross-cutting vulnerabilities and response strategies; and (iv) identify policy-relevant insights and research priorities to support climate-resilient development. By integrating climate science, socioeconomic analysis, and policy perspectives, this review aims to inform researchers, policymakers, and development practitioners engaged in climate adaptation and sustainable development in Ethiopia.

2. Overview of Previous Studies on Climate Change in Ethiopia

Research on climate change in Ethiopia has expanded significantly since the early 2000s, reflecting growing concern about climate risks and their development implications. Early studies primarily focused on climate variability and its impacts on agriculture, particularly rainfall variability and drought frequency. For example, Deressa et al. [10] assessed farmers' vulnerability to climate change and highlighted the

sensitivity of crop yields to temperature and rainfall fluctuations. Similar studies emphasized the role of adaptive capacity, access to resources, and institutional support in shaping vulnerability outcomes.

From 2010 onwards, research increasingly incorporated climate modeling and scenario analysis. Studies using regional climate models and downscaled global climate projections consistently reported rising temperatures across Ethiopia, with varying trends in precipitation depending on region and season [15, 18]. Simane et al. [19] demonstrated that agro-ecosystems in the Ethiopian highlands are particularly vulnerable to climate change due to combined effects of warming, land degradation, and population pressure.

More recent literature has adopted a multi-sectoral perspective, examining impacts on water resources, hydropower generation, health, and urban systems. Gebremichael and Hailu [14] synthesized evidence on climate variability and water resources, highlighting risks to river flows, groundwater recharge, and hydropower reliability. Kassaye [16] reviewed climate-related health vulnerabilities, emphasizing heat stress, vector-borne diseases, and nutrition outcomes. Urban-focused studies have drawn attention to flooding, heat islands, and infrastructure vulnerability in rapidly growing cities [7].

Despite these advances, gaps remain. Many studies rely on short-term datasets or coarse spatial resolution, limiting their ability to capture local-scale climate impacts. There is also limited integration across sectors and insufficient attention to governance, finance, and long-term adaptation pathways. This review builds on existing literature by synthesizing findings across disciplines and regions, with a focus on implications for policy and practice.

Conceptual framework linking climate drivers, sectoral impacts, and adaptation pathways in Ethiopia.

Description:

Climate drivers (temperature, rainfall variability, extremes)
 → Sectoral impacts (agriculture, water, health, urban systems)
 → Socioeconomic outcomes (food security, migration, GDP)
 → Adaptation responses (policy, technology, finance).

3. Climate Trends and Projections in Ethiopia

Ethiopia's climate is characterized by pronounced spatial and temporal variability due to its complex topography and influence of large-scale climate drivers. This inherent variability amplifies sensitivity to climate change and complicates adaptation planning. Observational records and climate model simulations consistently indicate significant warming, increasing rainfall variability, and a rise in extreme events over recent decades [15, 18].

Table 1. Observed and Projected Climate Trends in Ethiopia.

Climate Variable	Observed Trends	Projected Changes (21st Century)	Key Implications	Key Sources
Temperature	Increase of ~0.2–0.3 °C per decade; faster warming in highlands	+1.5 to >4 °C by 2100 depending on emission scenario	Heat stress, altered agroecological zones, increased evapotranspiration	IPCC (2022); NMA (2023); Kassaye (2020)
Rainfall	High interannual and seasonal variability; spatially mixed trends	Increased variability; shifts in seasonal distribution	Crop failure risk, water supply uncertainty	Alemu & Mengistu (2020); Gebremichael & Hailu (2023)
Extreme Events	More frequent droughts and floods	Increased intensity and frequency of extremes	Infrastructure damage, livelihood loss	Berhanu et al. (2022); World Bank (2020)

3.1. Temperature Trends and Heat Stress

Mean annual temperatures across Ethiopia have increased markedly since the mid-twentieth century. Observational data indicate warming rates of approximately 0.2–0.3 °C per decade in many regions, with higher rates observed in highland areas [15, 16]. Climate projections under multiple emissions scenarios suggest continued warming throughout the twenty-first century, with temperature increases ranging from 1.5 °C under low-emissions pathways to more than 4 °C under high-emissions scenarios by 2100.

Warming has profound implications for agriculture, ecosystems, and human health. Rising temperatures increase evapotranspiration, reduce soil moisture, and intensify heat stress on crops and livestock. Highland regions, traditionally considered climatically favorable for agriculture, are experiencing shifts in agroecological zones, altered crop calendars, and increased pest and disease pressure [19]. In urban areas, heat stress is exacerbated by the urban heat island effect, increasing risks of heat-related illness and energy demand for cooling [7].

3.2. Precipitation Variability and Water Availability

Rainfall patterns in Ethiopia exhibit strong interannual and intra-seasonal variability, influenced by climate phenomena such as the El Niño–Southern Oscillation and the Indian Ocean Dipole [3, 4]. Long-term trends in total annual rainfall are spatially heterogeneous, with some regions experiencing slight increases and others experiencing declines. However, a consistent finding across studies is increased rainfall variability and changes in seasonal distribution.

These changes pose significant challenges for rain-fed agriculture, which dominates Ethiopia's farming systems. Shifts in the timing and intensity of rainfall affect planting decisions, crop growth, and harvest outcomes. Water resources are similarly affected, with implications for river flows, groundwater recharge, hydropower generation, and urban water supply

[14]. Marginal agricultural areas are particularly vulnerable, as even small changes in rainfall can trigger crop failure and food insecurity.

3.3. Extreme Climate Events

The frequency and intensity of extreme climate events—especially droughts and floods—have increased in many parts of Ethiopia [6, 9, 17]. Droughts remain the most significant climate hazard, affecting millions of people and causing substantial economic losses. Flooding, often associated with intense rainfall events, causes damage to infrastructure, housing, and farmland, particularly in lowland and riverine areas.

Extreme events undermine development gains by destroying assets, disrupting livelihoods, and straining government and humanitarian response systems. Evidence suggests that community-based disaster risk management and early warning systems can reduce losses and improve preparedness, although coverage and effectiveness vary across regions [5].

4. Regional Dimensions of Climate Change Impacts

Climate change impacts in Ethiopia vary widely across regions due to differences in altitude, climate, livelihood systems, and adaptive capacity.

4.1. Highland Regions

The highlands of northern and central Ethiopia, including parts of Tigray, Amhara, and Oromia, are experiencing rising temperatures, recurrent droughts, and progressive soil degradation [2, 19]. These stressors reduce cereal crop productivity, intensify land degradation, and threaten household food security. Population pressure and continuous cultivation further exacerbate vulnerability.

Climate change interacts with existing land management challenges, accelerating erosion and nutrient depletion. Sustainable land management practices, such as terracing, agro-

forestry, and conservation agriculture, have demonstrated potential to enhance resilience but require sustained investment and institutional support.

4.2. Lowland and Pastoral Areas

Lowland and pastoral regions, particularly Afar, Somali, and parts of southern Ethiopia, face increasing aridity, erratic rainfall, and frequent droughts [21]. These changes disrupt pastoral mobility, reduce rangeland productivity, and increase livestock mortality. Flooding in some lowland areas further compounds vulnerability by damaging crops and infrastructure [4].

Pastoral systems are highly adapted to climate variability, but the increasing frequency of extreme events and constraints on mobility undermine traditional coping strategies. Strengthening pastoral governance, securing access to grazing and water resources, and improving climate information services are essential for enhancing resilience.

5. Sectoral Impacts of Climate Change

5.1. Agriculture and Food Security

Agriculture is the sector most directly affected by climate change in Ethiopia. Temperature increases, rainfall variability, and extreme events reduce crop yields, increase production risk, and threaten food security [5, 13]. Smallholder farmers, who dominate the agricultural landscape, have limited capacity to absorb shocks and adapt to changing conditions.

Climate change also affects livestock systems through heat stress, feed and water shortages, and disease outbreaks. These impacts have cascading effects on nutrition, income, and rural livelihoods.

5.2. Water Resources and Hydropower

Water resources are highly sensitive to climate variability and change. Altered rainfall patterns affect river flows, groundwater recharge, and reservoir levels, with implications for irrigation, hydropower, and domestic water supply [14]. Hydropower, which accounts for a large share of Ethiopia's electricity generation, is particularly vulnerable to drought-induced reductions in river flow.

5.3. Human Health

Climate change poses significant risks to human health through heat stress, malnutrition, and the spread of vector-borne diseases [16]. Vulnerable populations, including children, the elderly, and the poor, are disproportionately affected. Climate-induced food insecurity exacerbates malnutrition and undermines long-term health outcomes.

5.4. Urban Systems and Infrastructure

Rapid urbanization increases exposure to climate risks such as flooding, heat waves, and water scarcity. Informal settlements are especially vulnerable due to inadequate infrastructure and limited access to services [7]. Integrating climate considerations into urban planning and infrastructure development is critical for reducing future risks.

6. Cross-cutting Issues and Response Strategies

6.1. Gender, Vulnerability, and Inequality

Climate change impacts are unevenly distributed across society. Women and marginalized groups face disproportionate burdens due to limited access to resources, information, and decision-making processes [17]. Gender-responsive adaptation strategies are essential for inclusive resilience building.

6.2. Technology, Innovation, and Early Warning Systems

Technological innovation plays a central role in climate adaptation. Early warning systems, remote sensing, climate modeling, and mobile-based information services support climate-informed decision-making and risk reduction [11, 14].

6.3. Economic Impacts, Finance, and Migration

Climate shocks reduce productivity across sectors, affecting national economic growth and development trajectories [12, 20]. Recurrent droughts and floods contribute to migration and resource-based conflicts, placing additional pressure on urban areas and social services [17]. Innovative financial mechanisms are increasingly important for mobilizing adaptation finance.

7. Policy Frameworks, Governance, and Case Studies

7.1. National Policies and Institutional Capacity

Ethiopia's National Adaptation Plan provides a strategic framework for addressing climate risks across sectors [18]. However, implementation is constrained by limited institutional capacity, coordination challenges, and financing gaps. Strengthening governance and cross-sectoral collaboration is critical.

7.2. Case Studies and Best Practices

Successful initiatives, including watershed management,

micro-irrigation, rangeland governance reforms, and urban greening projects, demonstrate effective adaptation pathways [21]. Scaling up these approaches requires sustained investment and policy support.

8. Recommendations and Future Research Directions

Integrating climate risk into development planning, investing in resilient agriculture and water systems, strengthening pastoral governance, promoting nature-based solutions, enhancing urban resilience, implementing gender-sensitive strategies, and expanding climate finance are essential priorities [5, 11, 15]. Future research should focus on high-resolution climate projections, long-term impact monitoring, and urban climate risks.

9. Conclusion

Climate change poses escalating risks to Ethiopia's development, affecting livelihoods, food security, water resources, health, ecosystems, and urban systems [15, 20]. Achieving a climate-resilient future requires coordinated, well-financed adaptation strategies that integrate policy, research, technology, gender equity, and institutional strengthening. By synthesizing current evidence and identifying key gaps, this review contributes to informed decision-making and supports Ethiopia's transition toward sustainable and climate-resilient development.

Abbreviations

NAP National Adaptation Plan

Author Contributions

Tesfaye Ketema Defar: Conceptualization, Data curation, Methodology, Writing – original draft, Writing – review & editing

Ketema Negesse Tola: Conceptualization, Data curation, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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