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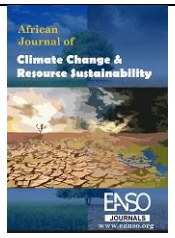

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Original Article

Forest Ecosystems and Climate Change in Ethiopia: Challenges and Adaptive Solutions: Review Article

Tesemash Abebe Mekuria[1*]

[1] Ethiopian Forestry Development, P. O. Box 30708, Ethiopia.
[*] Author for Correspondence ORCID ID; https://orcid.org/0000-0003-0571-1285; Email: tese.leta@gmail.com

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ABSTRACT

The review article, "Forest Ecosystems and Climate Change in Ethiopia: Challenges and Adaptive Solutions," explores the critical interrelations between Ethiopia's forest ecosystems and climate change. The primary objective is to assess the effectiveness of adaptive strategies, particularly community-based forest management and agroforestry, within climate resilience. A systematic literature review was conducted, encompassing 69 studies published since 2020, to evaluate the multifaceted impacts of climate change on forest health, deforestation drivers, and existing policy frameworks. The results reveal that Ethiopia's forests face severe threats from climate change, including shifts in biodiversity and an increase in deforestation driven by agricultural expansion and illegal logging. Despite initiatives like the Climate Resilient Green Economy (CRGE) strategy and the Green Legacy Initiative, challenges persist, including inadequate policy enforcement, land tenure issues, and socio-economic pressures that hinder effective conservation. The conclusion emphasises the necessity for integrated, community-focused strategies and enhanced policy coherence to address these barriers. The findings suggest that strengthening local governance, securing land rights, and exploring alternative livelihood options are essential for sustainable forest management in Ethiopia. Overall, this review provides insights that are vital for policymakers and stakeholders aiming to bolster forest resilience and contribute to global climate change mitigation efforts.

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INTRODUCTION

Forests are essential to global ecological balance, offering important services that regulate climate, sustain biodiversity, influence hydrological cycles, and provide resilience against environmental extremes. Their role as carbon sinks makes them central to mitigating the impacts of climate change (Girma et al., 2023; IPCC, 2019). As climate change intensifies, understanding how forest ecosystems interact with and influence climate patterns has become critical for both global and local environmental management. This scientific interest is underscored by the increasing recognition that forest ecosystems are not only vital for carbon storage but also for adapting to climate impacts, particularly in vulnerable regions like Ethiopia (Ellison et al., 2017; Girma et al., 2023).

Ethiopia's unique forest ecosystems, which span from humid tropical rainforests to dry woodlands, present a microcosm of the broader challenges posed by climate change. Ethiopia's forests are at a crossroads, threatened by deforestation, degradation, and the multifaceted impacts of a changing climate (A. B. Abera, 2021; Mekonnen et al., 2018). These threats risk the vital ecological functions that forests provide, such as carbon sequestration, soil protection, and water regulation, while increasing Ethiopia's vulnerability to climate change. Rising temperatures, erratic rainfall patterns, and extended droughts have been shown to exacerbate these threats, pushing the country's forest ecosystems to the brink (Weiskopf et al., 2020). The increasing challenges in Ethiopia's forests demand a deeper understanding of the interdependencies between climate change and forest health to inform sustainable management practices.

Previous studies have highlighted the need for integrated climate change adaptation strategies that consider the complex role of forests in climate resilience. Ethiopia has committed to enhancing forest conservation and management through the Climate Resilient Green Economy (CRGE) strategy, which prioritises reforestation and afforestation (Y. A. and A. Bekele, 2017). Despite these efforts, challenges persist in implementing these policies effectively, particularly at local levels, where socio-economic factors such as poverty, land tenure insecurity, and reliance on forests for fuel-wood continue to drive deforestation (Tadesse et al., 2016). Additionally, adaptive strategies like community-based forest management and agroforestry have emerged as viable solutions for balancing forest conservation with the pressing need for climate resilience. However, the effectiveness of these strategies remains underexplored, particularly in the context of Ethiopia's unique socio-environmental conditions (A. B. Abera, 2021; Esema & Hiferaw, 2025). This review study aims to address these gaps by exploring the relationship between Ethiopia's forest ecosystems and climate change. It seeks to assess the effectiveness of adaptive strategies that integrate forest conservation with climate resilience goals, with a focus on community-based management and sustainable agroforestry practices.

This study assumes that the integration of community-based forest management and agroforestry can enhance the resilience of Ethiopia's forest ecosystems to climate change while simultaneously addressing socio-economic pressures. The primary objective of this study is to evaluate the effectiveness of these adaptive strategies in Ethiopia, identifying the barriers to their success and proposing recommendations for improving their implementation. The findings are expected to inform both policy and practice,

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offering insights into how forest ecosystems can be leveraged to support both environmental sustainability and socio-economic development in the face of climate change. The next section of this review will delve into the methods used to assess the adaptive strategies for forest management in Ethiopia, laying the groundwork for the analysis of results and their implications for future policy and forest conservation practices.

METHODOLOGY

This review article is based on a systematic literature review, a well-established method for synthesising research findings. The review process began with identifying a clear research topic: the impacts of climate change on forest ecosystems and adaptive strategies in Ethiopia. A comprehensive search for relevant publications was carried out using major academic databases, such as Scopus, Web of Science, and Google Scholar, ensuring a broad and thorough review of existing studies on the topic.

From the 69 articles retrieved, a careful screening process led to the exclusion of 42 articles that were not aligned with the focus of this review. These articles were discarded for failing to address the central themes of forest ecosystems, climate change impacts, and adaptive strategies in Ethiopia. After the exclusion process, 27 articles remained, forming the core set for analysis. These articles were then systematically reviewed, with attention paid to the methodologies, study settings, and theoretical frameworks. The analysis also identified gaps in the literature and highlighted potential avenues for future research, while assessing the implications of the findings for policy and practical applications in forest management and climate change adaptation in Ethiopia.

To capture a wide range of relevant articles, a variety of search terms were used, including "climate change," "adaptation," "mitigation," "deforestation," "biodiversity," "forest management," "sustainable development," and "Ethiopia." These keywords helped ensure that the search results encompassed different aspects of climate change and forest ecosystems. Although the search initially returned a large volume of articles, the literature was limited to studies published since 2020, to focus on the most recent findings and developments in the field.

RESULTS AND DISCUSSION

The Impact of Climate Change on Forest Ecosystems in Ethiopia

Recent studies have underscored the severe and multifaceted impacts of climate change on Ethiopia's forest ecosystems, highlighting shifts in forest composition, biodiversity loss, and the exacerbation of existing environmental pressures. The increasing temperatures and changing precipitation patterns are affecting forest health, with predictions indicating more frequent and intense droughts, as well as altered rainfall distributions (Ayalew, 2023; Berhe et al., 2024; Mekonnen et al., 2018). These climatic changes are leading to forest degradation, reducing the regenerative capacity of native tree species and making them more susceptible to pests, diseases, and fire. For instance, the rise in forest fire risks has been linked to prolonged dry spells and higher temperatures, particularly in the northern and central highlands, where forests are already under threat from anthropogenic activities (Girma et al., 2023). As a result, the carbon sequestration potential of Ethiopian forests has been significantly diminished, undermining national and global climate mitigation efforts.

The ongoing deforestation crisis is further exacerbated by climate change, with agricultural expansion and illegal logging remaining key drivers of forest loss. In Ethiopia, forests provide essential resources for rural populations, particularly for fuel wood, construction materials, and fodder, contributing to unsustainable forest exploitation (Ayalew, 2023; Girma et al., 2023). This loss of forest cover has direct implications for soil erosion, water cycles, and local climate moderation. Recent studies have shown that the degradation of forests has led to a decline in the provision of ecosystem services such as water regulation, biodiversity support, and soil fertility, thereby affecting agricultural productivity and food security (A. B. Abera, 2021; W. Abera et al.,

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2021). Additionally, the retreat of Ethiopia's forests has led to a reduction in habitat availability for many endangered species, particularly those endemic to the country, further threatening biodiversity (S. Bekele et al., 2024; Berhe et al., 2024).

In response to these challenges, Ethiopia has implemented several initiatives aimed at mitigating the effects of climate change on forest ecosystems. The Climate Resilient Green Economy (CRGE) strategy and the Green Legacy Initiative have focused on large-scale reforestation and afforestation projects to restore degraded landscapes and enhance carbon storage capacities (A. B. Abera, 2021). Despite initial successes, the effectiveness of these programs is limited by ongoing challenges such as weak policy enforcement, land tenure issues, and the lack of community participation in forest management. The integration of community-based forest management and agroforestry practices has been identified as a promising strategy to enhance both climate resilience and forest conservation efforts. Studies indicate that community-led approaches are crucial for balancing conservation goals with local development needs (Endale et al., 2024; Hui et al., 2015). However, addressing socio-economic factors like poverty, land ownership disputes, and the dependency on forest resources for livelihoods remains a significant barrier to the sustainability of these efforts (S. Bekele et al., 2024).

Deforestation and Degradation: Key Drivers of Forest Loss

Deforestation and forest degradation remain two of the most significant challenges facing global and regional forest ecosystems, particularly in developing countries like Ethiopia. Recent studies confirm that the primary drivers of forest loss in Ethiopia include agricultural expansion, illegal logging, overgrazing, and the collection of fuel wood (Mekonnen et al., 2018; Muke, 2019; Toga et al., 2024). The rapid population growth in Ethiopia, coupled with a heavy reliance on natural resources for livelihood, particularly in rural areas, has resulted in unsustainable land-use practices. For instance, agricultural activities, driven by the need for more arable land to feed an expanding population, have led to the clearing of large tracts of forest, especially in the highlands (Girma et al., 2023). This has led to severe deforestation, with many forested areas being converted into agricultural land or degraded by extensive grazing. The expansion of smallholder farming and commercial agriculture further contributes to deforestation, often with little regard for the long-term environmental consequences.

Forest degradation is also driven by the unsustainable extraction of forest products, including timber, charcoal, and firewood, which are essential sources of energy for millions of Ethiopians. Despite efforts to promote sustainable harvesting practices, illegal logging and the overexploitation of forest resources remain pervasive in many parts of the country (A. B. Abera, 2021). These activities not only lead to the loss of valuable timber but also disrupt local ecosystems, reduce biodiversity, and affect water and soil quality. A particularly concerning aspect of this degradation is the impact on Ethiopia’s forest carbon stock, which is critical for mitigating climate change. Deforestation and degradation result in the release of large amounts of carbon dioxide into the atmosphere, undermining the country's climate mitigation efforts.

In response to these challenges, Ethiopia has implemented several national initiatives aimed at reducing deforestation and forest degradation, such as the Climate Resilient Green Economy (CRGE) strategy and the Green Legacy Initiative. These programs focus on reforestation, afforestation, and sustainable forest management, intending to increase forest cover and restore degraded lands (Kassa et al., 2022). However, despite the impressive scale of these initiatives, their success is often hindered by weak policy enforcement, limited financial resources, and a lack of adequate land tenure systems. Additionally, socio-economic factors such as poverty, population pressure, and dependence on forest resources for survival pose significant barriers to the effective implementation of forest conservation programs (Y. A. and A. Bekele,

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2017). More recent studies emphasise the need for integrated, community-based forest management approaches that incorporate local knowledge and engage communities in sustainable practices to address both the causes and effects of deforestation and degradation (Weiskopf et al., 2020).

In general, deforestation and forest degradation in Ethiopia are driven by a combination of socio-economic pressures, unsustainable agricultural practices, and inadequate forest management policies. While national policies and reforestation efforts have shown promise, the effectiveness of these initiatives depends on addressing the root causes of deforestation, improving governance, and fostering community involvement in forest conservation. Continued research is necessary to develop more context-specific, adaptive solutions to combat deforestation and degradation, particularly in the face of increasing climate-related stressors.

Adaptive Strategies for Forest Conservation and Climate Resilience

Adaptive strategies for forest conservation and climate resilience are critical in addressing the dual challenges of forest degradation and the impacts of climate change, particularly in countries like Ethiopia. Recent studies highlight several promising approaches that have been employed to enhance forest resilience and improve forest management practices in the face of climate-induced pressures. One widely recognised strategy is the integration of community-based forest management (CBFM), which has gained traction as an effective means of engaging local populations in sustainable forest management (A. B. Abera, 2021). By involving communities in decision-making processes and the management of forest resources, CBFM can help reduce illegal logging, promote sustainable harvesting, and restore degraded forests (Kassa et al., 2022). A study by Weiskopf et al. (2020) emphasised that CBFM contributes significantly to enhancing forest resilience by fostering a sense of ownership and stewardship among local people, ensuring that conservation efforts align with local livelihoods and needs.

Another adaptive strategy that has shown promise is agroforestry, which integrates trees with agricultural systems to promote sustainable land use while providing ecological and economic benefits. Recent research has demonstrated that agroforestry systems can enhance soil fertility, increase biodiversity, and improve water retention in areas affected by climate change (Hui et al., 2015). Agroforestry practices also provide local farmers with diversified income sources, reducing the pressure on forests for firewood and timber. The implementation of agroforestry in Ethiopia has been supported by government initiatives such as the Green Legacy Initiative, which promotes the planting of trees and the integration of trees into farming systems to combat deforestation and mitigate the impacts of climate change (Lemma et al., 2021; Shiferaw et al., 2023).

Ethiopia's national climate policy, notably the Climate Resilient Green Economy (CRGE) strategy, also emphasises the importance of forest conservation and restoration as part of broader climate adaptation and mitigation efforts (Muluneh et al., 2017). The CRGE focuses on large-scale reforestation and afforestation programs aimed at increasing carbon sequestration, improving water resources, and restoring degraded land. While these initiatives are promising, their success often depends on overcoming barriers such as weak policy enforcement, land tenure issues, and socio-economic constraints faced by rural communities (Tomalka et al., 2024).

In general, adaptive strategies such as community-based forest management and agroforestry, along with national policies like the CRGE, provide a solid foundation for enhancing forest conservation and climate resilience in Ethiopia. However, the effectiveness of these strategies is contingent on addressing challenges such as policy implementation gaps, land tenure issues, and the integration of local knowledge into forest management practices. Future efforts should focus on scaling up these approaches, improving

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governance structures, and fostering greater community involvement to ensure that forest ecosystems in Ethiopia can withstand the pressures of climate change and contribute to sustainable development.

Community-Based Forest Management: Opportunities and Challenges

Community-Based Forest Management (CBFM) has emerged as a promising strategy for promoting sustainable forest conservation while enhancing the resilience of local communities in Ethiopia. Recent studies underscore the potential of CBFM to foster collaboration between local communities, government agencies, and non-governmental organisations to address the dual challenges of deforestation and climate change. CBFM involves local communities in decision-making processes regarding the management of forest resources, which can help reduce illegal logging, enhance forest regeneration, and ensure sustainable resource use (A. B. Abera, 2021). One of the primary benefits of CBFM is its ability to align conservation efforts with the socio-economic needs of local populations, thereby increasing community support and participation in sustainable forest management practices. A study by Weiskopf et al. (2020) found that CBFM not only improves forest health but also strengthens social ties and governance structures within local communities, making it a powerful tool for building both environmental and social resilience (Weiskopf et al., 2020).

However, despite its potential, several challenges hinder the successful implementation of CBFM in Ethiopia. One of the major obstacles is the issue of land tenure, as many rural communities do not have secure land rights, making it difficult to incentivise long-term investment in forest management (Dagim, 2015). The lack of clear land ownership often leads to conflicts over resource use, with external factors, such as commercial interests and migrants, exacerbating pressure on forest resources. Moreover, the effectiveness of CBFM is compromised by inadequate policy frameworks, weak enforcement of existing regulations, and limited financial resources to support community-driven initiatives (Mekonnen et al., 2018). Studies have shown that while community engagement is crucial for forest conservation, the absence of strong institutional support and the persistence of land-use conflicts create barriers to the sustainability of CBFM projects.

In addition to these challenges, socio-economic factors such as poverty and dependence on forest resources for livelihoods complicate the implementation of CBFM in Ethiopia. Many communities rely heavily on forests for fuel wood, timber, and non-timber products, which creates a conflict between conservation goals and immediate economic needs. The introduction of alternative livelihood options, such as agroforestry and ecotourism, has been suggested as a way to alleviate this pressure on forests while providing communities with sustainable income sources (Y. A. and A. Bekele, 2017). However, these alternatives require substantial investments in capacity building, technical training, and market access, which remain significant hurdles. Despite these challenges, CBFM has demonstrated notable successes in certain regions, where local communities, with adequate support, have managed to restore degraded lands and increase forest cover.

Policy Gaps and Implementation Challenges in Forest Conservation

Forest conservation in Ethiopia has made notable progress in recent years, but significant policy gaps and implementation challenges continue to hinder the effectiveness of conservation efforts. Recent studies highlight the importance of strong and coherent policy frameworks in achieving sustainable forest management and climate resilience, yet the existing policies often suffer from inconsistencies and poor enforcement (Kassa et al., 2022; Melaku et al., 2014). The Ethiopian government has developed several strategies aimed at forest conservation, such as the Climate Resilient Green Economy (CRGE) initiative, which focuses on increasing forest cover through reforestation and afforestation programs. However, these policies often lack clear and

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enforceable guidelines, leading to difficulties in translating national goals into tangible outcomes at the local level (Kassa et al., 2022; Wiegant et al., 2023). A key issue is the insufficient integration of forest management into broader land-use and development policies, which results in fragmented approaches to conservation and land management, making it difficult to address the complex, interconnected issues of deforestation, land degradation, and climate change effectively (Tilahun et al., 2023).

Another major challenge is the inadequate implementation of existing policies due to weak institutional frameworks and limited financial resources. Despite the presence of national forest policies, local authorities cannot often enforce them. This governance gap is exacerbated by the absence of a coherent monitoring and evaluation system to track the progress of forest conservation initiatives and ensure accountability (Mekonnen et al., 2018). Additionally, studies have shown that forest management in Ethiopia is often undermined by corruption, poor coordination between different stakeholders, and the failure to prioritise forest conservation in local governance structures (A. B. Abera, 2021). Furthermore, land tenure issues remain a significant barrier, as many rural communities lack secure land rights, which diminishes their incentive to invest in long-term forest conservation (Weiskopf et al., 2020). This lack of tenure security leads to land-use conflicts, often with external factors such as commercial interests, exacerbating the pressure on forest resources.

Moreover, socio-economic challenges, such as poverty and dependence on forests for livelihood, complicate the successful implementation of forest conservation policies. Many rural Ethiopians rely on forest resources for fuel wood, timber, and non-timber products, and without viable alternatives, policies that restrict access to forests often face local resistance (Gatiso, 2019). The promotion of alternative livelihood strategies, such as agroforestry and ecotourism, has been proposed as a way to ease the pressure on forests, but these strategies require significant investment in training, market access, and infrastructure (Tebkew et al., 2024). Without addressing these underlying socio-economic issues, policy initiatives may struggle to gain community support and achieve long-term success.

In general, while Ethiopia has made strides in forest conservation through policies like the CRGE initiative, significant gaps in policy coherence, enforcement, and institutional capacity persist. The lack of clear land tenure, weak governance, and socio-economic factors continue to undermine forest conservation efforts. To overcome these challenges, there is a need for a more integrated approach that addresses both the environmental and socio-economic dimensions of forest conservation. Strengthening policy enforcement, improving land tenure systems, and investing in alternative livelihoods for local communities will be critical to ensuring the success of Ethiopia's forest conservation goals in the face of ongoing climate change pressures.

CONCLUSION AND RECOMMENDATIONS

This study underlines the critical challenges faced by Ethiopia's forest ecosystems, primarily driven by the combined impacts of climate change, deforestation, and ineffective policy implementation. The findings highlight that while the country has made strides in forest conservation through initiatives like the Climate Resilient Green Economy (CRGE) strategy and the Green Legacy Initiative, there are significant barriers to success. These include weak policy enforcement, insecure land tenure, and insufficient community involvement in forest management. Additionally, socio-economic pressures such as poverty and over-reliance on forest resources for livelihoods further complicate efforts to combat deforestation and degradation. The importance of addressing these challenges cannot be overstated, as Ethiopia’s forests play a crucial role in climate regulation, biodiversity conservation, and providing essential ecosystem services.

Given these key findings, it is essential that future research and conservation efforts focus on improving policy coherence, strengthening local governance, and integrating community-based

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forest management (CBFM) approaches. Future studies could explore the long-term effects of current policies, particularly focusing on the success of reforestation and afforestation initiatives under the CRGE framework. Additionally, research should delve into the socio-economic aspects of forest conservation, particularly the role of alternative livelihoods like agroforestry and ecotourism, in reducing pressure on forests. Understanding the socio-economic barriers to sustainable forest management and integrating local knowledge into national policies could significantly improve the effectiveness of conservation programs.

One of the primary limitations of this study is the lack of granular, field-level data on the actual outcomes of the national programs, which hinders a comprehensive evaluation of their impact. Future studies could address this gap by conducting longitudinal assessments of the CRGE and Green Legacy programs, examining their implementation at the local level. Additionally, more in-depth research is needed to explore the potential of integrating innovative financing mechanisms, such as public-private partnerships, to support forest conservation and restoration efforts.

In general, while Ethiopia has made progress in addressing forest loss and degradation, overcoming the barriers of policy gaps, weak enforcement, and socio-economic pressures remains essential. Strengthening governance, securing land tenure, and fostering community involvement in forest management are critical steps for ensuring the sustainability of Ethiopia's forests. Furthermore, expanding research to include more context-specific studies on forest resilience, socio-economic factors, and alternative livelihoods will be vital for advancing forest conservation efforts. Ultimately, the success of these initiatives will have far-reaching implications not only for Ethiopia's environment but also for global climate change mitigation and biodiversity conservation.

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Competing of Interest

The author declares that there is no conflict of interest.

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