Original Article

Synthesis of Deforestation and Forest-Based Climate Change Mitigation Strategies in Ethiopia: Review

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ABSTRACT

Despite diverse ecosystems and rich biodiversity, Ethiopia faces severe environmental challenges, including deforestation, land degradation, and climate variability and change. In Ethiopia, the forest cover dramatically decreased from 40% in the 19th century to 3% in 2000, largely due to agricultural expansion, population growth, and weak forest governance. Deforestation not only threatens biodiversity but also exacerbates the country's climate vulnerabilities, which is heavily dependent on rainfed agriculture. This study provides an overview of deforestation and forest-based climate mitigation strategies in Ethiopia. The review comprehensively examined over 80 documents, including peer-reviewed journal articles, MSc theses, reports, and policy documents from 2002 onwards. The findings revealed that the deforestation rate decreased by 69.8% from 2000 to 2023. This indicates that forest conservation strategies have been implemented. Ethiopia recently practised different forest-based mitigation strategies, including forest conservation, afforestation and reforestation, REDD+ programs, and agroforestry expansion for increasing forest cover and decreasing the adverse impact of climate variability and change. As a result, the forest cover has increased from 17.2% in 2019 to 23.6% in 2023. Despite significant efforts in the country, institutional weaknesses, political instability, land tenure insecurity, and inadequate policy enforcement continue to hinder sustainable forest management and development. We conclude that deforestation has been reduced significantly in Ethiopia. To strengthen forest-based mitigation efforts, the study recommends improving institutional coordination, enforcing environmental policies, enhancing community engagement, and ensuring data accessibility.

INTRODUCTION

Ethiopia has a wide variety of vegetation, which has been categorised into 12 major vegetation types (Friis, Demissew, and Breugel 2010). This rich biodiversity is largely a result of significant altitudinal variations, ranging from the lowlands of the Danakil Depression to the towering peaks of the Simien Mountains, coupled with distinct climatic conditions (Asefa et al. 2020). This extensive elevation range and associated climatic gradients have shaped a rich tapestry of vegetation types, including the distinct Afromontane rainforests, dry forests, and woodlands (Asefa et al. 2020). These ecosystems are essential not only for preserving their rich biodiversity, including a high number of endemic plant and animal species, but also for providing important ecological functions and socio-economic benefits to the country (Fashing et al. 2022).

Despite its diverse ecosystems, Ethiopia faces significant challenges related to deforestation, land degradation, and climate change and variability. The country's economy and the livelihoods of its predominantly rural population are heavily reliant on rain-fed agriculture, making the country highly sensitive to even slight changes in weather patterns (Daba, Regasa, and Mammo 2025). The country, a nation situated in the horn of Africa, is exceptionally vulnerable to the pervasive impacts of climate change, despite contributing a comparatively small proportion to global greenhouse gas emissions (Castro et al. 2019). Over recent decades, Ethiopia has experienced a discernible increase in mean annual temperatures, coupled with increasingly erratic and extreme weather events, including prolonged droughts, unpredictable rainfall, and devastating floods (Mohammed and Zhi 2025). Since the 1960s, the average temperature has increased by 1°C in the country, and there has been a 20% decline in rainfall in the south-central region (UNFCCC 2021).

Understanding the multifaceted context of climate variability and change in Ethiopia is therefore crucial for developing effective forest-based mitigation strategies to build resilience and ensure sustainable development (Sinore and Wang 2024). These strategies are not only crucial for reducing greenhouse gas emissions but also for enhancing biodiversity, improving livelihoods, and increasing resilience to climate-related shocks. Despite the increasing recognition of forest-based climate mitigation strategies, there remains a substantial gap in the availability of organised, accessible, and comprehensive information on these approaches in Ethiopia. Existing country efforts and mitigation strategies, such as forest conservation, afforestation, reforestation, and agroforestry, remain fragmented, poorly presented, and inadequately disseminated and discussed among stakeholders (Green and Abbadiko 2016). This information gap presents serious challenges for policymakers, researchers, and development partners in designing, implementing, and monitoring effective forest-based climate mitigation strategies and efforts. Therefore, this study aims to review and synthesise the major forest-based climate mitigation strategies in Ethiopia to address these gaps and provide an overview of information on this study area.

METHODOLOGY

This review is a systematic literature analysis approach to synthesise existing knowledge on forest cover trends and forest-based climate mitigation strategies in Ethiopia. This thematic area was outlined into main topics, including deforestation and forest coverage, the impact of climate change, forest-based climate mitigation strategies, and challenges and limitations of mitigation strategies. The authors searched different documents from databases such as Google Scholar, Science Direct, Web of Science, Scopus, and PubMed searching engines. The study used key terms to select appropriate literature, including deforestation, forest cover, forest trend, climate impact, mitigation strategies, afforestation, and agroforestry. All recorded documents were imported into reference management software and de-duplicated automatically, then verified manually. The list of references and citations was managed and organised using Mendeley software. The authors used multiple document types to triangulate, enhance credibility, and minimise bias. We incorporated peer-reviewed journal articles, MSc theses, national reports, country-based international reports, and policy documents, which have been published or accessed since 2002. The reports include organisational repositories such as FAO, UNFCCC, CIFOR, and national institutions like the Ethiopian Ministry of Environment, Forest, and Climate Change.

According to Page et al. (2021), the eligibility criteria and screening techniques (Inclusion and exclusion) were incorporated to select appropriate documents in this review study. The inclusion criteria were based on well-specified reports and peer-reviewed articles, written in English, published since 2002, focusing on deforestation and forest-based climate change mitigation strategies. The exclusion was based on literature that did not focus on the scope of study, irrelevant or low-quality studies, lacked full texts, or did not have a full address. After rigorous screening techniques, 82 documents were selected and included for this review study. These documents cover the scope of the study. This indicates no substantially new themes or concepts and suggests thematic literature saturation. Tables and figures are used for data organisation and presentation. The data analysis process involved systematically organising, synthesising, and interpreting the data and information extracted from the selected documents. A narrative approach was applied to identify and synthesise the patterns, similarities, and differences of data and information from different sources and generate meaningful insights about the study. Finally, the author identified major trends and research gaps in this study.

RESULT AND DISCUSSION

Deforestation and Forest Coverage in Ethiopia

In the past, Ethiopia experienced extensive deforestation and forest degradation. The forests were particularly cleared during the 20th century, leading to sharp declines in forest cover. The country's forest cover has declined dramatically from approximately 40% in the 19th century to less than 3% by the year 2000 (Dessie and Christiansson 2008). In 1989, the forest cover was estimated to be approximately 2.7% (FAO 2002). This alarming deforestation, primarily driven by agricultural expansion, demand for fuelwood collection, weak forest governance, global warming, logging, population growth, urbanisation, grazing, construction of dams and reservoirs (Betru et al. 2019; Hishe et al. 2021; Oljirra 2019). Changes in forest cover in Ethiopia are largely associated with a combination of biophysical conditions and social and economic drivers (Getahun et al. 2013). Despite some afforestation and reforestation efforts today, deforestation and forest degradation are observed in different parts of the country. Research carried out in the Dara district indicated a considerable growth in farmland area, which rose from 113.37 km² (45.35%) in 1990 to 141.92 km² (56.77%) by 2020, and forest cover experienced a sharp reduction over the same period, shrinking from 16.90 km² (6.76%) to 6.25 km² (2.50%) (Kasahun 2025). In the Biodiversity Hotspot Areas of the Semien Mountains National Park, the forest cover and grasslands have decreased by approximately

31% (33,084 ha), while cultivated lands and bare lands have expanded by about 159% (33,387 ha) and 220% (10,121 ha), respectively, over the past 36 years. This decline represents an average annual forest loss of around 1.02% (919 ha) (Debebe et al. 2023). Correspondingly, the forest coverages of Abidibor and Aba Gamta decreased by 28.4% and 19.1 % from 1990 to 2022 in Alle district, southwestern Ethiopia. This indicated that some parts of forests and wetlands had been converted to agricultural and grazing land in the respective period of years (Masha et al. 2024).

Table 1: Key Drivers of Deforestation in Ethiopia

Drivers	Description of drivers	References
Agricultural expansion	Clearing forests for small-scale subsistence farming and large-scale commercial agriculture	(Betru et al. 2019; Dessie and Kleman 2007)
Population growth	Increased demand for land, fuelwood, charcoal, construction materials, and other resources	(Bhatt et al. 2019)
Livestock grazing (Overgrazing)	Overgrazing and the prevention of forest regeneration	(Hishe et al. 2021; Masha et al. 2024)
Commercial logging	Timber harvesting for construction (woodwork) and marketing	(Sisay et al. 2024)
Weak Forest governance and law	Poor enforcement of forest protection laws and a lack of government attention	(Hishe et al. 2021)
Road infrastructure development	This made remote forest areas more accessible for resource utilisation	(Birhane, Tesfaye, and Kim 2020)
Environmental degradation	Soil erosion, reduced amount of land, loss of biodiversity, and increased desertification	(Tadesse and Hailu 2024)
Unstable land tenure systems	Unclear forest ownership discouraged sustainable management and allowed multiple claims on forestland, leading to overexploitation.	(Alemie and Amsalu 2020; Tadesse et al. 2014)
Forest fire	Forest fires refer to uncontrolled fires that burn in forests, grasslands, or other natural areas.	(Debebe et al. 2023)
Political agenda	A set of priorities, goals, or issues that political actors aim to address or promote through policy-making and public action	(Kassaye and Scholar 2024)

Impact of Deforestation and Forest Degradation in Ethiopia

Deforestation significantly contributes to climate change by increasing greenhouse gas emissions, particularly carbon dioxide, which is released back into the atmosphere when trees are cut down or burned (Palmer, Pearson, and Kyriacou 2023). In Ethiopia, the primary contributors to greenhouse gas (GHG) emissions are land use changes, particularly the conversion of forests into agricultural land, application of synthetic fertiliser to crop production, and the widespread reliance on biomass energy sources such as charcoal, firewood, animal dung, and crop residues (Feliciano et al. 2022; Yalew 2022).

Agriculture and land use systems release GHG with around 80 percent of the country's domestic emissions (FAO 2025b). The loss of forest cover not only contributes to rising temperatures but also disrupts local weather patterns, reduces biodiversity, and increases the vulnerability of ecosystems and communities to climate change-related disasters and warming (Seymour and Gibbs 2019). Deforestation has significantly reshaped the socio-economic landscape of Ethiopia, contributing to a wide range of challenges. The loss of forest resources has undermined agricultural productivity and disrupted local food systems, leading to widespread food insecurity. As forests disappear,

many rural communities face declining sources of income and livelihoods, driving them deeper into poverty. This worsening economic hardship has forced many people, particularly in rural areas, to migrate in search of better opportunities, often moving to urban centers or abroad. Furthermore, the social pressures and resource scarcity resulting from deforestation have intensified tensions and contributed to political instability, making it more difficult for the country to achieve sustainable development and social cohesion (Kassaye and Scholar 2024).

Impact of Climate Variability and Change in Ethiopia

Climate change describes persistent shifts in the climate system, characterised by notable changes in average weather patterns and/or fluctuations in its features, typically decades or longer (IPCC 2007). Climate change indicators such as drought, flood, variability of rainfall, and temperature are majorly observable in Ethiopia and affect all sectors with different intensity across the country (UNFCCC 2021). Ethiopia's agriculture sector is extremely vulnerable to climate change due to its high dependence on natural resources and limited adaptive capacity, particularly in rural areas (FAO 2025b). It affects crop production, livestock rearing, land productivity, water availability, biotic growth, rangeland quality, and soil productivity in Ethiopia (Daba et al. 2025).

In recent years, especially in the past four decades, drought has been devastating to people in the arid pastoral regions, and during the same period, flooding has caused significant damage to infrastructure and disrupted livelihoods in other parts of the country (World Bank 2024). Severely, drought affected some regions in Ethiopia, including Borena and Guji Zones, and lowland areas of Bale Zone in the Oromia region; South Omo and Segen Zones, as well as the lowlands of Gamogofa Zone in the SNNP region; and the southern parts of the Somali region, including Fafan, Dollo, Jarar, Korahe, Nogob, and Shebele (FAO 2017). According to the study's estimates, over 1.5 million livestock died due to drought between November 2016 and April 2017 in the southern and southeastern regions, resulting in an economic loss of over USD 350 million (FAO 2017). In the former region in a different year, approximately 172,000 livestock died, and about two million were in poor health conditions due to drought (FAO 2022). Climate change is a driving factor of floods. Flood events occurred in Ethiopia frequently and affected resources and infrastructures (Mamo, Berhanu, and Melesse 2019). In Ethiopia, heavy rains and flooding that occurred in April and early May 2024 affected over 560,000 people, and approximately 57,000 individuals were displaced in various districts and regions (WHO 2024).

Table 2: Impact of the Flood in Some Regions of Ethiopia

Some regions	Impact of the flood in Ethiopia
Oromia region, west Guji	Approximately 120,481 individuals have been impacted, with 102,128 displaced, and five deaths were reported. Over 3,000 houses have been either completely or partially destroyed, and about 13,779 hectares of farmland have been damaged.
Southern Ethiopia	Approximately 4,000 people were impacted, and three deaths were reported.
Central Ethiopia	Around 4,065 people were displaced, with six deaths recorded, around 100 houses destroyed, and 774 hectares of farmland were damaged.
Somali region, Shebelle zone	About 51,000 people were displaced, and two deaths were reported. About 20,365 hectares of irrigation farms were damaged, and about 1,150 livestock were affected.

Source: *Adopted from WHO (2024)*

Studies reveal that climate change will affect different sectors in the upcoming years. According to climate change projections, major crops such as teff, maize, sorghum, barley, and wheat are projected to decline significantly by 2050 due to climate change, with reductions ranging from 21% to 30% in Ethiopia (Solomon, Simane, and Zaitchik 2021). Similarly, climate

change-related risks reduce Ethiopia's GDP growth by 0.5–2.5% annually, potentially rising to 5% by the 2040s in Ethiopia (World Bank 2024). Thus, it concluded that climate change has severely impacted Ethiopia through intensified droughts, frequent floods, significant losses in livestock and crops, infrastructure damage, displacement, and substantial economic setbacks, with projections indicating even greater challenges in the coming decades in Ethiopia. Urgent responses are needed to enhance forest conservation and restoration efforts, prevent land degradation, and mitigate the effects of climate variability and change. Afforestation and reforestation are integral components of mitigation strategies for the adverse impact of climate variability and change (Psistaki and Tsantopoulos 2024).

Forest-Based Climate Mitigation Strategies and Efforts in Ethiopia

Forests play a pivotal role in mitigating climate change, primarily by acting as natural carbon sinks and storing carbon. They absorb vast amounts of carbon dioxide (CO_2) from the atmosphere through photosynthesis and store it in their biomass (trees, roots, leaves, dead wood) and soils (Psistaki and Tsantopoulos 2024). Forest-based climate mitigation efforts in Ethiopia have gained increased attention as the country faces rapid deforestation, land degradation, and climate-related vulnerabilities. The Ethiopian government has prioritised and designed different forest and environmental policies and strategies (Federal Democratic Republic of Ethiopia (FDRE) 2018, 2024; Ministry of Agriculture and Rural Development 2007) to overcome these climate-related problems. Afforestation and reforestation, forest conservation and protection, and agroforestry programs are among the prominent forest-based climate mitigation strategies and initiatives in Ethiopia. These strategies are integrated with national strategies such as the Climate Resilient Green Economy (CRGE) and the National REDD+ Program in the country.

Afforestation and reforestation involve establishing forests on previously non-forested or degraded lands to sequester carbon and restore ecological balance (UNFCCC 2021). They are an integral part of climate change mitigation strategies (Psistaki and Tsantopoulos 2024). Ethiopia's tree-planting campaigns, including the Green Legacy Initiative, aimed at combating the negative effects of climate change, restoring degraded landscapes, enhancing biodiversity, and improving environmental resilience. Additionally, Agroforestry techniques, which involve combining trees with crops and livestock, are being more widely practised throughout the country. Agroforestry not only sequesters carbon but also enhances soil fertility, diversifies farm productivity, enhances food security, and reduces pressure on natural forests. All of these efforts aim to enhance carbon sequestration, restore degraded landscapes, and reduce greenhouse gas emissions, while also improving livelihoods and food security for rural communities and enhancing sustainable development.

Forest Conservation and Protected Area

Forest conservation refers to the careful management and sustainable use of existing forest areas. Its primary aim is to protect, maintain, and restore the health of forests, ensuring their long-term viability. This includes activities, such as preventing deforestation, combating degradation, and promoting the overall well-being of forest ecosystems (EcolegIT 2024). It involves strengthening the management of natural forests by establishing protected areas, enforcing anti-deforestation laws, and implementing sustainable practices to conserve existing carbon stocks. These efforts are crucial for biodiversity conservation, climate regulation, and ecosystem service provision. Forest conservation and protection efforts aim to safeguard existing natural and plantation forests, particularly in biodiversity hotspots and watersheds, through improved management, law enforcement, and community participation. The government of Ethiopia is committed to protecting existing forests, which cover 17.2 million hectares (FDRE 2021).

Ethiopian Wildlife Conservation Authority (EWCA) is a governmental organisation under the Ministry of Tourism, given the authority to undertake the conservation and sustainable utilisation of wildlife resources in Ethiopia, with the establishment of Proclamation (Pro. No. 575/2008) (Fekede 2024). The country has designed a national drylands restoration strategy for protecting forests, parks, protected areas, and natural resources (Ministry of Agriculture and PENHA 2022). This restoration strategy has a strategic objective and strategic actions for protecting forests, parks, and protected areas. It improves the security of parks and protected areas by fostering collaboration among interregional, regional, and federal governments, as well as by enhancing management practices and building stronger relationships with surrounding communities through mutually agreed benefit-sharing arrangements (Ministry of Agriculture and PENHA 2022). Projects are being implemented in southwestern Ethiopia to make forest protection more effective by focusing on the digital collection of forest monitoring data. This involves training local forest management groups in using digital tools to better monitor and protect forests (Verdens Skove 2023). Exclosure is intended to restore degraded forestlands and their biodiversity, and secure a continuous supply of forest products and ecosystem services across the country (Birhane et al. 2020). These efforts contribute to reducing deforestation and degradation, conserving carbon stocks, and safeguarding essential ecosystem functions.

The figure illustrates the deforestation trend across three distinct periods: 2000-2013, 2014-2020, and 2020-2023 in Ethiopia. The blue line, representing total forest loss in hectares (ha), shows a significant decrease over time, starting at 1,192,559 ha for 2000-2013, dropping to 229,163 ha for 2014-2020, and further declining to 110,814 ha for 2020-2023. Similarly, the orange line, which indicates the annual forest loss in hectares per year (ha/yr), also demonstrates a decreasing trend, from 91,735 ha/yr for 2000-2013, to 38,194 ha/yr for 2014-2020, and finally to 27,703 ha/yr for 2020-2023 (Figure 1). Overall, the data suggest a positive trend of decreasing deforestation over these periods in the country. This is probably linked to the commitment of the government to forest conservation and protection through Participatory Forest Management in Ethiopia.

Figure 2: Trends in Deforestation Rates in Ethiopia (2000–2023)
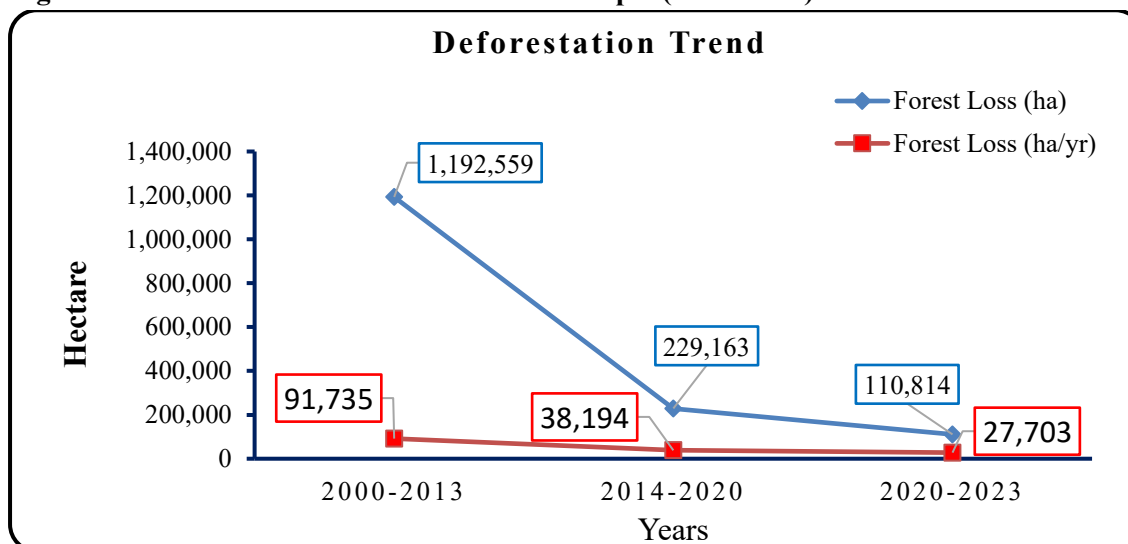
Source: *Adopted from Sebrala et al. (2024)*

Natural forest regeneration has been promoted in high-carbon-accumulating areas to maximise climate benefits. Natural forest regeneration offers considerable climate mitigation potential in regions with high carbon accumulation rates through carbon sequestration (Tomalka et al.

2024). The study revealed that the average carbon stocks in the grazing lands of Abijata-Shalla Lake National Park were 112.3 t C ha⁻¹ for aboveground biomass, 22.5 t C ha⁻¹ for belowground biomass, 6.9 t C ha⁻¹ for deadwood, and 0.95 t C ha⁻¹ for litter (Tilahun, Zewdu, and Ebro 2022). The average above-ground and below-ground biomass carbon stocks in the Lowland Area of Simien Mountains National Park were 270.89±154.50 t ha⁻¹ and 54.18±30.81 t ha⁻¹, respectively (Simegn, Soromessa, and Bayable 2014).

Afforestation and Reforestation

Reforestation and afforestation are two methods of tree planting in places presently without forests (Tomalka et al. 2024). Reforestation is the process of replanting trees in an area that previously had existing forests and woodlands that have been harvested, depleted, damaged, or destroyed (Zhang 2017). This often occurs due to deforestation, wildfires, logging, or other natural disturbances. Afforestation involves planting trees to create a new forest in a place that has not had a forest for a very long time (often defined as 50 years or more) (Zhang 2017). This could be on grasslands, agricultural land, deserts, or barren areas. These techniques help to mitigate climate change by capturing atmospheric carbon through biological sequestration and storing it in living and dead biomass within ecosystems, such as tree biomass and soil organic carbon (UNFCCC 2013).

Ethiopia has been actively engaged in reforestation and afforestation efforts to increase forest cover and reduce toxic gases, climate change, and deforestation (EPA 2023). The key methods employed include the widely acclaimed Green Legacy Initiative (GLI), which has mobilised millions of citizens to plant billions of tree seedlings, aiming to dramatically increase forest cover and combat climate change and environmental degradation (United Nations Environment Programme (UNEP) 2019). The government of Ethiopia has approved a policy on special fund allocation, which allows about 0.5% to 1% of the annual federal budget for restoring degraded landscapes and increasing forest cover in the country (ENA 2025).

In recent years, several regions have made significant contributions to Green Legacy initiatives in Ethiopia. Oromia consistently led in the number of seedlings planted, about 1,900 million in 2019, increasing to 2,750 million in 2020, and 3,700 million in 2021. The Southern Nations, Nationalities, and Peoples' Region (SNNPR) planted about 1,400 million seedlings in 2019, followed by 1,500 million in 2020, and 1,000 million in 2021. The Amhara region contributed to planting seedlings of about 1,600 million in 2019, 1,475 million in 2020, and 1,200 million in 2021. Overall, the Oromia region demonstrated the highest total with 8,350 million seedlings, followed by Amhara with 4,275 million, and SNNPR with 3,900 million over the three years approximately. The table represents the number of seedlings planted in millions across these regions for the last three years. Moreover, Ethiopia planted more than 31 billion plants in the green legacy project, which indicated that it was combating deforestation and promoting reforestation across the country (EPA 2023).

Table 3: No. of Seedlings Planted in Millions for the Last 3 Years by Some Regions of Ethiopia

| No	year	Some regions in Ethiopia			
		Sidama	SNNPR	Oromia	Amhara
1	2019	-	1,400	1,900	1,600
2	2020	-	1,500	2,750	1,475
3	2021	60	1,000	3,700	1,200
Total		60	3,900	8,350	4,275

All figures in the table are approximate values

Source: *Adopted from Beyene & Shumetie (2023)*

As a result, the forest coverage has increased over three distinct periods: 2000-2013, 2014-2020, and 2020-2023 in Ethiopia. From 2000 to 2013, the forest coverage was approximately 15.5%. Ethiopia has been significantly increasing its forest cover from 17.2% in 2019 to 23.6% in 2023 (Ethiopian News Agency (ENA) 2024; Policy Studies Institute (PSI) 2024). This implies that the most significant increase occurred between 2020 and 2023, during which forest coverage rose sharply. The figure demonstrates a positive trend in forest coverage, with a notable acceleration in the most recent period in the country. This indicated that efforts have been made to improve the survival rate of planted seedlings, with growing community awareness about the importance of forests in the country. Recently, Ethiopia has intended to undertake large-scale afforestation and reforestation to increase total forest cover to 30% by 2030 (FDRE 2017, 2021). The forestry industry is projected to yield more than 100 million USD in revenue from carbon sales by 2030 (EPA 2023). Studies conducted in different parts of the country have supported the above findings regarding the increase in forest coverage in Ethiopia. For instance, a study conducted in the Fagita Lekoma district revealed that forest cover increased between 2003 and 2017 due to the expansion of *Acacia decurrens* (Belayneh et al. 2018).

Figure 3: Recent Trends in Forest Cover in Ethiopia (2000–2023)
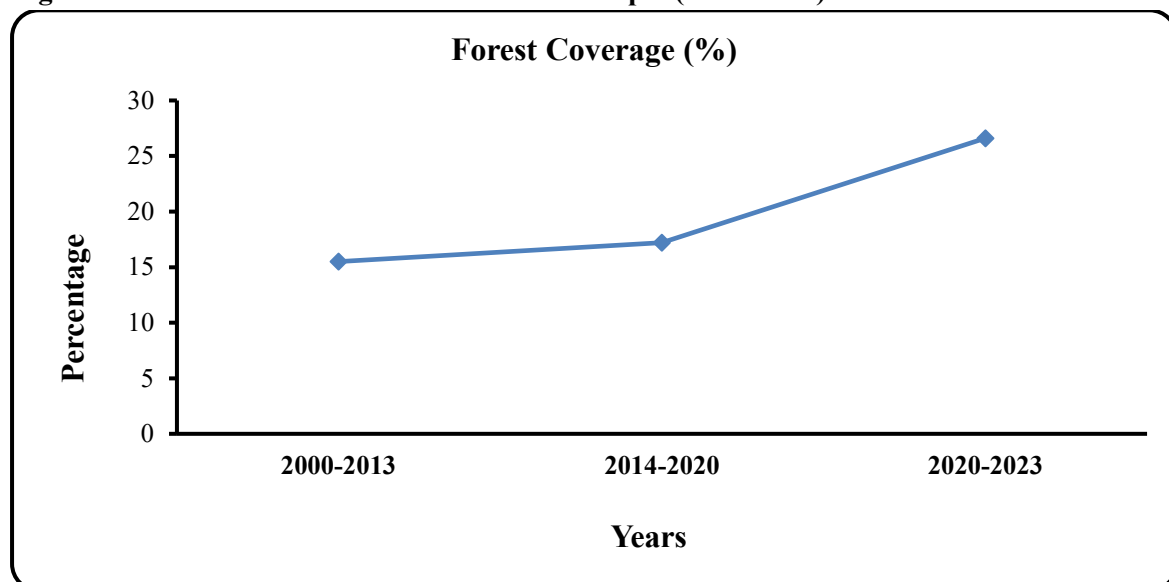
Source: *Adopted from Sebrala et al. (2024)*

REDD+ Initiatives

Ethiopia has made notable progress in implementing REDD+ (Reducing Emissions from Deforestation and Forest Degradation) as part of its broader climate change mitigation and sustainable development agenda. The country has embraced REDD+ initiatives as a cornerstone of its climate change mitigation strategy, aiming for a carbon-neutral and climate-resilient society by 2030 through its Climate Resilient Green Economy (CRGE) Strategy (UN-REDD programme 2024). These initiatives primarily focus on reducing emissions from deforestation and forest degradation, while also promoting forest conservation, sustainable forest management, and enhancement of forest carbon stocks (FAO 2025a).

The government of Ethiopia launched the first REDD+ (Reducing Emissions from Deforestation and Forest Degradation) project in 2012 in the Bale Eco-region by Farm Africa and partners. The project, based on Participatory Forest Management (PFM), aimed to reduce deforestation by incentivising forest conservation through carbon credit sales. Between 2012 and 2015, the project achieved a 62% reduction in deforestation, saving 12,496 hectares of forest and preventing 5.5 million tonnes of CO_2 emissions

(Lemenih and Biot 2012). Farm Africa and a consortium of partners have been working in Ethiopia's Bale Eco-region on a participatory forest management scheme. The project not only enhanced the livelihoods of more than 350,000 individuals within Bale but also ensured the continued provision of vital ecosystem services to 12 million people beyond the borders of the forest. Furthermore, it assisted the Ethiopian government in developing enduring strategies for forest conservation by integrating the participatory forest management into national forestry and REDD+ policies and programs. In the period of 2019 2022, the project preserved 25,133 hectares of forest from deforestation and prevented 10.5 million tonnes of CO_2 emissions (Farm Africa 2019).

Agroforestry and Integrated Land Use

Integrating trees with crops and livestock farming systems is used to improve land productivity, store carbon, and provide multiple benefits such as fuelwood, fodder, and fruits. The Ethiopian government has been actively promoting agroforestry practices as a key strategy to combat the negative effects of climate change and enhance food security across the country. Various institutions play distinct roles in the country's agroforestry practices (ICRAF 2015). The Ministry of Agriculture (MoA) is responsible for overseeing the extension system and integrating agroforestry into the agricultural landscape. The Ministry of Environment and Forests (MEF) is responsible for creating and implementing policies and strategies aimed at developing the nation's forests and agroforestry. Both the Institute of Biodiversity Conservation Research (IBCR) and the Ethiopian Environment and Forest Research Institute (EFER) play leading roles in influencing government policies related to agriculture, forestry, and agroforestry. The Ministry of Science and Technology (MoST) is expected to establish an agroforestry technology transfer framework to promote capacity building. Finally, the Regional Bureau of Agriculture and Rural Development (BoARD) is tasked with implementing regional agroforestry regulations and managing the technical preparation of natural resource management plans.

Table 4: Most Relevant Institutions and Their Roles in Agroforestry Practices in Ethiopia

Some institutions in Ethiopia	Role of institutions in agroforestry practices
Ministry of Agriculture (MoA)	Involves leading the agricultural extension system and strategising how agroforestry can be integrated into existing agricultural land use
Ministry of Environment and Forests (MEF	Developing policies and strategies for forests, agroforestry, and the associated landscape
Institute of Biodiversity Conservation Research (IBCR)	The institution plays a prominent role in guiding the creation of policies and strategies on agricultural and agroforestry
Ethiopian, Environment and Forest Research Institute (EFER	The institution takes a leading role in influencing the development of government policies related to forestry and agroforestry.
Ministry of Science and Technology (MoST)	Expected to create an agroforestry technology transfer framework that can promote capacity building on the use of agroforestry techniques.
Regional Bureau of Agriculture and Rural Development (BoARD)	Responsible for implementing regional agroforestry regulations and overseeing the technical organisation of natural resource management plans

Source: *Adopted from ICRAF (2015)*

Ethiopia's national policies, particularly the Climate Resilient Green Economy (CRGE) strategy (Federal Democratic Republic of Ethiopia (FDRE) 2019) and the National Agroforestry Development Strategy (2020-2030) (Regreening Africa 2022), explicitly recognise agroforestry as a key component for achieving green growth and climate resilience. The strategy

consists of eight objectives (Table 5). The strategy aims to ultimately reduce greenhouse gas emissions and build adaptive capacity within vulnerable communities. The government's initiatives, supported by programs like the Sustainable Land Management Programme (SLMP) and the Climate Resilient Forest and Landscape Restoration (CRFLR) Program (Global Green Growth Institute (GGGI) 2022), demonstrate a commitment to scaling up agroforestry practices to combat climate change while simultaneously enhancing food security and rural livelihoods in different parts of the country.

Small- to medium-scale agroforestry projects have demonstrably proven their efficacy in restoring degraded lands and enhancing food security across various regions of Ethiopia, including Tigray, southern Oromia, and Amhara (ICRAF 2015). The rate of adoption of agroforestry practices substantially accelerated from 0.23% before 1980 to 3.95% during the period from 2011 to 2022 (Yirga et al. 2024). This indicates a significant acceleration in the adoption and implementation of agroforestry practices over recent decades in Ethiopia.

Table 5: Objectives of National Agroforestry Development Strategy (2020-2030) in Ethiopia

No	Some objectives of the agroforestry development strategy in Ethiopia
1	Create an enabling policy environment and resourced institutional framework (structure and systems) to support the implementation of the strategy and enhance agroforestry development.
2	Enhanced extension system, knowledge management, and communication for agroforestry
3	Establish/strengthen the agroforestry input supply system.
4	Improve the production, productivity, and service roles of agroforestry in all agro-ecological zones of Ethiopia through a wide range of demonstration, dissemination, and implementation of best agroforestry practices and technology packages.
5	Develop agroforestry value chains to facilitate smallholders' access to the market for agroforestry products.
6	Strengthen innovative research and collaborations for agroforestry development.
7	Create incentives for agroforestry adoption and partnerships.
8	Empower women and youth through agroforestry development.

Source: *Regreening Africa (2022)*

Agroforestry is a sustainable land management approach that integrates trees with crops, livestock, or both within the same land area (Gassner and Dobie 2022). Integrating trees with crops and livestock on the same land-use system helps capture atmospheric carbon dioxide and store it in biomass and soil, thereby reducing greenhouse gas concentrations. It contributes not only to climate change adaptations but also to mitigation efforts through carbon sequestration, thereby helping to reduce greenhouse gas concentrations (Tomalka et al. 2024). Agroforestry systems with perennial trees sequester carbon more effectively than conventional land use practices (Hailu 2025). The tree component, including fruit trees such as papaya, avocado, and mango, has a large share in carbon sequestration in the integration of tree, coffee, and enset agroforestry systems (Semere, Cherinet, and Gebreyesus 2022). The overall mean carbon sequestration in the present coffee agroforestry systems was 287.1 t C/ha in the agroforestry systems of Southwestern Ethiopia (Niguse and Iticha 2022). The study reveals that the mean total biomass carbon in the three-agroforestry practices, namely, multistory, woodlots, and parkland, were 40.7 ton ha^{-1}, 20.8 ton ha^{-1}, and 5.4 ton ha^{-1}, respectively, in Ethiopia (Getnet, Mekonnen, and Anjulo 2023). The total mean carbon stock of parklands practice in Minjar Shenkora of Ethiopia was 59.65 Mg C ha^{-1} (Tsedeke, Dawud, and Tafere 2021).

Challenges and Limitations in Ethiopia's Forest-Based Climate Mitigation Efforts

Despite forest-based interventions, challenges remain in terms of financing, institutional coordination, and technical capacity in the country. The effectiveness of forest-based mitigation is often constrained by inadequate

policy enforcement, limited access to reliable data, and insufficient community engagement. Strengthening policy coherence, enhancing monitoring and follow-up systems, and ensuring equitable benefit-sharing mechanisms are critical to scale up and sustain Ethiopia's forest-based climate mitigation actions. Below are the major challenges and limitations:

Poor institutional arrangement: The Green Legacy Initiative in Ethiopia suffered from inadequate integration and coordination among stakeholders such as government agencies, local administrations, communities, extension services, and research institutions. This is a lack of clear responsibility of the institutions, both at the federal and regional levels (Beyene and Shumetie 2023). This disconnect limits the effectiveness of planning, knowledge sharing, and resource utilisation, ultimately undermining the success and sustainability of forestry initiatives. A more collaborative and well-aligned approach among these stakeholders is essential to ensure scientifically informed, locally adapted, and practically feasible plantation programs.

Lack of security and political instability: The prevalent lack of security and political instability across various regions of Ethiopia (e.g., Oromia region, such as Borena and Western Wollega, and the northern part of the country, Tigray and Amhara regions) significantly hampers afforestation and reforestation efforts (Beyene and Shumetie 2023). This instability undermines tenure security and makes communities reluctant to invest in long-term reforestation projects when their land rights or the benefits from their efforts are uncertain. The focus on immediate humanitarian and security concerns often overshadows long-term environmental strategies, leading to a diminished capacity for the government and other stakeholders to effectively implement and sustain greening programs in the country. In essence, a volatile environment makes it exceedingly difficult to foster the stable conditions and community engagement essential for successful large-scale afforestation and reforestation programs.

Inadequate policy enforcement and governance: Inadequate policy enforcement and governance have significantly undermined forest conservation efforts in Ethiopia, despite the existence of legal frameworks and strategies aimed at protecting and managing forest resources. Weak institutional capacity, limited coordination among government agencies and insufficient funding have hampered the implementation of forest protection laws and regulations. Moreover, the lack of trained personnel and monitoring systems makes it difficult to detect and prevent illegal logging, land encroachment, and deforestation (Mekuria 2025).

Land tenure insecurity and community rights: Land tenure insecurity is a significant barrier to the development of plantation forestry in Ethiopia (Lemenih and Kassa 2014; Tadesse et al. 2015). When individuals or communities lack clear and legally recognised rights regarding land use systems, they are often discouraged from making long-term investments such as tree planting. Plantation forestry requires years, sometimes decades, before it yields returns, and without guaranteed ownership or use rights, farmers and investors may fear losing access to the land before they can benefit from their efforts. This uncertainty undermines confidence, limits private sector involvement, and reduces the motivation of smallholders to engage in sustainable forestry practices.

Poor silvicultural practices: The use of proper silvicultural practices both during the establishment and after the planting of various plantation species remains underdeveloped in Ethiopia. This limitation reflects a lack of comprehensive planning, technical capacity, and follow-up management in plantation forestry. As a result, many forest plantations fail to achieve their intended goals in terms of survival rate, growth performance, productivity, and sustainability. Key silvicultural activities such as site preparation, species-site matching, spacing, pruning, thinning, and pest and disease control are often inadequately implemented in the country (Lemenih and Kassa 2014; Tadesse et al. 2019). In Ethiopia, tree planting campaigns often focus on the number of planted seedlings but pay less

attention to the management of planted trees. Lack of weeding, mulching, and watering after planting reduces the survival rate of trees.

Forest fire incidence: Forest fire incidence in Ethiopia has become an increasingly serious environmental concern, particularly in the highland and montane forest regions such as the Bale Mountains and Simien Mountains (Livingstone et al. 2022). These fires are often triggered by human activities, including agricultural expansion, illegal honey harvesting, charcoal production, and the use of fire for land clearing. Climate change has also intensified the frequency and severity of wildfires due to rising temperatures, prolonged dry seasons, and erratic rainfall patterns. Forest fires not only lead to the loss of biodiversity and forest cover but also contribute to greenhouse gas emissions, soil degradation, and the disruption of local livelihoods. Despite growing awareness, limited institutional capacity, lack of early warning systems, and weak enforcement of forest protection laws have hindered effective prevention and control of forest fires in Ethiopia.

CONCLUSION AND RECOMMENDATION

The study underlined that the main livelihood of Ethiopia has been challenged by the combined impacts of climate change, deforestation, and forest degradation. There has been an ongoing debate in the literature regarding forest cover change in Ethiopia.. Forest loss to agricultural expansion, population pressure, commercial logging, weak forest governance and law, and unsustainable land use practices were factors for the reduction of forest cover in Ethiopia. However, deforestation is reduced and forest cover change is increasing by about 23.6%. The change has been improved by government-led initiatives, such as reforestation programs, afforestation efforts, forest conservation, and natural regeneration activities, for not only increasing forest cover but also sequestering carbon and reducing emissions of greenhouse gases. On the other hand, there is still deforestation in the highlands of Ethiopia for agricultural land expansion, an increase in fuel wood demand and grazing land due to high population growth. We recommend clear and strong law enforcement, expansion of agroforestry approaches by incorporating multipurpose trees (fodder, fuel and timber) and incentive mechanisms for those farmers and communities engaged in forest conservation approaches.

Author Contribution Declaration

Mulat Shibabaw originated the idea, designed the review study, wrote the paper, and reviewed the manuscript in total. Sewale Wondimneh reviewed and improved the pepper.

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The authors declare no conflict of interest.

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