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The Federal Democratic Republic of Ethiopia
Ethiopian Forestry Development

FOLUR
Food · Land Use · Restoration
ETHIOPIA

FOLUR Project "Preventing Forest Loss, Promoting Restoration, and Integrating Sustainability into Ethiopia's Coffee Value Chains and Food Systems"

TITLE: **Forest Cover Change Analysis in Ethiopia's Coffee Forest Systems: A Case Study of the Yayu and Kafa Biosphere Reserves**

February, 2025

Addis Ababa

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1. Introduction

Forests are essential to the global carbon cycle and the preservation of biodiversity (Feysel and Abdi, 2020[1]). Ethiopia stands out as one of Africa's key nations for biological resources, featuring a rich variety of flora and fauna (Abiyot et al., 2019[2]). To tackle the effects of climate change while promoting socio-economic growth, Ethiopia has integrated climate resilience into its development strategies, notably through the Climate Resilient Green Economy (CRGE) initiative (Dessalegn and Tesfaye, 2018[3]). This initiative aims to achieve middle-income status by 2025, following a carbon-neutral development path way (Fisseha et al., 2019[4]).

Forests are crucial to this vision, serving both as a strategy to reduce greenhouse gas emissions and as providers of vital ecosystem services. Reducing Emissions from Deforestation and Forest Degradation (REDD+) program plays a pivotal role in achieving these goals within the forestry sector (Tegenu and Yordanos, 2021[5]). In this regard the Ethiopian Forestry Development (EFD) is tasked with implementing REDD+ initiatives, supported by a robust Measurement, Reporting, and Verification (MRV) system to ensure effective and reliable forest monitoring at both national and regional levels (Abiyot et al., 2015[6]).

The Ministry of Planning and Development (MoPD), in collaboration with its partners, is implementing the “Preventing Forest Loss, Promoting Restoration and Integrating

[1] Feysel Mohd and Abdi Kedir (2020). "The state of biodiversity in Ethiopian forests: An overview." *Ethiopian Journal of Science and Technology*, 13(2): 139-145.

[2] Abiyot Berhanu, Zerihun Woldu, Sebsebe Demissew and Seid Melesse (2019). Temporal Vegetation Cover Dynamics in Northwestern Ethiopia: Status and Trends. Ethiopian Journal of Biological Sciences. 18(2): 123–143.

[3] Dessalegn Ayele and Tesfaye Awas (2018). Ecology of vascular epiphytic plants in Gedeo agro-forestry system, southern Ethiopia. International Journal of Current Research 10:02, pp. 64849-64854.

[4] Fisseha Asmelash, Tamrat Bekele and Zerihun Belay (2019). Comparative field survival and growth of selected Ethiopian native tree species and the effect of whole soil arbuscular mycorrhizal fungi inoculation. Journal of Horticulture and Forestry 11(2):19-31.

[5] Tegenu Mekuria and Yordanos Germame (2021). Woody species composition and community analysis of Ezanitula forest in Chencha woreda, Southwestern Ethiopia. Asian Journal of Plant and Soil Sciences 7(1): 237-246.

[6] Abiyot Berhanu, Sebsebe Demissew, Zerihun Woldu and Motuma Didita (2015). Woody Species Composition and Structure of Kuandisha Evergreen Afromontane Forest Fragment, Northwestern Ethiopia. Journal of Forestry Research 28: 343-355.

Sustainability into Ethiopia's Coffee Value Chains and Food Systems" project under the GEF-7 Food Systems, Land Use and Restoration (FOLUR) Impact Program. Funded by the Global Environment Facility (GEF) through UNDP Ethiopia, the project promotes integrated landscape planning and sustainable production practices in forested regions of Ethiopia.

One of the project's key components is the conservation and restoration of natural habitats through Participatory Forest Management (PFM), with a focus on protecting indigenous Afromontane forests (Elias and Getachew 2002[7]). These forests provide essential ecosystem services for agriculture and play a significant role in climate change mitigation. EFD serves as a co-implementing partner for this component, leading the activities under Outputs 3.1 and 3.2, including forest geospatial analysis (Activities 3.1.1 and 3.2.1).

The Yayu and Kafa Biosphere Reserves are two of Ethiopia's most ecologically and culturally significant protected areas. The Yayu Biosphere Reserve, located in the Oromia Region of Ethiopia, is a UNESCO-designated site recognized for its unique biodiversity and cultural significance. Established in 2010, it spans approximately 167,000 hectares and is renowned for its dense forests, which are part of the Afromontane biodiversity hotspot (Amsalu et al., 2013[8]). The reserve is particularly famous for its wild coffee (Coffea arabica) populations, which are of global importance as they represent the genetic origin of cultivated coffee.

Yayu forest is also home to a variety of endemic plant and animal species, making it a critical area for conservation. The local communities have a deep cultural connection to the forest, relying on it for coffee production, traditional medicine, and other forest resources. The biosphere reserve aims to balance conservation efforts with sustainable development, promoting eco-friendly practices and supporting the livelihoods of the indigenous population (Elias and Solomon, 2020[9]).

The Kafa Biosphere Reserve, also in Ethiopia, is situated in the Kafa Zone of the Southwest Ethiopia Region. Designated by UNESCO in 2010, it covers an area of about 760,000 hectares and is named after the ancient Kingdom of Kafa, which is believed to

[7] Elias Taye and Getachew Berhan (2002). Regeneration status of moist montane forests of south west Ethiopia.

[8] Amsalu Amsalu, B. Lemenih, and J. K. N. Asfaw (2013). "Impacts of land use change on ecosystem services and carbon stocks in the highlands of Ethiopia." *Ecosystem Services*, 4: 57-68.

[9] Elias Amare and Solomon Mulugeta (2020). "Assessment of tree species diversity and their potential in carbon sequestration in the Yayo Forest." *Journal of Sustainable Forestry*, 39(6): 492-507.

be the birthplace of coffee (Tarris and Soromessa ,2021[10]). The reserve is characterized by its lush montane rainforests, which are rich in biodiversity and house numerous endemic species, including the critically endangered Ethiopian wolf and various bird species. Like Yayu, Kafa is deeply intertwined with the history of coffee, as it is here that coffee was first discovered and cultivated.

The local communities, who have lived in harmony with the forest for centuries, practice traditional agroforestry and sustainable land use. The biosphere reserve focuses on conserving this unique ecosystem while fostering sustainable economic activities, such as eco-tourism and organic coffee production, to benefit the local population. Both Yayu and Kafa Biosphere Reserves are vital for preserving Ethiopia's natural heritage and promoting global biodiversity conservation.

Forests are crucial for sustaining global biodiversity and maintaining ecological balance, particularly in regions rich in biological resources like Ethiopia (Seyoum and Assefa 2018[11]). Recognized as one of Africa's biodiversity hotspots, Ethiopia is home to a wide array of flora and fauna, many of which exist nowhere else on the planet (Abdulahi and Oumer 2021[12]). Understanding forest dynamics is essential for the nation's environmental health and is intrinsically linked to the livelihoods of communities that depend on these ecosystems (Hassan and Yilma, 2016[13]).

The Ethiopian government has integrated climate resilience into its development strategies, most notably through the Climate Resilient Green Economy (CRGE) initiative, which seeks to achieve middle-income status by 2025 while adhering to a carbon-neutral

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[10] Seyoum Tesfaye and Assefa Abate (2018). "Ecological importance of the Sodo Afromontane forest, Ethiopia." *International Journal of Biodiversity and Conservation*, 10(11): 385-392.

[11] Seyoum Tesfaye and Assefa Abate (2018). "Ecological importance of the Sodo Afromontane forest, Ethiopia." *International Journal of Biodiversity and Conservation*, 10(11): 385-392.

[12] Abdulahi Mohammed and Oumer Mohammed (2021). "Forest degradation in Ethiopia: Causes and implications for sustainable development." *Journal of Environmental Protection*, 12(2): 70-83.

[13] Hassan H. D. and N. G. Yilma (2016). "Assessing the contribution of forests to the livelihoods of rural households in Ethiopia." *Journal of Rural Studies*, 45: 93-104.

growth trajectory (Bashir and Teshome, 2020[14]). Forests play a pivotal role in this vision; they serve as carbon sinks that reduce greenhouse gas emissions and provide essential ecosystem services.

This study report presents the forest cover change analysis undertaken for Yayu and Kafa Biosphere Reserves for the period between 2016 and 2025. The main objective of this study is to map the dynamics of forest cover change in the Yayu and Kafa Biosphere Reserves from 2016 to 2025. This analysis aims to provide crucial insights that will support the development of evidence-based conservation strategies. Through understanding of these dynamics, the study seeks to contribute to sustainable land management practices.

2. Significance of the Study

Yayu and Kafa Biosphere Reserves are not only ecologically important but also culturally significant, providing a unique context for the study. The presence of wild coffee populations in Yayu and the historical importance of coffee cultivation in Kafa make these areas critical for both local communities and global biodiversity. This study's examination of forest cover changes between 2016 and 2025 will aid in understanding how current land use practices intersect with traditional livelihoods, thereby helping to identify sustainable management strategies that accommodate both ecological preservation and socio-economic needs.

Moreover, the study aligns with the goals of the "Preventing Forest Loss, Promoting Restoration and Integrating Sustainability into Ethiopia's Coffee Value Chains and Food Systems" project. Funded by the Global Environment Facility (GEF), this initiative emphasizes the nexus between forest conservation and sustainable agricultural practices, particularly in coffee production. Hence, mapping forest cover dynamics, this study contributes valuable data to support integrated landscape planning, which is necessary for achieving the dual objectives of forest conservation and enhanced agricultural productivity.

This study ultimately seeks to develop evidence-based recommendations for policymakers, conservationists, and local stakeholders that can help balance the need for coffee production in these regions with long-term biodiversity preservation. In this way, the study serves not only as a critical assessment of current forest conditions but also as

[14] Bashir Abdela and Wolelaw Teshome (2020). "Community-based forest management in Ethiopia: Challenges and prospects." *Forestry,* 93(6): 767-775.

a roadmap for sustainable land management that benefits both people and the biosphere reserve areas.

The significance of this study lies in its potential to inform policies and programs, such as Ethiopia's Reducing Emissions from Deforestation and Forest Degradation (REDD+) framework. It is crucial for conducting a forest cover change analysis in the Yayu and Kafa Biosphere Reserves, to contribute vital information to the ongoing discourse around biodiversity conservation and sustainable land management in Ethiopia.

3. Objective

The main objective of this study is to map forest cover change dynamics between 2016 and 2025 in the Yayu and Kafa Biosphere Reserves.

With specific objectives

- To quantify and map spatiotemporal forest cover changes in the Yayu and Kafa Biosphere Reserves from 2016 to 2025 using multi-temporal satellite imagery and GIS techniques.
- To analyze the land use land cover change matrix of the biosphere reserves
- To develop management strategies that balance forest coffee production with biodiversity preservation based on the forest cover dynamic.

4. Methodology

This study employs a robust, satellite-based approach to map forest cover change of Yayu and Kafa Biosphere Reserves for the period between 2016 and 2025, utilizing high-resolution Planet NICFI imagery and advanced geospatial processing techniques. The methodology consists of data acquisition, preprocessing, and classification.

4.1. Satellite Data Acquisition

4.1.1. Planet NICFI Imagery

To achieve high-precision forest cover mapping, Planet NICFI (Norway’s International Climate & Forests Initiative) Level-1 satellite imagery was selected due to its:

- High spatial resolution (4.77 m), enabling detection of small forest patches and fragmented landscapes.
- Monthly temporal coverage, ensuring up-to-date observations.
- Free availability for tropical regions, making it cost-effective for large-scale forest monitoring.

- Consistent acquisition schedule, reducing gaps in data availability.

Image Selection & Mosaicking:

- Timeframe: Two date image acquisition: December 2015 – June 2016 and May 2025 – July 2025 (minimizing cloud interference and optimizing vegetation visibility).
- Processing Platform: The System for Earth Observation Data Access, Processing, and Analysis for Land Monitoring (SEPAL), developed by the Food and Agriculture Organization of the United Nations (FAO), was used to download, mosaic, preprocess and classify the imagery.

4.1.2 Data Processing Using SEPAL

SEPAL, a cloud-based geospatial platform, was chosen for its ability to streamline large-scale forest monitoring with:

- Automated cloud and shadow masking (reducing manual errors).
- Multi-temporal compositing (enhancing image clarity).
- Integration with machine learning classifiers (facilitating accurate land cover classification).

4.2. Forest Cover Change Classification Approach

A supervised classification workflow was implemented, combining spectral analysis, and vegetation indices to distinguish forest from non-forest areas.

4.2.1 Preprocessing

1. Cloud & Shadow Removal:
    - SEPAL's built-in Quality Assessment (QA) masks were applied to filter clouds, haze, and shadows.
    - Visual inspection ensured radiometric consistency across mosaics.
2. Image Enhancement:
    - Normalized Difference Vegetation Index (NDVI) was computed to improve vegetation detection.

4.2.2 Training Data Collection

- Reference Samples:
    - training points were manually collected for Stable Forest, Stable non-Forest, Deforestation and Afforestation classes using:
        - Planet NICFI imagery (primary source).
        - Google Earth high-resolution basemaps (secondary validation).

Table 1: Training datasets

Class	Yayu Biosphere Reserve	Kafa Biosphere Reserve
Stable forest	24	459
Stable non forest	19	1078

Deforestation	9	887
Afforestation	12	158
Total	64	2582

4.2.3 Classification Algorithm

The Random Forest (RF) classifier was selected due to its:

- Robustness against overfitting and noise.
- Ability to handle non-linear spectral relationships.
- High performance in heterogeneous landscapes.

Input Features:

- Spectral bands (Red, Green, Blue, Near-Infrared).
- Derived indices (NDVI).
- SRTM
- JRC Global Surface Water layers

The analysis of forest cover dynamics in the Yayu and Kafa Biosphere Reserves employ a combination of statistical tools and remote sensing techniques to effectively quantify changes over the specified period from 2016 to 2025. Multi-temporal satellite imagery will be utilized to monitor and assess variations in land cover. Geographic Information System (GIS) software will facilitate spatial analysis, allowing for the mapping of different land use types and their respective changes. This includes the classification of forested areas, non-forest areas, and other land uses, enabling a detailed visualization of how land cover dynamics have evolved over time.

In addition to GIS and Remote Sensing techniques, statistical methods will be employed to analyze the data comprehensively. Descriptive statistics will summarize the extent and percentage of different land cover categories to provide robust, evidence-based findings that will inform conservation strategies and sustainable land management practices in both biosphere reserves

5. RESULTS AND DISCUSSIONS

The result in Table-2 indicates the forest area in hectares for each Biosphere reserve. Additionally, Figures 1 and 2 illustrate the spatial locations of the forest cover and change. The rate of deforestation in Kafa Biosphere Reserve (0.44 % per year) is ten times higher than that of Yayu Biosphere Reserve (0.04 % per year) (Table-2). This information helps to differentiate fragmented natural forests that should be reconnected through establishing corridors for connecting fragmented habitats.

The findings from the analysis of forest cover change in the Yayu and Kafa Biosphere Reserves reveal critical insights into the urgent need for targeted conservation strategies.

The stark difference in deforestation rates 0.44% per year in the Kafa Biosphere Reserve compared to just 0.04% in the Yayu highlights the varying pressures faced by these ecosystems.

As reported by (Tigabu & Gessesse, 2025[15]) land use change driven by agricultural expansion and unsustainable practices is a significant factor contributing to forest degradation in Ethiopia. Addressing these pressures is vital not only for maintaining biodiversity but also for enhancing local livelihoods dependent on forest resources. Recent studies underscore the importance of forest corridors, which facilitate wildlife movement and genetic exchange, thus strengthening the ecosystem's resilience (Wirtu & Abdela, 2026[16])

The assessment of forest cover change also emphasizes the role of community involvement in conservation efforts. Initiatives that engage local communities, as advocated by (Shibabaw & Wondimneh, 2025[17]) have shown promise in mitigating deforestation and encouraging sustainable practices. Furthermore, the integration of scientific data with traditional ecological knowledge can enhance the effectiveness of conservation strategies (Demessie, 2024[18]). Hence, adopting collaboration among local stakeholders, policymakers, and international organizations, the findings from the Yayu and Kafa Biosphere Reserves can help inform sustainable development pathways that balance environmental preservation with socio-economic needs. Such integrated approaches are essential for addressing the challenges posed by climate change while safeguarding Ethiopia's rich biodiversity for future generations.

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[15] Tigabu, A., & Gessesse, A. A. (2025). Mapping forest cover change and estimating carbon stock using satellite-derived vegetation indices in Alemsaga forest, Ethiopia. *PLOS ONE*, *20*(2). 24-56.

[16] Wirtu, Y. D., & Abdela, U. (2026). Impact of population pressure on forest resources depletion in Yayo coffee forest Biosphere Reserve, Southwest Ethiopia. *Frontiers in Environmental Science*, *14*. 12-45.

[17] Shibabaw, M., & Wondimneh, S. (2025). Synthesis of deforestation and forest-based climate change mitigation strategies in Ethiopia: Review. *East African Journal of Forestry and Agroforestry*, *8*(1). 34-56.

[18] Demessie, H. (2024). Ecosystem services of Entoto Mountain Forest in Addis Ababa: Biomass and oxygen production rates. *Addis Ababa University Repository (AAU-ETD)*.

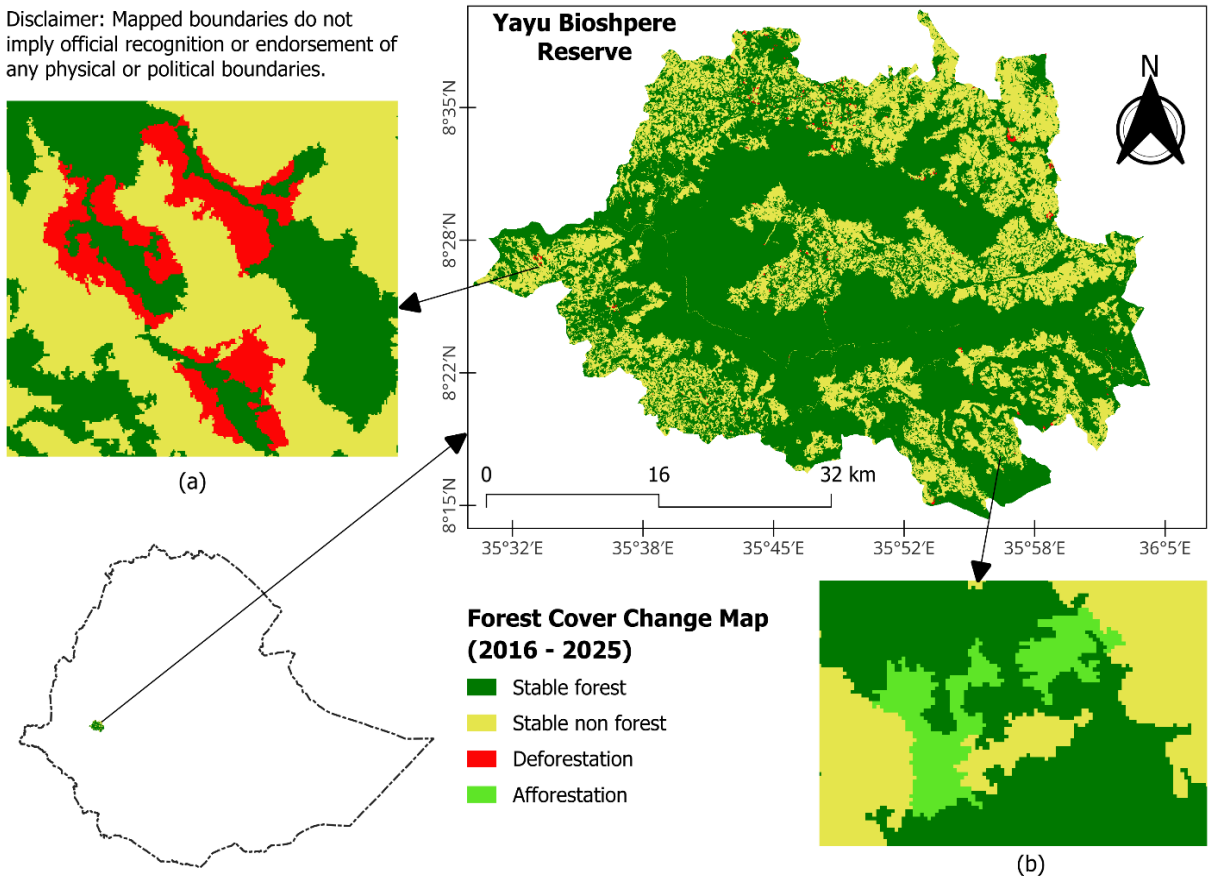

Figure 1: Forest cover change map of Yayu Biosphere Reserve for the period between 2016 and 2025 with two zoomed in areas of deforestation (a) and afforestation (b).Yayu Biosphere Reserve Matrix (2016–2025)

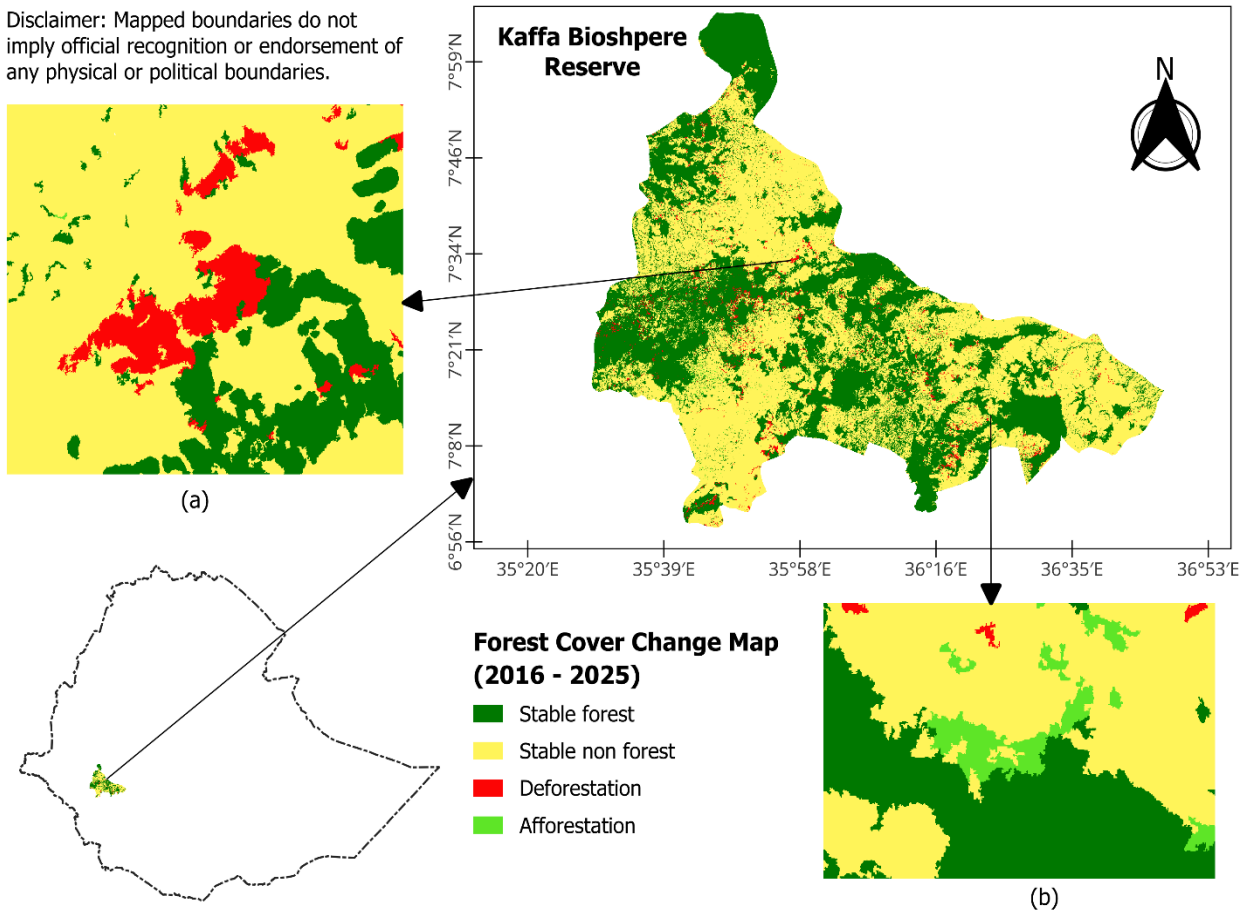

Figure 2: Forest cover change map of Kafa Biosphere Reserve for the period between 2016 and 2025 with two zoomed in areas of deforestation (a) and afforestation (b).

Result in Table-1 show the comparative analysis of land cover data for the Yayu and Kafa Biosphere Reserves that reveals significant differences that have important implications for forest management. The Yayu Biosphere Reserve comprises 112,849 hectares of stable forest, representing 67.35% of its total area, while the Kafa Biosphere Reserve has a larger stable forest area of 319,286 hectares, accounting for only 42.83% of its total area. This discrepancy highlights a more substantial proportion of forest cover in Yayu, indicating effective management and relatively minimal disturbances compared to the vulnerabilities evident in Kafa.

In terms of stable non-forest areas, Yayu has 54,261 hectares (32.38%), whereas Kafa shows a significantly higher stable non-forest area of 409,605 hectares (54.94%). This larger percentage in Kafa indicates a shift in land use due to agricultural expansion or urban development, putting additional pressure on the remaining forests. Such changes underscore the importance of comprehensive management strategies that balance economic development with conservation goals.

The analysis of deforestation rates reveals a stark contrast showing Yayu has a low deforestation rate of 438 hectares (0.26%), indicative of successful conservation practices, while Kafa faces a much higher rate of 14,851 hectares (1.99%). This significant level of forest loss in Kafa necessitates immediate action to halt degradation and to understand the drivers behind this trend, which may include illegal logging and land conversion for agriculture.

When examining afforestation efforts, Yayu reports an area of only 10 hectares (0.01%), while Kafa shows a considerably larger area of 1,782 hectares (0.24%). Despite this, the afforestation figures in both reserves remain modest, indicating that current initiatives are not sufficient to counterbalance the deforestation rates. This finding emphasizes the need for more aggressive reforestation programs aimed at restoring and expanding forested areas.

The comparative analysis of land cover data in the Yayu and Kafa Biosphere Reserves reveals significant implications for forest management in the biosphere reserves in Ethiopia. The Yayu Biosphere Reserve, with 112,849 hectares of stable forest representing 67.35% of its total area, exhibits effective management and minimal disturbances. In contrast, the Kafa Biosphere Reserve, despite its larger stable forest area of 319,286 hectares, has only 42.83% of its area covered by stable forests. This discrepancy underscores the vulnerabilities faced in the Kafa Reserve, where extensive agricultural expansion and urban development have transformed land use patterns (Molla & Menelik, 2026[19]). As (Daba et al., 2025[20]) indicate these transformations pose significant threats to biodiversity and ecosystem services, necessitating a comprehensive approach to land management that balances economic growth with conservation efforts.

The stark differences in stable non-forest areas further highlight the urgent need for targeted interventions. Yayu's stable non-forest area comprises 54,261 hectares (32.38%), compared to Kafa's 409,605 hectares (54.94%). This disparity suggests that the Kafa Reserve is experiencing greater pressure from agricultural activities, which has

[19] Molla, M., & Menelik, S. (2026). *High-resolution mapping of forest degradation in the Southwestern Ethiopian Highlands using machine learning*. (Pre-publication/Recent Journal Release).

[20] Daba, I., et al. (2025). Economic growth and forest cover dynamics in Ethiopia (1992–2021). *Journal of Science, Technology and Arts Research*, *14*(2).

been confirmed by numerous studies indicating that agricultural encroachment is a primary driver of deforestation and land degradation in Ethiopia (Bekele & Hailu, 2025[21]).

Furthermore, the analysis of deforestation rates 0.26% for Yayu compared to 1.99% for Kafa reinforces the notion that effective conservation practices are vital for forest protection. The high deforestation rates in Kafa necessitate immediate action to address underlying issues, including illegal logging and land conversion (Lemenih & Kassa, 2024[22]).

To combat these pressing challenges, engaging local communities in conservation initiatives is paramount. Community-based approaches, such as agroforestry, can promote agricultural productivity while conserving forest resources (Mkiwa et al., 2024[23]). Furthermore, enhancing afforestation efforts, especially through the planting of native species, is essential for restoring degraded areas in both reserves.

Collaborative strategies involving local stakeholders can ensure these initiatives are contextually relevant and effective (Shibabaw, & Wondimneh, 2025[24]). Strong policy frameworks prioritizing forest conservation, along with strict enforcement of environmental regulations to reduce rate of deforestation, are crucial for the sustainability of these biosphere reserves. Through prioritizing strategic management interventions, Ethiopia can preserve the ecological integrity of the Yayu and Kafa Biosphere Reserves, contributing to long-term sustainability of forest resources.

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[21] Bekele, Z. T., & Hailu, L. (2025). The impacts of Ethiopia's Green Legacy on soil conservation and on climate change: A review. *Applied Engineering*, *9*(1), 45-49. [https://doi.org/10.11648/j.ae.20250901.14]

[22] Lemenih, M., & Kassa, K. (2024). *Review of the historic trajectory of deforestation, its drivers and implications in Ethiopia*. Preprints.org. https://doi.org/10.20944/preprints202401.0332.v2

[23] Mkiwa, B. P., Mauya, E. W., Jonas, J. N., & Mbeyale, G. E. (2024). Integrating geospatial tools in mapping forest fire severity and burned areas in the Western Usambara Mountain Forests. *PLOS One*. https://doi.org/10.1101/2024.09.29.615696

[24] Shibabaw, M., & Wondimneh, S. (2025). Synthesis of Deforestation and Forest-Based Climate Change Mitigation Strategies in Ethiopia: Review. *East African Journal of Forestry and Agroforestry*, *8*(1).45-78.

From a management perspective, these findings highlight the need for prioritized conservation efforts, particularly in the Kafa Biosphere Reserve, where higher deforestation rates present urgent challenges. Engaging local communities in conservation initiatives can enhance support for sustainable practices, with community-based approaches such as agroforestry that promote agricultural productivity alongside forest conservation. Furthermore, sustainable land use practices must be developed to minimize ecological impacts, while monitoring systems should be established to evaluate land use changes and the effectiveness of management strategies.

The results from the Yayu and Kafa Biosphere Reserves underscore the pressing need for strategic management interventions to tackle the challenges posed by deforestation. By prioritizing conservation, engaging communities, promoting sustainable practices, enhancing afforestation initiatives, and implementing monitoring systems, it is possible to preserve the ecological integrity of these vital biosphere reserves, ultimately contributing to the long-term sustainability of forest resources in Ethiopia.

Table 1- Forest cover change analysis per Biosphere reserve (2016-2025)

		Yayu Biosphere Reserve		Kafa Biosphere Reserve	
No	Class	Area (ha)	Percentage (%)	Area (ha)	Percentage (%)
1	Stable forest	112,849	67.35	319,286	42.83
2	Stable non forest	54,261	32.38	409,605	54.94
3	Deforestation	438	0.26	14,851	1.99
4	Afforestation	10	0.01	1,782	0.24
	Total	167,549		743,742	
	Rate of deforestation (%/year)		0.04		0.44

6. Conclusion and Recommendations

The data presented highlights that Yayu maintains a relatively stable forest area, demonstrating effective management practices, whereas Kafa is facing alarming rates of deforestation. With the deforestation rate in Kafa being ten times higher than in Yayu, it is evident that urgent and targeted interventions are necessary to curb habitat loss, protect biodiversity, and sustain local livelihoods. The alarming findings not only indicate the need for immediate action but also emphasize the importance of collaborating with

local communities, as stakeholders are crucial in addressing these environmental challenges.

Furthermore, the study underscores the pressing issue of inadequate afforestation efforts in both biosphere reserves. While Kafa has made some headway in restoring forests, the scale remains insufficient to offset the ongoing loss due to deforestation. This trend points to the necessity for implementing more aggressive and contextually appropriate afforestation initiatives that prioritize native species, enhance community involvement, and incorporate traditional ecological knowledge. Such measures can lead to effective reforestation strategies that not only restore forest cover but also support biodiversity and local economies.

The following recommendations are made to enhance forest management and conservation:

- Conduct further study on the direct and underlying drivers of deforestation and forest degradation in the Kafa and Yayu Biosphere Reserves, with a focus on areas experiencing high deforestation and forest degradation.
- Foster active participation of local communities in conservation efforts, ensuring that their needs and traditional practices are incorporated into management strategies.
- Implement reforestation initiatives focusing on native species to restore ecosystems and enhance biodiversity while securing community benefits.
- Review and strengthen existing environmental policies to ensure effective enforcement and minimize illegal logging activities.
- Develop robust monitoring and verification systems to continuously assess forest health and track the effectiveness of conservation interventions.
- Implement integrated land-use planning that balances economic development needs with the goals of forest conservation.