Assessing Spatiotemporal Forest Cover and Eco-Tourism activity: in Entoto using geospatial technology Addis Ababa

Betelhem Getachew

A Thesis Submitted to the Department of Geomatics Engineering,

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Geo-Informatics Engineering

Office of Graduate Studies

Adama Science and Technology University

November, 2024

Adama, Ethiopia

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APPROVAL SHEET

I, the advisor of the thesis entitled "Assessing Spatiotemporal Forest Cover and Eco-Tourism activity in Entoto Using geospatial technology, Addis Ababa," and developed by Betelhem Getachew here by certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Roba Gemechu (PhD) ______________________ _______________

Advisor Signature Date

We, the undersigned, members of the Board of Examiners of the thesis by Betelhem Getachew have read and evaluated the thesis entitled "Assessing Spatiotemporal Forest Cover and Eco-Tourism activity in Entoto Using geospatial technology, Addis Ababa" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Geo-informatics Engineering.

Chairperson	Signature	Date
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Final approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

Department Head	Signature	Date
School Dean	Signature	Date
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DECLARATION

I hereby declare that this Master Thesis entitled "Assessing Spatiotemporal Forest Cover and Eco-Tourism activity in Entoto Using geospatial technology, Addis Ababa" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Betelhem Getachew __________ ______________________

Name of student Signature Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "Assessing Spatiotemporal Forest Cover and Eco-Tourism activity in Entoto Using geospatial technology Addis Ababa" prepared under my guidance by Betelhem Getachew submitted in partial fulfillment of the requirements for the degree of Masters of Science in Geo-informatics Engineering. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Roba Gemechu (PhD) _______________________ _______________

Major Advisor/Supervisor Signature Date

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LIST OF ABBREVIATION

CSA	Central Statistics Agency
ENC	Enhanced Thematic Mapper
ERDAS	Earth Resources Data Analysis System
FAO	Food and Agriculture Organization
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
LULC	Land Use Land Cover
ML	Machine Learning
NGO	non-governmental organization
SSGI	Space Science and Geospatial Institute
SVM	Random Forests and Support Vector Machines
UNEC	United Nations Environment Program
USGS	United States geological survey
UTM	Universal Transverse Mercator

ABSTRACT

Forests, one of the most important natural resources on Earth, play an important role for the environment and mitigate climate change by absorbing carbon dioxide and releasing oxygen, biodiversity, and ecosystem stability. Forests offer opportunities for recreation and tourism activities; they play an important role for the economy. Forest cover is being influenced by infrastructure and direct investment. Study examines the spatiotemporal changes in forest cover in the Entoto Forest over a 20-year period from 2003 to 2023 and evaluates the impact of eco-tourism on these changes. Using advanced machine learning algorithms to classify (LULC) data, the analysis reveals significant growth in forested areas, from 1,354.77 hectares in 2003 to 2,141.75 hectares in 2023, marking an overall increase of 12.55%. This growth is attributed to reforestation efforts and natural recovery; the built-up areas, largely due to urban expansion and infrastructure development related to eco-tourism, increased by 9.78% during the same period, underscoring the need for balanced development. The findings suggest that eco-tourism has had both positive and negative impacts on forest cover. While well-managed eco-tourism activities have contributed to forest conservation and community development, poorly regulated tourism has led to localized degradation, particularly in areas with uncontrolled infrastructure. This is the general importance of implementing sustainable eco-tourism practices that balance economic gains with environmental preservation. In addition to community engagement and regulatory frameworks, the study concludes by emphasizing the role of sustainable eco-tourism in promoting forest conservation while fostering local economic growth. To ensure long-term environmental sustainability, future efforts should focus on expanding eco-friendly tourism initiatives, involving local communities in conservation efforts, and adopting technology-driven monitoring systems. These measures will help preserve the ecological integrity of the Entoto Forest while supporting its potential as a key eco-tourism destination in Ethiopia.

Keywords: spatiotemporal forest. Eco-tourism Machine learning Entoto forest

CHAPTERI: INTRODUCTION

1.1 Background of the Study

Forests, one of the most precious natural resources on Earth, are essential to maintaining the ecological balance of the entire universe. Global pollution and depletion of these resources have occurred and continue to occur (Bloom & Reenen, 2013). Forests play an indispensable role in sustaining the hydrological cycle, mitigating disaster risks, and providing a wide array of ecosystem services that are essential for both human life and biodiversity. They offer crucial resources, such as wood for fuel, materials for construction, and land for agriculture, while also serving as habitats for countless species. Beyond their material benefits, forests regulate water quality, prevent and reduce the impact of natural disasters like floods, landslides, and droughts, and contribute to climate regulation at regional and global levels. Additionally, forests provide significant socioeconomic benefits, creating jobs, supplying forest products, and preserving areas of cultural and spiritual importance. Their protection is vital for both environmental stability and human well-being (FAO.2005).

Forests are one of the most essential resources, supporting both human and animal life by regulating key environmental factors such as soil, water, temperature, and rainfall. In Ethiopia, forest cover holds significant value on multiple levels, particularly for indigenous peoples and forest-dependent communities that rely on forests for their livelihoods. Forests provide food, medicinal plants, fruits, honey, bush meat, firewood, and shelter, while also supporting cultural and spiritual practices. Whether located on private or public land, forests are a shared national and global treasure. Their critical role in maintaining ecosystems, preserving biodiversity, and supporting human life is increasingly recognized as vital to global environmental sustainability (Brockerhoff et al., 2017).

Forests and eco-tourism share a deeply interconnected and mutually beneficial relationship. Forests provide the primary attraction for eco-tourism by offering a rich natural environment, diverse wildlife, and scenic beauty that captivate visitors. In return, eco-tourism raises awareness about the importance of conserving these forest ecosystems and creates economic incentives for local communities to engage in preservation efforts. Activities like hiking, wildlife observation, and nature photography allow tourists to appreciate the value of forests while promoting sustainable management practices. This synergy fosters conservation efforts, supports local economies, and encourages the responsible use of forest resources, ensuring their long-term sustainability (A. Rahman, 2010).

Geospatial technology plays an important role in forest and eco-tourism activity by aiding in the mapping, analysis, and monitoring of natural landscapes, as well as the design of sustainable tourism routes that promote responsible travel experiences and enhance conservation efforts. GIS can offer a more comprehensive approach. Generally, this technology is used for collecting spatial information, storage, analysis, and display of results in the form of maps or graphs, which are easier for users to understand. It is also used to promote participation at the decision-making level. An integration of RS and GIS can also play an important role in ecotourism planning because this technology is considered to act as effective tools for storing, manipulating, and analyzing Currently, ecotourism is considered the most attractive subset of the tourism industry and a stable solution, particularly in developing countries like Ethiopia if it is properly managed Developing (Idris, 2022).

Machine learning utilization of geospatial technology and can be extremely beneficial in tackling issues pertaining to forest cover and ecotourism. Through the utilization of advanced analytics and geospatial data, these technologies can offer significant insights for the sustainable management and utilization of forest resources. Large-scale satellite imagery and other geospatial data can be used to train machine learning algorithms to analyses and predict areas at risk, as well as to precisely track changes in the forest cover and identify hotspots for deforestation (Kanevski, 2016).

1.2Statement of the Problem

The Entoto Forest, located in Addis Ababa, plays a crucial role in environmental conservation, supporting biodiversity, and offering eco-tourism opportunities. Over the past two decades, rapid urbanization, land use changes, and eco-tourism development have had both positive and negative impacts on the forest ecosystem. While forest cover has increased due to reforestation efforts, infrastructure development, driven by growing eco-tourism demands, has led to concerns about habitat degradation and the sustainable management of natural resources. Despite the potential benefits of eco-tourism, such as local economic development and environmental awareness, poorly managed tourism activities can lead to deforestation, habitat destruction, and loss of biodiversity. Additionally, the expansion of built-up areas may threaten the long-term ecological health of the forest, reducing its capacity to support wildlife and provide ecosystem services. Therefore, a comprehensive understanding of the spatiotemporal changes in land use and land cover, particularly forest cover, is essential for creating strategies that promote sustainable eco-tourism while safeguarding the forest ecosystem.

This study addresses the need to evaluate the balance between forest conservation and the growing eco-tourism industry in the Entoto Forest region. By analyzing forest cover changes from 2003 to 2023, the study aims to understand the impacts of eco-tourism and urban expansion on the forest and provide insights into sustainable land management practices that support both ecological preservation and economic development.

1.3. Objectives of the Study

1.3.1. Genera objective

The general objective of this study is to assessing spatiotemporal forest cover and eco-tourism activity in Entoto using geospatial technology, Addis Ababa.

1.3.2. Specific objectives

- To generate spatiotemporal maps of 2003, 2013 and 2023 of the study area
- To analyses the spatiotemporal changes of Entoto forest
- To analyses the relationship between forests and eco-tourism

- **1.4. Research questions**
- What are the spatial changes in forest cover between the selected three years?
- What is the spatiotemporal change of Entoto Forest?
- What is the relationship between forests and eco-tourism in the study area?

1.5. Significance of the Study

The study on the spatiotemporal changes in forest cover and eco-tourism in the Entoto Forest from 2003 to 2023 holds significant importance for various reasons, particularly in terms of environmental conservation, sustainable development, and policy-making. Environmental Conservation and Forest Management: By analyzing the changes in forest cover over two decades, this study provides crucial insights into the dynamics of reforestation, deforestation, and land use in the Entoto region. The findings highlight the positive effects of conservation efforts, such as reforestation and natural recovery, which have resulted in a notable 12.55% increase in forest cover. This information is essential for policymakers, environmentalists, and forest managers seeking to protect and expand forested areas while mitigating the negative impacts of urbanization and land conversion. Ecotourism Development: The study underscores the relationship between ecotourism and forest conservation, showing how sustainable tourism practices can contribute to preserving natural ecosystems. Entoto's rich biodiversity, cultural significance, and proximity to Addis Ababa make it an ideal destination for eco-tourism. The study's findings can guide tourism stakeholders in developing eco-friendly tourism strategies that benefit both the environment and the local economy. It emphasizes the need for balanced eco-tourism initiatives that promote community engagement and economic growth while minimizing ecological harm.

Sustainable Land Use Planning and Policy: As urbanization and tourism infrastructure expand, the study provides valuable data for land-use planning. The growth in built-up areas, as identified in the study, points to the need for policies that carefully regulate development to prevent habitat degradation. Policymakers and urban planners can use this data to ensure that development projects align with conservation goals, maintaining the forest's ecological integrity while accommodating eco-tourism growth.

Overall, the study serves as a critical resource for promoting sustainable eco-tourism, forest conservation, and effective land management in the Entoto region. It provides a framework for future research, offering insights that are relevant not only for Ethiopia but for other regions facing similar challenges with eco-tourism and forest conservation.

1.6. Scope of the Study

The spatial scope of this study is confined to the Entoto Forest, covering an area of 4,992.84 hectares in Addis Ababa, Ethiopia. The focus of the research is primarily on analyzing the temporal and spatial changes in forest cover and exploring the relationship between forest dynamics and eco-tourism. To achieve this, the study employs geospatial techniques to generate spatiotemporal maps that illustrate land use and land cover classes for the years 2003, 2013, and 2023. The analysis aims to determine trends in forest cover change and assess how these changes relate to eco-tourism activities. The research utilizes various satellite imagery and field observation data while also encompassing the organization of necessary materials and processes to effectively conduct the study.

1.7. Organization of the Thesis

This study is organized into five chapters. The first chapter briefly described the background of the study, statement of the problem, objectives of the study, research questions, scope of the study, and significance of the study. The second chapter contains a review of related literature. This chapter tried to review different theoretical, empirical, and conceptual frameworks of the study to provide relevant information for the forest and eco-tourism of the study. The third chapter discusses the methodology of the study area, which includes research approach and population, sources of data, data collection instruments, and methods of data use. Moreover, describe the study area population and climate. And the fourth chapter describes the results and discussion, which presents the quantified results about spatiotemporal forest and eco-tourism activity in Entoto Forest, and also the finale chapter, discusses conclusions and recommendations. This chapter generally discourses about the further study that has been forwarded as a recommendation for future work.

1.8 Definition of terms

Eco-tourism is a type of responsible travel that emphasizes going to natural places to protect the environment, honor local customs, and advance sustainable lifestyles. While offering tourists immersive and educational experiences, it seeks to reduce the adverse effects on ecosystems (Hill & Gale, n.d.2020).

A Forest is an expanse of land covered mostly with trees and other plants that create intricate ecosystems that are home to a variety of wildlife. In addition to preserving water and supplying resources like oxygen and lumber, forests are essential for controlling the climate (Tesema & Berhan, 2019).

Sustainable development is to meet present needs without sacrificing the capacity of future generations to meet their own. To ensure resilience and well-being over the long term, it strikes a balance between social equity, environmental protection, and economic progress (Nations, 2020).

Spatiotemporal forest: Forest cover changes over time and space are examined in a process known as spatiotemporal forest analysis. It makes use of technologies like remote sensing, GIS, and satellite imagery to track how forests change in response to things like deforestation, climate change, and human activity. Understanding biodiversity, forest dynamics, and the effects of changing land use on the environment all depend on this method (Nations, 2020).

Geographic Information Systems (GIS) is capturing, storing, analyzing, and visualizing spatial and geographic data. This technology is known as Geographic Information Systems (GIS). Decision-making for applications like urban planning, environmental management, and disaster response is aided by the integration of multiple data sources that produce comprehensive maps and spatial analysis (Remote et al., 2022).

Machine learning is allowing computers to learn from data and make decisions or predictions without the need for explicit programming. It involves algorithms that learn from experience and iterative processing to detect patterns and perform better (Mahcer et al., 2024).

Forest ecology is studying interactions between living things in forest ecosystems and their surroundings. The study looks at the interactions between trees, plants, animals, and microorganisms as well as the ways in which soil and climate affect the dynamics and overall health of forest ecosystems (Rahman et al., 2024).

Remote sensing, which is gathering data about the Earth's surface without going on a physical visit, is known as remote sensing, and it usually involves using satellite or aerial photography. Through data analysis, it is possible to monitor and control changes in the environment, land use, and natural resources. This is accomplished by using sensors on satellites or aircraft to collect data (N. Rahman et al., 2024).

2. LITERATURE REVIEW

2.1 Concept of Forest

Forest is defined and used throughout the world, incorporating factors such as tree density, tree height, land use, legal standing, and ecological function. (FAO) defines a forest as “land 0.5 hectares with trees approximately higher than 5 meters and a canopy cover of 10 percent, or trees able to reach these thresholds in situ excludes land used primarily for urban or agricultural purposes assessment of Global Forest Resources using this definition use (F A O, 2005).

Found that forests covered 4.06 billion hectares (10.0 billion acres; 40.6 million square kilometers; 15.7 million square miles, or approximately 31 percent of the world's land area in 2020). Forest has been defined in many ways and reflects the diversity of forests and forest ecosystems in the world and of the diversity of human approaches to forests. In this document, a forest is a land area of more than 0.5 ha with a tree canopy cover of more than 10%, which is not primarily under agricultural or other specific non-forest land (Takano, 2010).

Forests form distinctly different biomes at different altitudes and elevations with different precipitation and evapotranspiration rates. The majority of the known terrestrial plant and animal species are found in forests, which make up slightly more than 30% of the world's land area. Unfortunately, the conversion of forest land to agricultural use or excessive, mostly illegal, exploitation poses a persistent threat to the forests and the biodiversity they support (Nations, 2020).

spatiotemporal forest cover and its understanding are essential for a country’s economic, environmental, and political engagements (Rashid & Iqbal, 2018).Deforestation is the process by which people cut down or burn trees in a forest to make room for farming or to harvest lumber. Today, tropical forests are the sites of most deforestation. The deliberate clearing of forest land is known as deforestation. Throughout recorded history and up to the present day, forests have been cleared for agriculture, animal grazing, and the production of wood for construction, manufacturing, and fuel (Name, 2021).

One of the most important and valuable resources that contributes to human well-being through ecosystem services is the forest. Regrettably, both natural and man-made forces have contributed to the decline in the amount of forest cover over time (Rashid & Iqbal, 2018) .

Studies conducted in a number of nations have demonstrated that as more people use forests, there is a decline in forest development. Depletion and shrinking forests are posing a serious threat to the delivery of ecosystem services. The main reason for this may be the increasing population and the fact that people are less aware of the benefits of forests. The provision of ecosystem services from the forest sector is expected to decline as a result of changing spatiotemporal forest cover since forests are used in small and large factories, if the relevant (Tsegaye, 2023)**.**

Forests could soon experience a sharp decline because the authorities do not maintain them the limited investment in the development of commercial agro-industrial businesses has resulted in a limiting use of forest resources for industry throughout Africa (Rashid & Iqbal, 2018)**.**

2.2 Forest in Ethiopia

The altitude and slope were the topographical variables that had the strongest influence on species distribution. The overall densities of mature trees 1and four individual species forest cover decline is a commonly known problem in Ethiopia (Workaferahu, 2015) .

In Ethiopia, the current rate of deforestation is estimated at 160,000 to 200,000 hectares per year. Large-scale forest cover change has its own negative impact on wildlife habitats and the environment. The study area represents one of the areas in which forest cover has changed and loss of some wildlife has taken place. A large area was covered by high-density and dense forest before a few years, but currently, this forest is changing at an alarming rate due to the impact of the local community. This affected the environment. Deforestation has exposed large areas of dense forest, resulting in environmental degradation and a serious threat to wildlife (Ameha, 2016).

The Entoto Mountains forest, which is located in a high-altitude area close to Addis Ababa, is predominantly a mountain forest. A variety of native tree species, including junipers, cypress, and acacias, are commonly found in this type of forest, which is well-known for its distinctive biodiversity. As a habitat for a variety of wildlife and a component of the local water cycle and climate regulation (Tesema & Berhan, 2019).

2 .3 Forest cover and Forest Cover Change:

The term forest cover change describes how forested areas change over time in terms of their size, composition, and structure. Reforestation, which is the restoration of forested areas; afforestation, which is the creation of new forests; and deforestation, which is the reduction of forested land, can all contribute to this. Numerous factors, such as natural processes, human activity, and environmental policies, all have an impact on the change in forest cover. Here is a summary of the main elements of the change in forest cover (Tsegaye et al., 2023).

Deforestation is the permanent loss of forest cover, usually due to infrastructure development, urbanization, or agricultural expansion. Deforestation causes ecosystems to be disrupted, biodiversity to decline, and it releases stored carbon, which fuels climate change. Planting new trees in previously unfrosted areas is known as afforestation. Many times, initiatives to mitigate climate change or restore the environment include reforestation. Reforestation is the process of naturally re growing forests in previously cleared areas. The goal of reforestation is to restore ecosystem functions like soil stability, water regulation, and carbon sequestration (Turner 2003).

2.4 Eco-Tourism

Use of GIS and Remote Sensing in Tourism: A geographic information system is a computer-based system in terms of using special tools to manage location-based data and their attributes for decision-making. Geospatial functions across many fields and support problem solving through design and analysis (Magige., 2022).

There are three main application areas of tourism development: research, marketing, and planning. This is the purpose of the application. Geographic Information System Tourism plays an important role as one of global tourism's largest and fastest-growing service-based niche industries. In 2019, the tourism sector, including ecotourism businesses, contributed around 10% of the world's GDP, and it was the main driver of job creation, resulting in one in every four new jobs created globally (Yasin & Woldemariam, 2023).

Conservation: Ecotourism aims to contribute to the conservation of natural areas, including protected areas, biodiversity hotspots, and fragile ecosystems. It promotes the preservation of ecosystems, wildlife, and cultural heritage through responsible visitor behavior and supporting local conservation initiatives (Adeniran, 2010).

Ecotourism, which is defined as environmentally conscious travel to natural areas, is one of the tourism segments that are expanding the fastest in the world. It is expanding at a rate of over 20 percent per year, which is two to three times faster than the growth of the tourism sector as a whole. Its common knowledge that ecotourism draws visitors to delicate settings that support endangered species and highly diverse forest ecosystems (Conservancy, 2011).

2.5. Relationship between forest and eco-tourism.

The relationship between forests and eco-tourism is that complex forests are essential for eco-tourists, and on the other hand, eco-tourism can support sustainable development and forest conservation. The main points of the correlation (Wang & Tian, 2023).

Forests and ecotourism are closely associated. Because they offer a multitude of habitats, an abundance of species, and captivating natural beauty, forests are well-liked travel destinations for ecotourism. Eco-tourism, in turn, promotes moral travel and environmentally conscious travel practices, benefiting local economies and helping to keep forests intact. Through guided tours, animal observation, and environmental education, eco-tourists gain an appreciation for forests and become activists for their preservation. This contributes to the long-term viability of these vital ecosystems (Saavedra, 2022).

Protection: Forest ecotourism may contribute to the preservation of these vital ecosystems by raising public awareness of them and funding conservation efforts. Biodiversity: Forests have a great deal of biodiversity. Eco-tourism raises awareness of the value of preserving these ecosystems by teaching visitors about various plant and animal species. Sustainable Development: In forested regions, ecotourism can boost regional economies and encourage low-impact, ecologically friendly lifestyles among locals. Education and Awareness: By learning about the ecological significance of these regions and the challenges they face through eco-tourism visits, visitors can develop a greater appreciation for and commitment to the sustainability of forests (Tang, 2022).

Forests are often a key focus of eco-tourism because they offer opportunities for conservation, education, and sustainable economic development. There is a positive relationship between ecotourism and forests, but it takes careful management to make sure that ecotourism promotes rather than undermines the preservation of forests. The environments and natural resources found in forests draw eco-tourists, and eco-tourism can provide the financial and social motivations required to preserve these forests for coming generations. Eco-tourism essentially takes advantage of the biodiversity and natural beauty of forests to develop sustainable tourism opportunities and to encourage the preservation of these important ecosystems (Adeniran,2010).The beneficial relationship between forests and eco-tourism is founded on a reciprocal relationship in which the former supplies the natural setting and resources that draw the latter, and the latter helps to preserve and manage forests sustainably. The salient features of this fruitful partnership are as follows: Forest and tourism have a complicated relationship because of the ways in which they both influence and are affected by the reduction (or incising) of forest cover. The effects of declining forest cover on eco-tourism and the subsequent effects of eco-tourism on forest conservation are outlined below (Chew, 2023).

Through highlighting the value of forests as travel destinations, eco-tourism generates financial incentives for forest conservation. This promotes the protection of forests over deforestation-causing activities like logging and agriculture among local communities, governments, and stakeholders (Liu et al., 2019).

Balanced Development: Ecotourism promotes striking a balance between environmental preservation and economic growth. Eco-tourism ensures that forests are not only preserved but also used in a way that supports the long-term economic viability of the surrounding communities by promoting sustainable tourism (Idris, 2022).

Better Air Quality: By generating oxygen and absorbing pollutants, forests serve as organic air filters. Fresh, clean air improves eco-tourists' overall experience and supports their health and wellbeing while they are there. Improved Outdoor Recreational Opportunities: Thick, healthy forests make the perfect backdrop for outdoor pursuits like hiking, camping, canopy walks, and nature trails. Extensive forest cover contributes to these activities, which are essential to ecotourism (Adeniran, 2010).

Forests play a critical role in water conservation by preventing soil erosion, improving water quality, and maintaining consistent water flow in rivers and streams. Increasing forest cover ensures that eco-tourism destinations have sustainable water resources. General Increasing Forests cover many advantages of eco-tourism activities by increasing biodiversity and ecosystem services. It also supports sustainable tourism development and helps ensure that eco-tourism can contribute to both economic growth and environmental conservation. The long-term sustainability of eco-tourism relies on maintaining and expanding healthy forest ecosystems. Support for Ecosystem Services: Different ecosystem services, such as carbon sequestration, soil fertility, and pollination, are provided by forests. Ecotourism activities that are sustainable are made possible by healthy ecosystems, which also guarantee that the natural environment will continue to be resilient and flourish (Tigabu, 2016).

2.6 Eco-Tourism in Ethiopia

Ethiopia's ecotourism industry is centered on encouraging environmentally friendly travel while protecting the nation's stunning natural settings and rich cultural legacy. Travelers can enjoy trekking, wildlife viewing, and bird watching in pristine environments by visiting Ethiopia's unique highland forests, like those in the Simien Mountains and Bale Mountains. Ethiopia offers a wide range of ecotourism opportunities. Ethiopian ecotourism also contributes to community-based projects that safeguard the nation's natural resources, strengthen local communities, and offer learning opportunities regarding the biodiversity and conservation efforts of the region (Published, 2022).

Eco-tourism in Ethiopia also encompasses several distinctive attractions and practices. Integration of Rural Communities Several ecotourism projects in Ethiopia involves local communities, giving tourists the chance to experience customs while also advancing the economic growth of the area. Through initiatives like handicraft workshops, guided tours, and local food experiences, this strategy supports sustainable livelihoods while assisting in the preservation of cultural heritage (Idris, 2022).

One of the hottest and most geologically active regions on Earth is the Danakil Depression; Ethiopia is also home to a variety of other unique ecosystems and landscapes, such as the Great Rift Valley, which is home to breathtaking lakes and a wealth of biodiversity. In these regions, ecotourism activities that guarantee little environmental impact frequently involve hiking, guided tours, and the exploration of distinctive geological formations (Kapure et al., 2020). Ethiopia's rich cultural heritage, which includes historic sites like Lalibela and Aksum as well as antiquated churches and monasteries, is incorporated into ecotourism activities. While advocating sustainable practices that reduce impact on these historical sites, these tours frequently center on appreciating and comprehending Ethiopia's rich cultural legacy. A rare chance to investigate a highland ecosystem close to Addis Ababa is provided by ecotourism in the Entoto Forest, which also promotes sustainable development and conservation. Entoto offers hiking along beautiful mountains, watching, and other activities for visitors to enjoy. The forest's rich biodiversity includes wildlife and native plant species, an educational element to the ecotourism experience by shedding light on the forest's ecological significance and the conservation efforts underway (Asefa et al., 2019).

Preservation of Wildlife: The safeguarding of threatened species, including the Ethiopian wolf, Gelada baboon, and Walia ibex, is a major focus of Ethiopia's ecotourism endeavors. Encouraging wildlife enthusiasts to witness these species in their natural environments while contributing to conservation and research endeavors are the benefits of national parks and protected areas, such as the Simien Mountains and Bale Mountains National Parks (Asefa et al., 2019).

Entoto ecotourism incorporates cultural experiences in addition to its natural attractions by emphasizing the region's historical and cultural significance. Interact with the local population, picking up knowledge of customs and lending support to neighborhood-based initiatives. This strategy ensures that the advantages of tourism support both the preservation of the forest and the welfare of locals by fostering environmental conservation and local economic development (Asefa et al., 2019).

2.7. Role of GIS and Remote Sensing for Spatiotemporal Forest Assessment

Remote sensing is a technique of imaging the earth's surface by capturing the electromagnetic radiation (EMR) reflected or backscattered from the features present on the earth’s surface without any human intervention. The onboard sensor on a satellite with multi-spectral bands is to observe all resources on the earth surface based on reflection characteristics. Each feature on the surface has unique reflection characteristics in the electromagnetic spectrum (EMS), and this is a primary principle in remote sensing technology. The temporally acquired remote sensing and GIS data are used to explore the area to identify the species types and to estimate their changes periodically (Kaliraj et al., 2012).

Remote sensing provides several advantages for forest monitoring and management; it allows for large-scale coverage, enabling the assessment of forests over vast areas that may be inaccessible or difficult to access. This capability supports efficient and comprehensive monitoring of forest conditions, including changes in deforestation, land cover, and forest health. Secondly, remote sensing provides a consistent and objective method for data collection. It enables the acquisition of data at regular intervals, facilitating the detection of temporal changes in forest dynamics. Additionally, remote sensing allows for the integration of various data sources, such as satellite imagery and aerial photography, providing a multi-dimensional understanding of forest ecosystems. These advantages make remote sensing a valuable tool for forest management, conservation planning, and policy-making (Suzuki et al., 2014).

Geography information systems and remote sensing data supporting forest management are stored primarily in the form of forest inventory databases within a GIS environment. An assessment of the distribution, composition, and location of forest resources is called a forest inventory. As one of the principal sources of forest management information, these computerized systems provide support for many different management choices, ranging from long-term strategy planning to harvesting preparations. Forest management inventories in the past were mostly used for timber management and concentrated on recording area and volume by species. Over the last ten years, the scope of forest management duties has expanded. Measures of non-harvest-related features like forest structure, wildlife habitat, biodiversity, and forest hydrology are now required to be included in inventory data (Bill, 2018).

Applications of remote sensing and GIS to forestry The use of remote sensing by forest managers has steadily increased, promoted in large part by better integration of imagery with GIS technology and databases, as well as implementations of the technology that better suit the information needs of forest managers. The most important forest information obtained from remotely sensed data can be broadly classified in the following categories: detailed forest inventory data broad area monitoring of forest health, natural disturbances, and assessment of forest structure in support of sustainable forest management (Bill, 2018).

Forest cover changes are calculated from satellite imagery through computer-enabled digital image processing techniques. The basic principle of change detection through remote sensing is that changes in spectral signatures are comparable to changes in land cover. The process of change detection is premised on the ability to measure temporal impacts (Kaliraj et al., 2012). Geographic information system GIS and remote sensing are widely used to monitor spatiotemporal forest cover change for effective data analysis and updating geospatial technology. Combining this with remote sensing data is time-saving, cost-effective, and can be accurately entered into the geographic information system. Various geo statistics models are used to analyze spatial-temporal land use and land cover change (Bill, 2018).

2.8 Machine learning in spatiotemporal forest

Arthur Samuel first used the term "machine learning" (ML). It is regarded as a branch of artificial intelligence (AI) because it is predicated on the idea that machines are capable of making decisions with little assistance from humans and can learn from data (Remote et al., 2022).

Machine learning in spatiotemporal forest analysis is utilizing advanced algorithms and techniques to analyze large volumes of spatiotemporal data related to forests. Machine learning algorithms can be trained to recognize patterns and relationships within this data, enabling the extraction of valuable insights for forest analysis. By integrating spatiotemporal data from various sources, such as satellite imagery and environmental data, machine learning models can identify and classify different forest types, monitor changes in forest cover over time, predict forest health and vulnerability, and detect forest disturbances such as deforestation or forest fires. These models can also assist in generating accurate forest inventories, estimating biomass and carbon stocks, and predicting future forest conditions. By leveraging machine learning in spatiotemporal forest analysis, researchers and forest managers can gain a deeper understanding of forest dynamics and make informed decisions for sustainable forest management, biodiversity conservation, and climate change (Li et al., 2013).

Machine learning can optimize resource management by analyzing data on visitor flows, helping to alleviate overcrowding and minimize the environmental impact of tourism activities. It is allowing eco-tourism providers to identify areas for improvement and enhance service quality. Machine learning aids in predicting visitor demand and trends, enabling better planning and decision-making for eco-tourism businesses. Overall, machine learning empowers eco-tourism stakeholders to enhance visitor experiences, optimize resource utilization, and foster sustainability in the industry (Afsahhosseini & Al-Mulla, 2020).

Any learning process has an associated machine learning algorithm. As with statistical methods, the goal of supervised machine learning algorithms is similar. The goal of both is to increase accuracy by minimizing a function, which in regression problems is usually the sum of squared errors. The technological advancement that is transforming geographic analysis is machine learning (ML). With machine learning (ML), systems can learn from data and perform tasks like guesswork and decision-making without requiring specialized programming. The concept of reinforcement learning, along with unsupervised and supervised learning, is acknowledged by the tech. In various fields, such as geographic information, it is helpful. This article aims to provide an overview of machine learning and its applications in the field of geographic information (Kanevski et al., 2008).

2.9. The effect of Eco-tourism Activity in forest

According to the FAO, ecotourism activities in forests can have both positive and negative effects and also The effects of ecotourism are frequently divided into two categories: the direct effects of the tourists themselves and the "indirect" effects of the infrastructure or activities required to deliver the visitor experience (F A O, 2005).

Positive Effects: Funding for Conservation: Ecotourism brings in money that can be used to support conservation initiatives like preserving endangered species, repairing damaged habitats, and promoting sustainable forest management. Funding for conservation initiatives and protected areas is frequently derived from entry fees, guided tours, and other ecotourism services. Environmental Awareness: Promoting forests and ecosystems through eco-tourism increases public awareness of their value. Through the dissemination of knowledge regarding the ecological and cultural importance of forests, eco-tourism cultivates a more profound bond with the natural world and encourages tourists to adopt more ecologically conscious actions. Local Economic Development: Ecotourism generates cash and jobs for nearby communities, thereby relieving the pressure that illicit logging and unsustainable agriculture place on forests. It may result in the growth of nearby companies that offer alternatives to the exploitation of the forest, such as eco-lodges, guided tours, and handicraft manufacturing (Hill & Gale, n.d.2019).

Negative Effects: Eco-tourism emphasizes sustainability; if it is not properly managed, it can have detrimental effects. Excessive visitor numbers, especially in fragile forest ecosystems, can cause pollution, habitat disruption, and soil erosion. A poorly planned trail system or lodging facility can also harm the surrounding ecosystem. Disturbance of Wildlife: A greater number of people in forests can disturb wildlife, particularly if they enter sensitive areas or act inappropriately by feeding animals or creating loud noises. This may result in altered behavior patterns in animals, lower rates of successful reproduction, and more strain on wildlife. Cultural Impact: Although ecotourism has the potential to boost local economies, it also runs the risk of modifying culture or eradicating customs. There is a chance that traditional ways of life will change or cultural heritage will be compromised as local cultures adjust to suit the needs of tourists (Tang et al., 2022).

The popularity of eco-tourism has increased as a means of protecting and enhancing the economy through the utilization of forests and natural resources. The effects of ecotourism are divided into two categories: the direct effects of the tourists themselves and the indirect effects of the infrastructure or activities required to deliver the visitor experience. Using the latter groupings, the following are some on-site effects: Increased frequency of wildfires, soil erosion and compaction, trampling of plants, trampling of wildlife, destruction of vegetation, unintentional introduction of foreign species, and litter and vandalism are the causes of environmental degradation resulting from tourism or other factors (Adeniran et al., 2010).

2.10 sustainable developments

The concept of sustainable development in forest and eco-tourism entails the promotion of responsible and environmentally conscious tourism practices within forested regions (Takano et al., 2010).

This approach ensures the preservation and well-being of the ecosystem and local communities in the long run. It requires finding a harmonious equilibrium between economic progress, social advantages, and environmental conservation. Essential elements of sustainable development in forest and eco-tourism involve the protection of biodiversity, engagement of communities for shared advantages, mitigation of environmental effects, preservation of cultural aspects, promotion of forest education and awareness, and facilitation of collaborations and partnerships (Extent et al., 2005).

The conservation of biodiversity is vital for the protection of the forest ecosystem. This includes the preservation of natural habitats, the safeguarding of endangered species, and the promotion of sustainable forestry practices (Moon & Solomon, 2018).

The involvement of local communities is vital for the advancement of sustainable forests and eco-tourism. By engaging them in decision-making and offering economic opportunities and social benefits, we can guarantee their active participation and endorsement of conservation endeavors (Tang et al., 2022).

Sustainable tourism practices strive to minimize negative environmental impacts through responsible waste management, energy conservation, water preservation, and the use of eco-friendly transportation and infrastructure. Forests and eco-tourism should prioritize the preservation of the cultural heritage of local communities, ensuring that their traditional practices are promoted and respected. It is crucial to value indigenous knowledge and encourage cultural exchange while being mindful of avoiding any form of cultural exploitation (Partial et al., 2021).

It is crucial to educate and create awareness among tourists, local communities, and stakeholders regarding the importance of sustainable practices. By implementing educational initiatives, we can encourage responsible behavior, enhance ecological understanding, and foster a deep appreciation for the natural and cultural values associated with forested areas (Schuck et al., 1989)

Collaboration and partnerships are essential for achieving effective sustainable development in forest and eco-tourism. This involves working together with various stakeholders, including government agencies, local communities, tour operators, NGOs, and researchers. Through partnerships, sustainable tourism strategies can be developed and implemented, leading to the efficient management of natural resources(Hill & Gale, n.d.).

Sustainably managed forests serve various environmental and socio-economic purposes that hold significance at global, national, and local levels. They play a crucial role in promoting sustainable development. It is essential to have accurate and current information about the condition of forest resources. This information should not only cover the area and changes in the area but also include variables like growing stock, wood and non-wood products, carbon content, protected areas, recreational use of forests and other services, biological diversity, and the contribution of forests to national economies. Such information is vital for decision-making in forestry and sustainable development policies and programs at all levels (F A O, 2005) .

Sustainable tourism has proven to be one of the best strategies for preserving the environment and giving local communities access to jobs and other forms of income. Local communities may become more motivated to preserve and safeguard forests and wildlife as a result of ecotourism. Large crowds of visitors at well-known locations, however, can quickly overwhelm ecosystems and harm delicate natural resources, sometimes irreversibly. Increased recreational possibilities: Hiking, camping, canopy walks, and nature trails are all made possible by dense, healthy forests. An abundance of forest cover facilitates these activities, which are essential to ecotourism (Liu et al., 2019).

2.11. Spatiotemporal analysis of forests and (LULC)

The study of changes in forest conditions and cover over time (temporal) and across various locations (spatial) is known as spatiotemporal analysis of forests. This analysis monitors, evaluates, and visualizes how forests change in response to different factors by combining time-based information with geospatial data, such as satellite imagery or aerial photographs. It facilitates the understanding of patterns of land-use changes, forest degradation, and reforestation over particular time periods and geographical areas by researchers and policymakers (Advisor & Zewdie, 2022).

Data on forest coverage, vegetation health, biodiversity, and land-use dynamics are usually gathered and analyzed using technologies like Geographic Information Systems (GIS) and remote sensing. Spatial-temporal analysis detects rapid changes, helps identify trends, and forecasts future forest conditions by comparing the conditions of the forest over a period of time, such as a decade or several years. For instance, it can display the locations of deforestation, the success of forest restoration projects, and the effects of climate change on forests (Published, 2022).

Land used defines how people manage and alter the natural environment for a variety of uses including forestry, mining, urban development, agriculture, and leisure. It entails choosing how to distribute and use land to meet societal demands for housing, transportation, economic activity, and other purposes. These activities change the way that natural landscapes look; farms, cities, roads, or industrial areas frequently take the place of wetlands, grasslands, or forests. Different regions have different land-use patterns, which are influenced by social, economic, political, and environmental factors (Deribew & Dalacho, 2019).

The environment and ecosystems are significantly impacted by land-use practices. For instance, turning forests into agricultural land can result in biodiversity loss, deforestation, and climate change in the area. In a similar vein, urbanization may lead to pollution, habitat fragmentation, and a rise in the need for energy and water resources. To ensure that land resources are used responsibly for both the present and the future generations, it is crucial to balance development needs with environmental protection and sustainability through effective land-use planning and management (Advisor & Zewdie, 2022).

The terms land use and land cover (LULC) describe how humans use and study the surface of the Earth, taking into account both its natural features and human activities. The physical elements of the surface, such as grasslands, forests, bodies of water, and urban infrastructure, are referred to as land cover. Conversely, land use describes how people use the land for purposes other than farming, such as urbanization, industrialization, recreation, or agriculture (Name et al., 2021).

Urban planning, environmental management, and conservation initiatives all depend on an understanding of LULC. Scientists and policymakers can evaluate the effects of human activity on ecosystems, spot trends like deforestation or urban sprawl, and make well-informed decisions to ensure sustainable development and environmental protection by keeping an eye on changes in land use and land cover. LULC patterns are often mapped and analyzed using geographic information systems (GIS) and remote sensing technologies. Land use is a more technical term. When human activities such as forestry, building, and agriculture affect land surface processes like biogeochemistry, hydrology, and biodiversity, it is said to be implementing land use and land cover. Image classification is the process of sample points being collected randomly for LULC classification for each period. Categories of data based on their data file values are assigned to the class that corresponds to those criteria (Fikadu et al., 2023) .

2.12. Forest ecology

The intricate relationships that exist between living things (plants, animals, and microbes) and their surroundings in forest ecosystems are the subject of the study of forest ecology. It entails comprehending the connections between these species and their interactions with the soil, water, and climate, as well as the physical environment. Forest ecologists research the effects of human activity (logging, deforestation, and climate change) and natural disturbances (such as fires, storms, or insect outbreaks) on forest ecosystems. They also look at processes including nutrient cycle, energy flow, species diversity, and forest dynamics (Bolstad et al., 2018).

An ecosystem with a preponderance of trees is called a forest. Ecology is the study of living things' interactions with their surroundings and ecological systems. Understanding the factors that influence the distribution patterns and abundance of various organisms in global forests is the main goal of forest ecology. The observation that forests harbor a large proportion of the world's species and dominate the natural landscape over a large portion of the planet makes forest ecology relevant to understanding biodiversity. Forest ecology, to put it simply, is the study of forest ecosystems. Different biotic and abiotic elements coexist in forest ecosystems where they engage in varying degrees of interaction with one another (Tigabu, 2016).

Forest ecosystems have been greatly impacted by human activities like logging, agriculture, and urbanization. Reduced biodiversity, fragmented habitats, and deforestation are the results of forest degradation and deforestation. Through the release of stored carbon into the atmosphere, these activities also contribute to climate change. Worldwide initiatives are being made, nevertheless, to preserve and rehabilitate forests (Remote et al., 2022).

For the preservation of forest ecology, reforestation initiatives, protected area creation, and sustainable forestry practices are crucial tactics. In an effort to conserve forests for wildlife as well as for human health, governments, non-governmental organizations, and local communities frequently work together. Maintaining the ecological functions of forests and making sure they sustain life on Earth for future generations depend on sustainable forest management (Getahun & Yoseph, 2022).

2.13 Forest degradation

Forests play an important role for the national economy because of their natural resources and tourism activities. They have been recognized globally for their importance as a reservoir of biodiversity. However, it has been facing some problems due to unplanned development. These problems can be increasing deforestation, biodiversity losses, and decreasing upstream flows (A. Rahman, 2010).

According to FAO (2022), with 3.9 million hectares of net forest loss annually between 2010 and 2020, Africa has the highest pace, followed by South America with 2.6 million hectares.

Since 1990, an estimated 420 million hectares of forest have been lost worldwide due to deforestation, yet the rate of forest loss has significantly decreased. The ever-year rate of deforestation increased to 10 million hectares (ha) in the most recent five-year period (2015–2020) from 12 million ha in 2010–2015 (Nations, 2020).

Africa is most vulnerable to the process of desertification. There are arid regions, or deserts, covering two-thirds of the continent. Major ecological changes, such as land conversion for diverse purposes, overdependence on natural resources, and numerous forms of unsustainable land use, are the obvious drivers of desertification and deforestation. However, societal factors like poverty and land tenure are inextricably linked to the problem of desertification. People's movements are impacted by politics, conflict, and natural calamities, which in turn have an effect on the land (Moon & Solomon, 2018).

Africa's forests are among its most valuable natural resources because of their impact on the continent's environment as well as their economic value Advantages. However, the continent's forest cover is being influenced by a combination of unsustainable management, uncoordinated externally driven resource extraction, and additional externally driven resource extraction, as well as the additional influence of foreign direct investment and infrastructure (Extent et al., 2005).

The forest cover is being influenced by infrastructure and foreign direct investment. Africa is losing almost 4 million hectares (9.9 million acres) of land as a result of this. Because of this, the continent is losing twice as much forecast as the rest of the world- more than 4 million hectares (9.9 million acres) of forest annually (Moon & Solomon, 2018).

Ethiopia's high population growth, low agricultural productivity, inadequate economic growth, moving agriculture, raising livestock, and fuel production in drier regions are the primary drivers of degradation in the country. Loss of forests the rapid deforestation and decline of land resources are problems for Ethiopians. The growing population has led to overgrazing, massive forest removal for agriculture, and overuse of the remaining forests for building materials, fuel wood, and feed (Bishaw, 2001).

2.14. Research Gaps from Empirical Review

In reviewing several research articles related to my thesis, I have identified significant research and knowledge gaps as follows: Firstly, previous research on Entoto Forest has largely focused on a limited, small part of the area, specifically covering only 2,300 hectares of Entoto Natural Park. This park represents a small fraction of the larger Entoto Forest, leaving a significant portion of the forest unexamined in terms of spatiotemporal changes. Additionally, while earlier studies employed traditional image classification techniques like ERDAS Imagine and ENVI, the advancements in technology, particularly the use of machine learning algorithms, offer substantial improvements. These newer methods, such as decision tree classification and random forest algorithms, enable more accurate and efficient analysis of large datasets, automating processes and enhancing the precision of forest cover classification. The integration of machine learning reduces the need for manual intervention and provides more robust predictive capabilities, a gap not fully addressed in previous studies. Secondly, research on eco-tourism in the Entoto Forest area has predominantly focused on suitability analyses and assessments of eco-tourism potential. However, there is a lack of comprehensive examination of the negative environmental impacts of eco-tourism, such as pollution, wildlife displacement, soil erosion, and habitat disturbance. Most of the existing research on eco-tourism has relied heavily on qualitative methods like interviews, without adequately leveraging remote sensing and geospatial technology to provide a more data-driven understanding of eco-tourism's effects on the environment. This represents a critical knowledge gap that needs to be addressed to develop sustainable eco-tourism strategies that minimize environmental degradation while promoting conservation.

3. MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Location of study area

The study was conducted in the Entoto Forest, located to the north of Addis Ababa, the capital city of Ethiopia. This forest area encompasses the Entoto mountain range, and the majority of the forest is inside the boundary of the sheger city of Oromia regional state. The specific study sites of the current study are on a part of the forest found in the administrative boundary of Addis Ababa city, which serves as a prominent natural feature in the northern part of the city. The Entoto Mountains and forest cover a significant area and are known for their historical, cultural, and ecological importance to Addis Ababa and its surrounding regions. Its coordinates are between 9°1'30" and 9°6'0" N latitude and 38°42'30" and 38°50'0"E longitude. The altitude range is minimum 2,400 m and maximum 3,100 m above sea level.

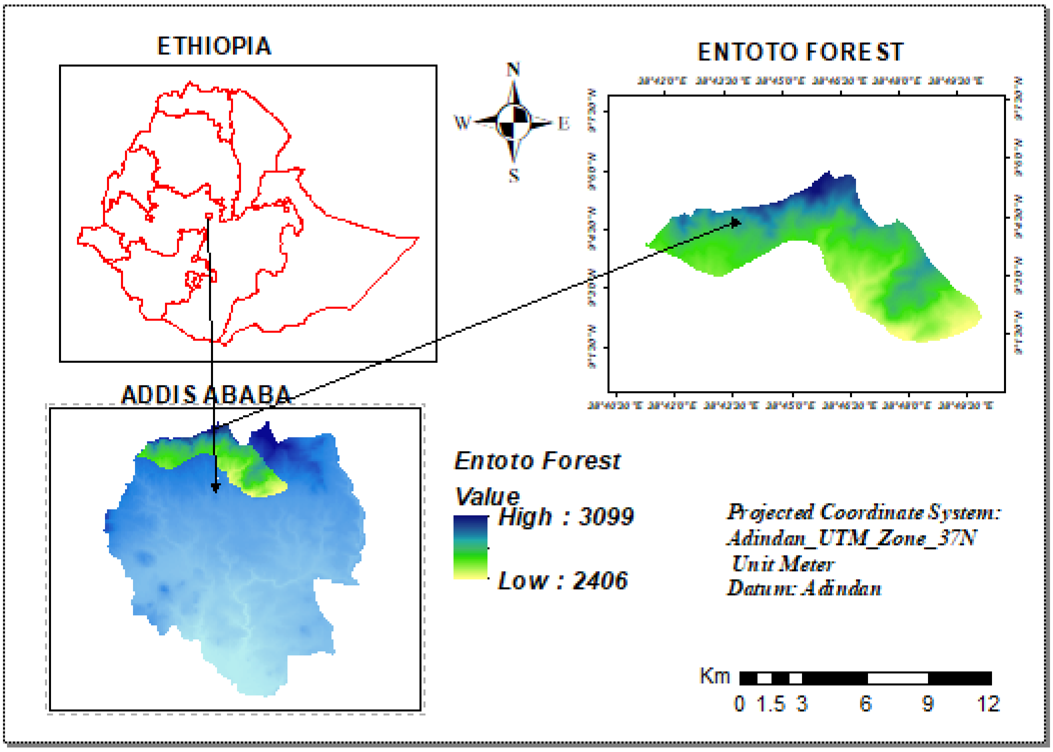

Figure 1: Location map of the Study area

3.1.2Climate of the Study Area

There are distinct wet and dry seasons in Ethiopia's subtropical highland Entoto forest, which is located close to Addis Ababa. Due to its high altitude, the region experiences consistently mild temperatures throughout the year. Nights are typically cold after warm days. While the biggest proportion of rain falls during the so-called main rainy season from June to September. In turn, this facilitates the growth of the greenery in the forests. On the other hand, the dry season from October to May offers a drier climate, making a significant impact on both the environment and landscape. Rain and drought lead to changing humidity seasons. Forest height matters because it can influence the local range of temperature variations and potentially increase rainfall at higher elevations. The diversity of wildlife that makes a home in Entoto is strongly impacted by it.

3.1.3. Vegetation of study area

The vegetation of Entoto Forest mixes indigenous exotics commonly found in the Entoto Forest. Covering Mount Entoto forest slopes lays a sizable expanse of natural forest. There are both native and exotic plant species found in the vegetation of Entoto Forest. The following are a few typical plant species found in the Entoto Forest. A wide range of native plants, including Ethiopian juniper, African olive, African yellowwood, Ethiopian alpine, and African pencil cedar, are found in the Entoto Forest in Addis Ababa. The two main eucalyptus tree species that have been extensively planted for their lumber and fuel wood are Eucalyptus globules and Eucalyptus gran dis. The prickly branches of Acacia species, like Acacia Abyssinian, provide habitat for a variety of bird species. The forest also contains open grasslands that support a range of herbaceous species and provide livestock with grazing grounds. Wildflowers, ferns, grasses, and shrubs make up the undergrowth. (Demessie, 2021).

3.2 Data collection and Data sources

Spatial data collection for this study collects data from the USGS Earth Explorer web page for the years 2003, 2013 and 2023 G.C.

Primary data collection a preliminary field survey was conducted so as to get a general view of the physical condition of the area, the forest cover and forest condition, topography, and tourism activity of the study area. Data collected for the validation of spatiotemporal forest analysis and land cover classification. And also gather attribute data related to the spatial features.

Secondary data collection for this study Most of the data collected from secondary sources is topographic maps, satellite data, attribute information from space science and geospatial institutes, and secondary data were collected from various published and unpublished sources. Background information about the study area was obtained from previous research works in the area, and other sources such as documents, journals, and books were used for this study.

Table 1: Data use

No	Satellite Data	Path/Row	Spatial resolution	Source	Purpose
1	Landsat 7snd 8	168/54	30x 30m	Downloading from USGS Earth Explorer	Fore classification 2003_2023
2	(Digital Elevation Model)	168/54	15m	Downloading from USGS Earth Explorer	For topography

Table 2: Software used

NO	Software Used	Purpose
1	Arc map 10.8	for map lay outing and analyzing
2	R Studio	For data processing
3	Microsoft office Excel 2016	writing the report, Integrating attribute data and power point for presentation
4	Google earth pro	Used for visual analysis identify the location

Satellite image data source For this study, Assessing Spatiotemporal Forest Cover and Eco-Tourism Activity in Entoto Using Geospatial Technology, Addis Ababa, the satellite images employed in this study were downloaded from the USGS Earth Explorer official website. From this interval, different chronological timelines were the years 2003, 2013 and 2023, with 10 years different.

3.3 Methods of data analysis

3.3.1 Image preprocessing

Satellite images contain some haze, noise, distortion, and stripes. As a result, image preprocessing was carried out prior to data processing. Preprocessing involves importing the image, layer stacking, data subset, and clipping it according to the Entoto Natural Park boundaries shape file, correcting for geometric and radiometric errors, removing stripes, pan sharpening, and other image-enhancing methods. In order to make the ground truth conditions based on the sensors more representative, radiometric correction involves removing air noise.

3.3.2Training Classes

Training sets are using classification methods to determine the representative locations for any particular class of shrub, land, grassland, or forest area in remote sensing data. The features that were extracted and the matching class labels from the training samples are used to train the chosen classification algorithm for accurate model performance in forest classification.

Finally, non-forest areas need to be adequately represented so that the model can learn to differentiate between the various land cover and forest types. Selection and validation of training samples allows the model to generalize well to new data, making it a useful aid for mapping and tracking forest ecosystems (Kwenda et al., 2022). This step is the classification against characteristics. Statistical correlations between the characteristics and the classifications are area to the classifier. A machine learning model is trained to identify and distinguish between forested areas and other types of land cover using the labeled data points known as training samples for forest classification. These samples are normally captured from aerial photos, satellite images, or ground surveys. In these samples, the suitable land cover class (forest, grassland, urban, or water) is manually or semi-automatically labeled. Each training sample is a pixel representing a small area with identifiable features, enabling the machine learning model to learn how spectral, textural, and spatial features correlate with forest presence (Magige et al., 2022).

3.3.3 Image Classification

This study Using machine learning to classify images in remote sensing data Training and Validation with Random Forests and Support Vector Machines (SVM): Distribute the preprocesses dataset into sets for validation and training. To train the machine learning model on the acquired features, use the training set. Random Forest, a machine learning algorithm, is used for both classification and regression issues. It is through ensemble learning that the accuracy of the model can be improved and the problem of over fitting can be better addressed by generating a number of decision trees during training and integrating their outputs. At every branch of the decision tree, a different group of features is being dealt with, and each tree in a random forest is built from a randomly picked subset of the training set. The next step is that the projections from all the trees are combined by the algorithm to give the final prediction, which will be more precise and will have a low variance. The main benefits of Random Forest are its flexibility to handle the missing data, its robustness to over fitting, and its ability to deal with large data with higher dimensionality.

Additionally, it develops a feature importance metric that looks for the feature that best predicts the result. Given that Random Forest is used in a variety of industries, such as environmental modeling, healthcare, and finance, because it is accurate and dependable when performing complex predictive tasks.

The image analysis process of Random Forest involves sequentially converting the image data into the feature vectors representing important attributes, namely the color, texture, and shape. Next, in trained on those features as input resulting in the creation of many decision trees. Each tree ranks the picture independently, and the final category is determined by the majority vote of the whole community. In comparison to more complex models such as neural networks, Random Forest gives not only robustness but also interpretability; hence, it is very applicable in the situation of image classification when we deal with smaller datasets or feature extraction Random Forest model.

3.3.4Visualizing the training samples

Visualizing training samples in geospatial classification refers to the process of producing graphical representations of the spatial data used in a machine learning model's training phase (Mosisa, 2011). The researcher collected 277 train samples for 2003. Comparing the 2013 and 2023 samples, the researcher used vast training samples because the satellite image is difficult to identify. In the year 2013, the researcher used 109 training samples, and also the last year 2023 training sample was 142 in general. 528 sample points were collected randomly for classification for each period. As shown in the table below.

Table 3trainig sample point

classes	Number of Sample Points		
	2003	2013	2023
	Training	Training	Training
Bare land	32	8	12
Built Up	47	20	26
Farmland	23	11	9
Forest Land	87	29	32
Grass Land	16	18	24
Shrub Land	72	23	39
Total	277	109	142

3.3.5 Accuracy Assessment

The measured or classified data are compared to reference data in order to determine the degree of agreement or discrepancy. The accuracy evaluation is typically performed when assessing the dependability and quality of generated information, such as land cover classifications, item detection, or change detection. It facilitates the process of deriving analytical conclusions and comprehending the constraints and uncertainties associated with the data regarding the acquisition of reference data. Accurate reference data can be gathered without the use of GIS or remote sensing. Ground truth, high-resolution images, and field surveys: the Random Forest algorithm's accuracy evaluation process compares the model's predicted classifications to the actual labels of a validation or test dataset to determine how well the model performed. Typical evaluation metrics include confusion matrix, which provides information about performance in various classes, and overall accuracy, which quantifies the percentage of correctly classified images. Specific class performance can be understood by examining.

Accuracy assessment is the most important in spatiotemporal forest cover, and eco-tourism activity mapping is a critical step in the results of spatial analysis. They came from satellite imagery, area photos, or different remote sensing data, and maps were made so that scientists could comprehend the land use pattern and the nature of the interactions between humans and the environment. That's the reason why accuracy assessment is fundamentally important for a certain project like spatiotemporal forest cover and eco-tourism activity mapping.

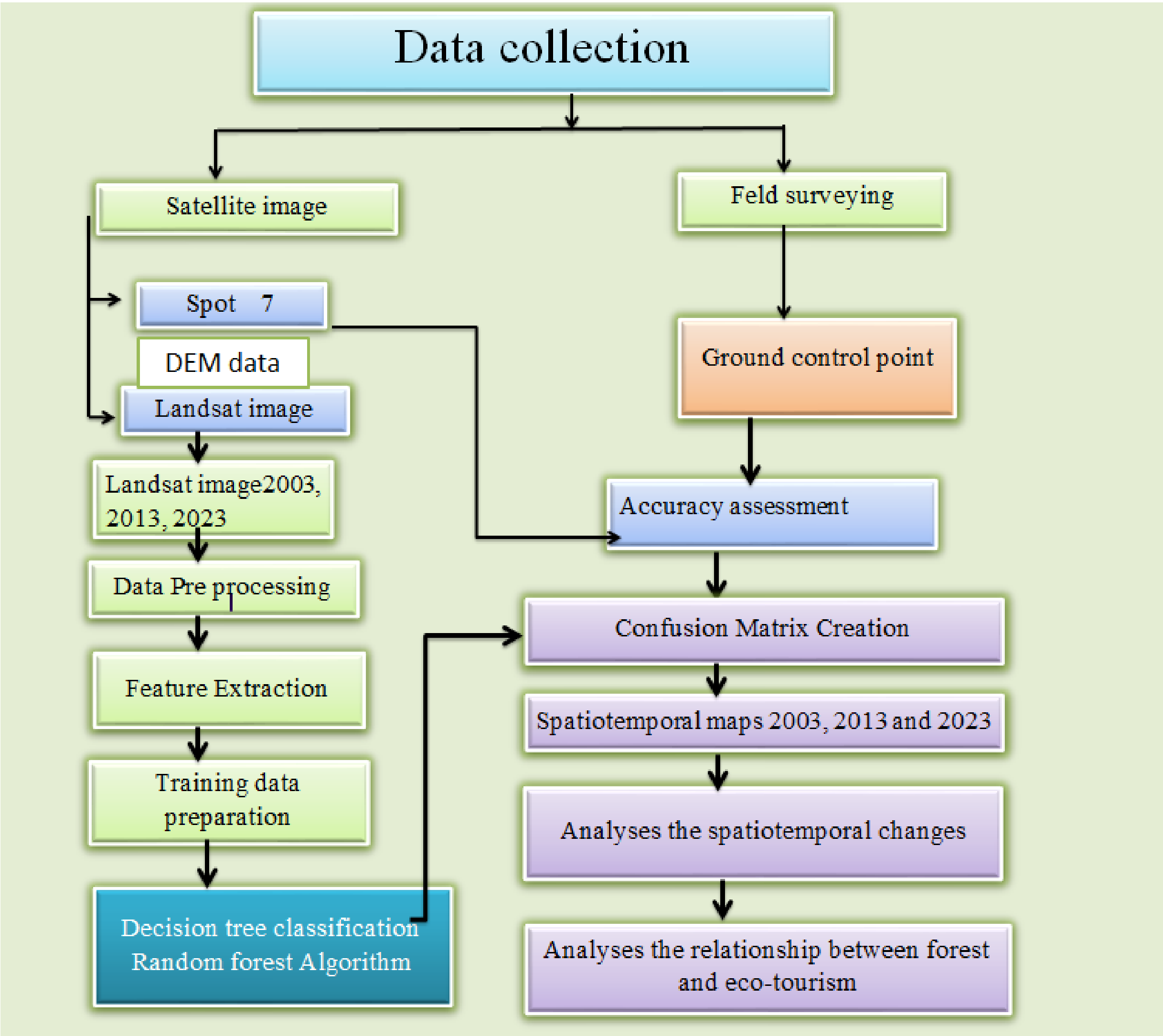

Figure 2: research design flowchart

4. RESULT AND DISCUSSION

This study analyzed interrelationships between the forest and ecotourism. The results, which can be shown as a map, table, graph, and chart to show information about the results achieved in each step, describe the results obtained through data processing and analysis methods. In the process of spatiotemporal forest analysis, Random Forest was selected over alternative classifiers.

4.1 Spatiotemporal forest classification analysis

Spatiotemporal analysis for Entoto Forest during the years 2003-2013 and 2023 has been done to determine changes in forest cover using satellite imagery and GIS technologies. Deforestation trends, reforestation, or degradation within such forest conditions over these years can be traced by researchers with factors such as urbanization, infrastructure development, and eco-tourism activities at play. This therefore provides an intensive insight into the dynamics of the forest over two decades. It develops a new, more accurate forest classification using the Random Forest classifiers supervised machine learning approach. Random Forest is chosen for spatiotemporal forest classification since it can work with big data by minimizing over fitting problems, hence increasing the precision of classification. It could define the spatiotemporal forest classification as the identification and categorization of various classes of land use-like settlements, agriculture, and forest or land cover-like vegetation, water, and bare soil from satellite or aerial imagery by algorithms. The help of machine learning in this respect, especially Random Forest, has made it far more accurate and efficient (Turner et al., 2003).

The spatiotemporal forest classification of 2003

With a total area of 49.93 square kilometers (4,992.84 hectares), the Entoto area offers a thorough overview of the distribution of different land cover types. This classification aids in understanding the extent of human and natural activity in landscapes as well as how the land is used. Below is a detailed explanation of each land cover class and its significance.

Forest land is the dominant land cover, occupying 1,354.77 hectares (13.55 km^2) which accounts for 27.13% of the total area. This indicates the importance of forest cover in the region, providing essential ecological services such as biodiversity conservation and climate regulation. Shrub Land (969.39 hectares / 9.69 km^2 / 19.42%) Shrub Land covers 19.42% of the area, making it the second most prevalent land cover. Shrub lands are transitional ecosystems that often occur between forested areas and grasslands or agricultural land. They provide habitats for a variety of plant and animal species, contributing to the region's biodiversity.

With respect to Entoto shrub lands are typically transitional zones between more forested areas and human settlements, and they help to prevent erosion and provide wildlife habitat; however, shrub lands are frequently subject to human pressures such as overgrazing or conversion to farmland, which would degrade their ecological purposes.

Built-Up Area (925.02 hectares) 9.25 km² 18.53% Built-up area represents 18.53% of the total land cover, reflecting the extent of urban development within or near the Entoto region. That would be structures, streets, and the like things that accompany human life and industry. There is a large amount of developed land, which is a sign of continued urbanization, perhaps related to the growth of Addis Ababa and other nearby towns. Urban development can have both positive and negative impacts. Well, it does stimulate economic growth and it does provide the basis for tourism, but at the same time it could cause habitat loss and fragmentation, and it would put more pressure on the natural environment, particularly the surrounding forest ecosystems.

Farm Land (921.33 hectares) 9.21 km² 18.45% Farm land accounts for 18.45% of the total area, representing agricultural activities in the Entoto region. Which of course is cultivated Agriculture is very important to the livelihood of the local economy and food security for the surrounding communities of Entoto. The expansion of agricultural land is associated with deforestation, soil degradation, and the depletion of water resources. To maintain food production while safeguarding the natural environment, it is crucial to adopt sustainable agricultural practices.

The grassland an area of 482.94 hectares (4.83 km²), accounting for 9.67% of the overall land area. This region is generally characterized by large open areas, mostly grassy, with a few trees.

Depending on how these grasslands are managed, they can also be used for eco-tourism, wildlife, and bird watching, specifically the Endemic birds of the area.

Class Area km² Area (%) Bare Land 339.39 hectares 3.39 km² 6.80% bare land includes areas with little or no vegetation, such as rocky outcrops, exposed soil, or land degraded by human or natural processes, and it is 6.80% of the total area. Total Area:

The total study region totals 4,992.84 ha (49.93 km2), and contains a heterogeneous array of natural and anthropogenic environments. 2003 land class data offers.

Forest and shrub land together accounted for almost half of the area (46.55%), indicating that these natural landscapes contribute significantly to environmental and eco-tourism functions; however, they almost equal the contribution to built-up and farm land (36.98% combined), suggesting high pressure of urbanization and agriculture that need care to meet the potential risk to conservation through sustainable development in the area, particularly broadened eco-tourism dependency in the future around the Entoto regions.

Having this classification is crucial information in regulating the Entoto forest ecosystem, urban planning, conservation, and also promoting eco-tourism activities sustainably. Classification of Entoto Map of 2003

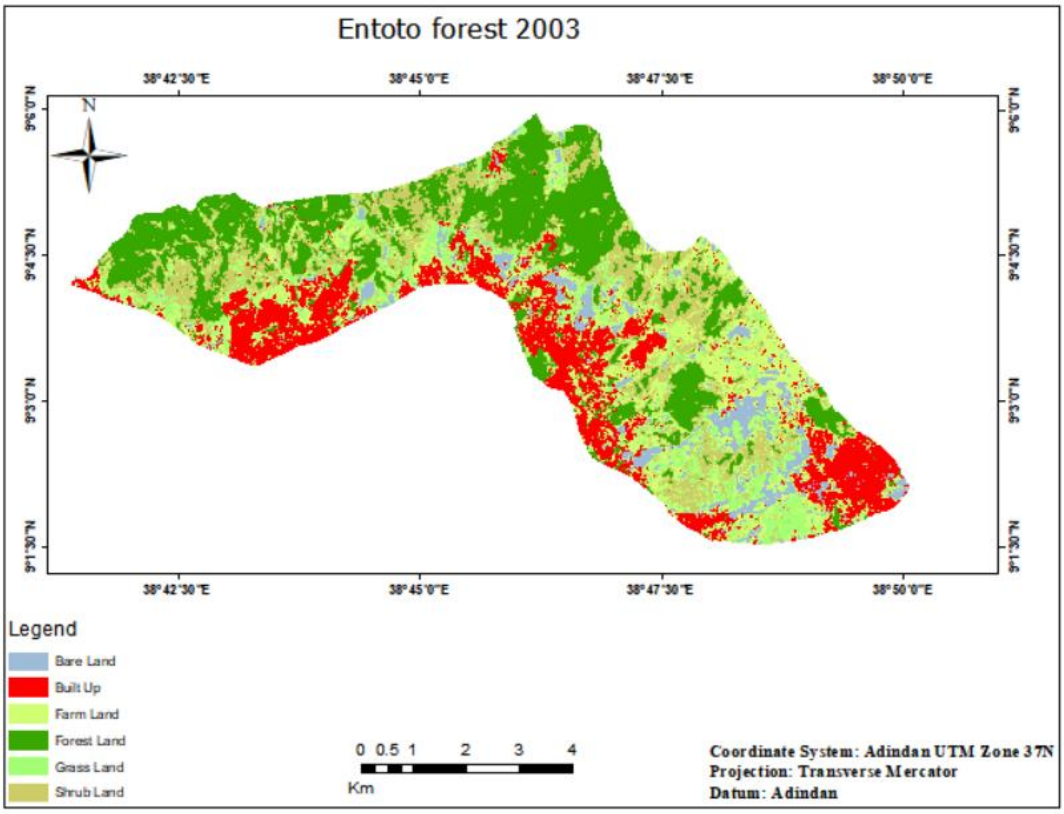

Figure 3 LUL Classification 2003

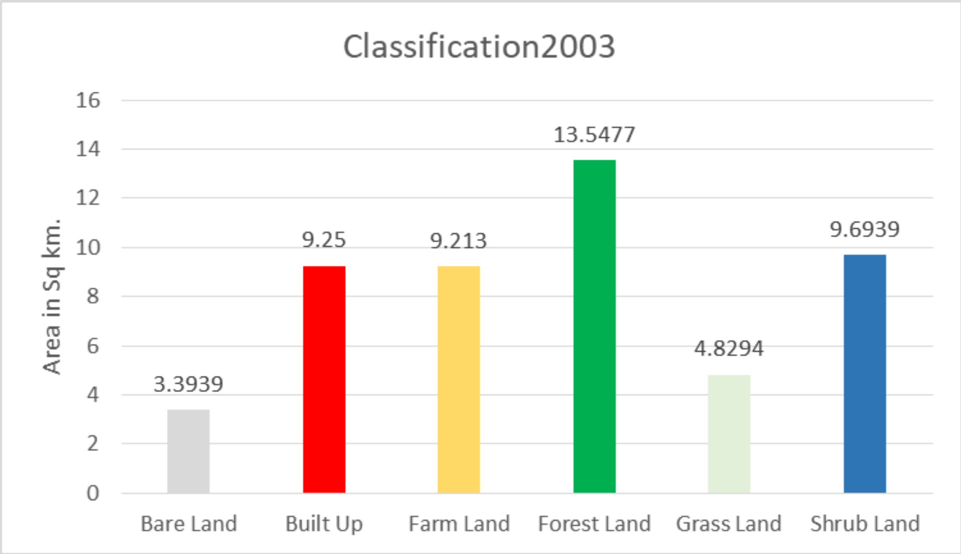

Figure 4show percentage of LULC

The figure (6) shows the classification of 2013. The spatiotemporal forest classification of 2013 provides valuable insights into the distribution and changes in land cover across the 49.92 km² (or 4992.12 hectares) area of Entoto. Here's a brief breakdown and comparison with previous years. Forest Land: Area in Hectare: 1839.78 ha Area in Km²: 18.3978 km²Percentage: 36.85% Forest land was the largest land cover in 2013, covering 36.85% of the total area. Compared to previous years it increased by 9%, indicating positive trends for reforestation or improved conservation.

Bare Land: The area is 158.13 hectares, or 1.5813 square kilometers. This makes up 3.17% of the total area. This percentage has decreased by 3.63% compared to previous years.

Shrub Land: The area covered by shrubs is 1211.22 hectares, or 12.1122 square kilometers. This is 24.26% of the total area. The shrub land has increased by 4.85%, which might show that natural vegetation is expanding.

Grass Land: The grassland area is 541.89 hectares, or 5.4189 square kilometers. This is 10.85% of the total area. Grassland has increased by 1.18% compared to the previous year.

Built-Up Areas: The area of built-up areas is 924.84 hectares, or 9.2484 square kilometers. This is 18.53% of the total area. Built-up areas have increased by 5.3%, which shows growth in infrastructure, likely to support tourism and local development.

Farm Land: The area of farmland is 316.26 hectares, or 3.1626 square kilometers. This is 6% of the total area.

Classification spatiotemporal Map of 2013

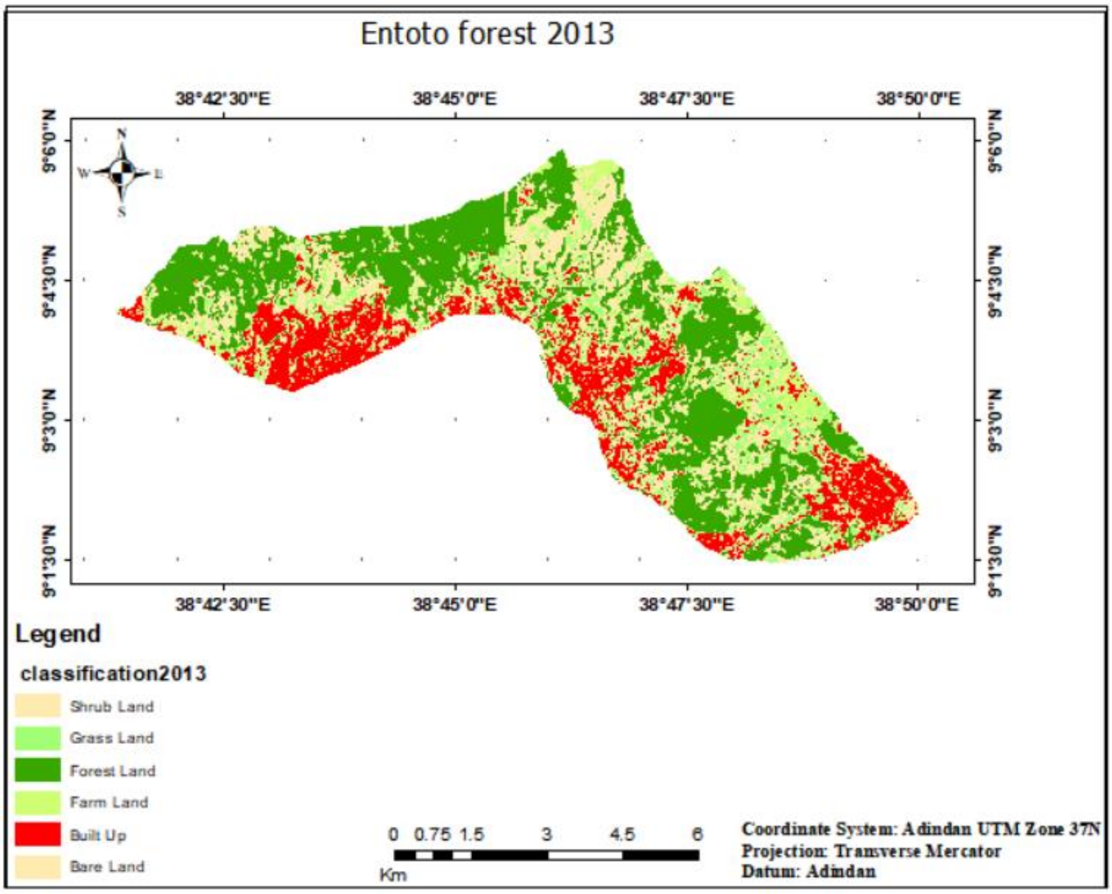

Figure 5 LUCL. Classification 2013

From previous year2003 to 2013

As can be seen in Figure 7, forest land expanded by 9%, a good sign of forest cover regrowth. Bare land decreased by 3.63%, which could be a result of reforestation or natural recovery. Shrub land grew by 4.85%, which adds to the ecological diversity. Grass land also increased by 5.3% reflecting urban and infrastructure development for tourism or local activities emphasize the necessity for sustainable management practices to harmonize conservation efforts with the advancement of eco-tourism.

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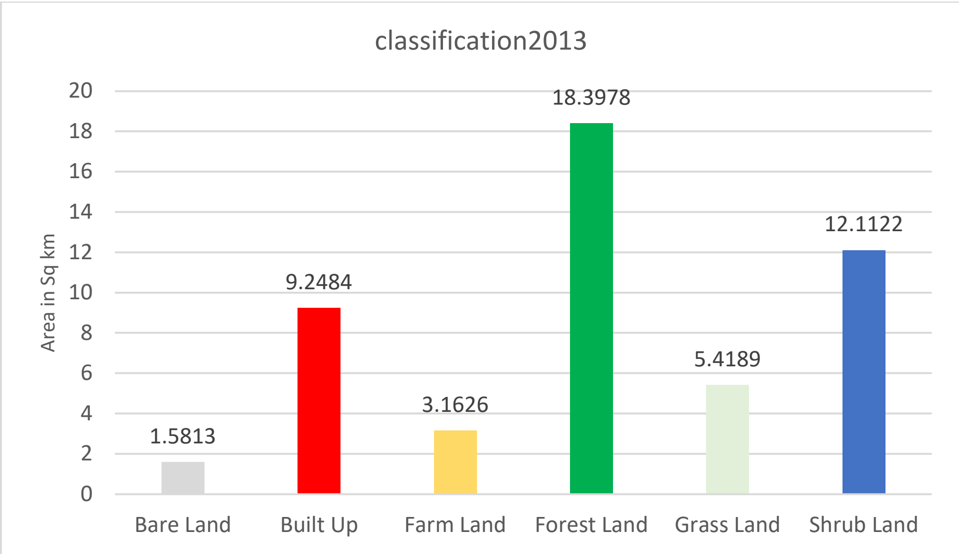


Figure 6 LULC in Area hectare

The spatiotemporal forest classification of 2023 for the Entoto area highlights significant changes in land cover over a total area of 49.93 km² or 4992.84 hectares. These classifications are critical for understanding how land use patterns have evolved, particularly in relation to eco-tourism activities.

Forest Area: Size: 1981.62 hectares (19.82 square kilometers) Percentage: 39.69% Forest land is the main type of land in this area, making up almost 40% of the total. The presence of forests is very important for eco-tourism, as it offers hiking, wildlife watching, and other nature activities. The stability or growth of forest cover helps make Entoto a popular place for eco-tourism.

Bare Land: Area6.76 km² (676.26 hectares) 13.54% as a percentage More than 13% of the land area is covered by bare land, which may be a sign of degraded land or areas in need of reforestation. It's critical to manage these bare areas to reduce soil erosion and maintain the ecosystem's appeal to visitors looking for scenic views. Built-Up Regions: 1413.63 hectares, or 14.13 km², in size 28.31% as a percentage.

Built-up land now covers over 25% of the total area, as a result of infrastructure buildup for the growing tourist activity. Although it is needed to accommodate eco-tourism, it also points out the need for intelligent urban planning to minimize the effect on the environment.

Grass Land: Area: 348.57 hectares (3.49 km²) Percentage: 6.98% Grassland occupies just fewer than 7% of the area, contributing to the open spaces that are valuable for recreational activities such as picnics, events, and open-air tourism activities. When grasslands are taken care of properly, they are beautiful and ecologically sound.

Farm Land: Area: 127.89 hectares (1.28 km²) Percentage: 2.56% Farmland covers a small portion of the total area; its presence contributes to the local food supply and livelihoods Maintaining sustainable agricultural practices can support eco-tourism by providing locally sourced food and preserving the cultural landscape.

Classification spatiotemporal Map of 2023

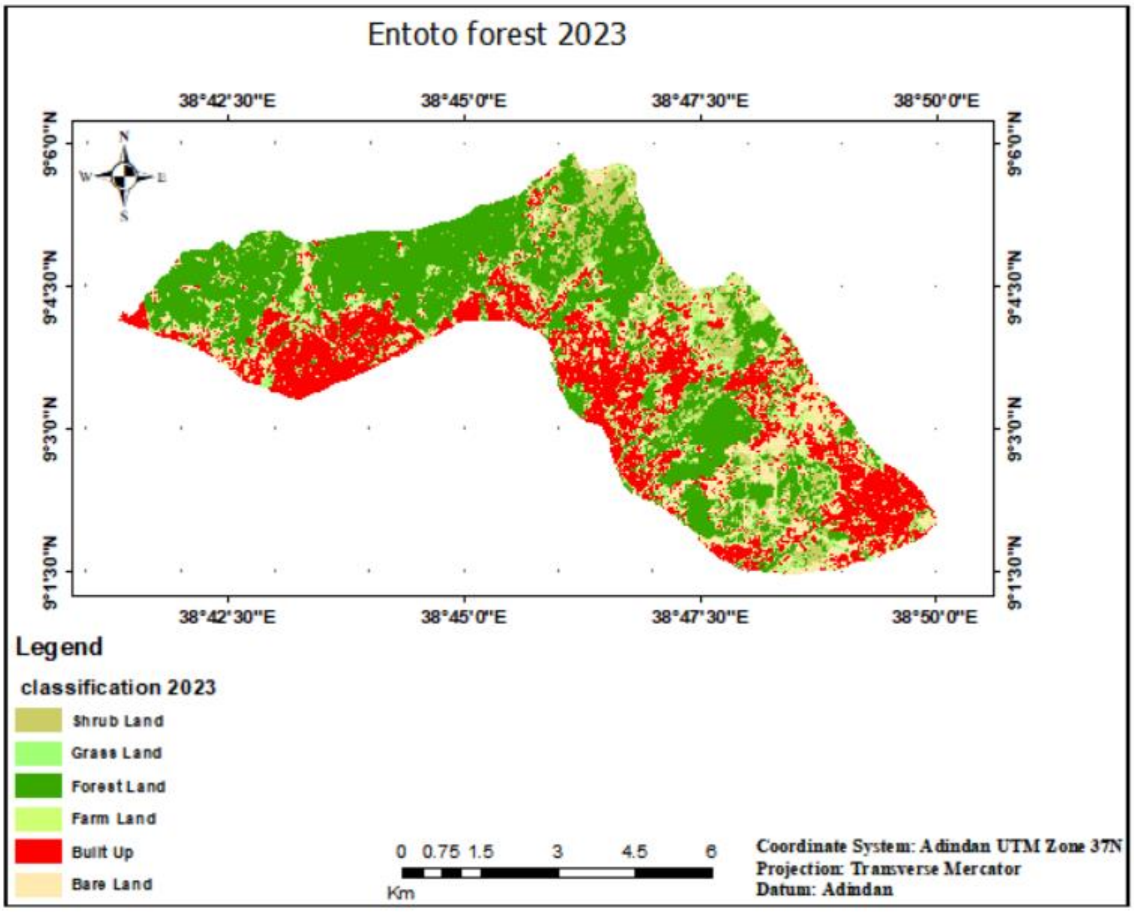


Figure 7 Classification of Entoto Map of 2003

In the classification of spatiotemporal forest in the year 2023 for the Entoto, the most area covered by forest land is 19.82 hectares; it is implied the forests are important for eco-tourism and biodiversity conservation. And other way, built-up areas have expanded significantly to 14.14 hectares, a radical increase compared to 2013. This is increased infrastructure development to be growing demand for tourism in the region. The bare land is now 6.76 hectares, a decline in coverage that indicates rehabilitating the areas. And also, shrub land covers 4.45 hectares, playing a role in maintaining the ecological balance and providing shrub land between the forest and open spaces. The area in 2023 is farmland, with 1.28 hectares, which plays an important role in supporting local agriculture and the livelihoods of communities around the forest.

Overall, the data from 2023 illustrates how Entoto environment changes over time, with development taking place with initiatives to preserve and improve forest cover (Figure 9). With the forest maintaining to be the primary natural resource and the built-up areas increasing to provide tourism infrastructure, these changes directly affect ecotourism.

Ecotourism Implications:

The general shows an intricate balance between human activity and natural land cover. The protection of forest land is essential for preserving the natural environment that attracts tourists to Entoto, while the development of built-up areas is enhance ecotourism infrastructure. By managing these places sustainably, ecotourism can grow without compromising the health of the ecosystem.

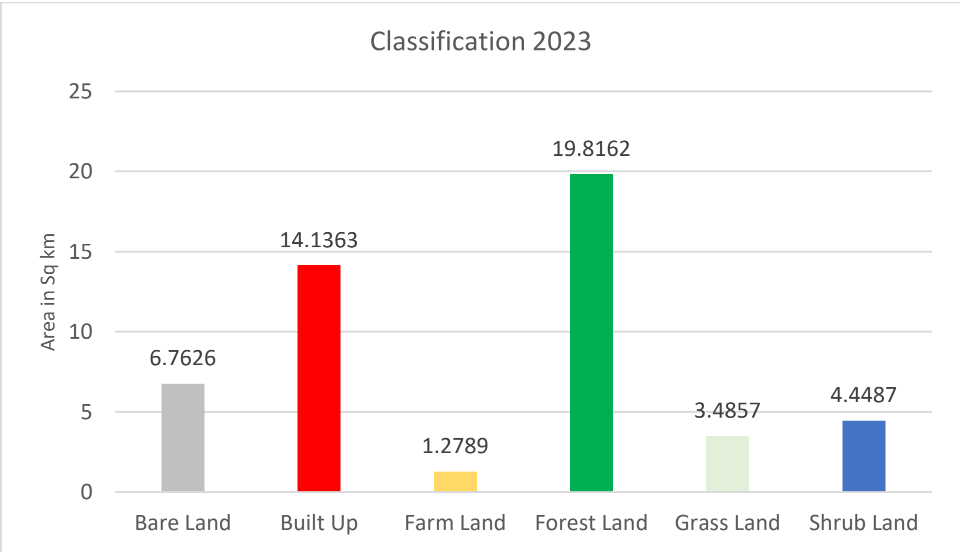


Figure 8 LULC. Area in hectare

4.3 Spatiotemporal analysis 2003_2023

Spatiotemporal analysis in Entoto Forest from 2003 to 2023 shows changes in land cover types over the years. Farmland covered 921.33 hectares (18% of the total area) in 2003, decreased to only 1.28 hectares by 2023, and a 12% reduction bare land, which covered 6.79% of the area in 2003, decreased to 3.16% in 2013 and to 13.5% by 2023. Built-up areas, which remained stable at 18.5% in both 2003 and 2013, a significant increase to 28.33% by 2023, show a 9.78% growth, likely due to urbanization and infrastructure development. Grassland, which increased from 9.6% in 2003 to 10.8% in 2013, decreased to 6.98% in 2023, indicating land-use changes that may have changed grassland areas into urban or forested areas. These have shown the dynamic interaction between development, urbanization, and environmental conservation in the Entoto area.

Table 4spatiotempora Cove Classification in2003-2023

Land Use Land Cover - Year 2003				Year 2013		Year 2023	
VALUE	Class Name	Area in hectare	%	Area in hactar	%	Area in hectare	%
1	Bare Land	339.39	6.798	158.13	3.168	676.26	13.545
2	Built Up	925.02	18.527	924.84	18.526	1413.63	28.313
3	Farm Land	921.33	18.453	316.26	6.335	127.89	2.561
4	Forest Land	1354.77	27.134	1839.78	36.854	1981.62	39.689
5	Grass Land	482.94	9.673	541.89	10.855	348.57	6.981
6	Shrub Land	969.39	19.416	1211.22	24.263	444.87	8.91
Total Sum		4992.84	100	4992.12	100	4992.84	100

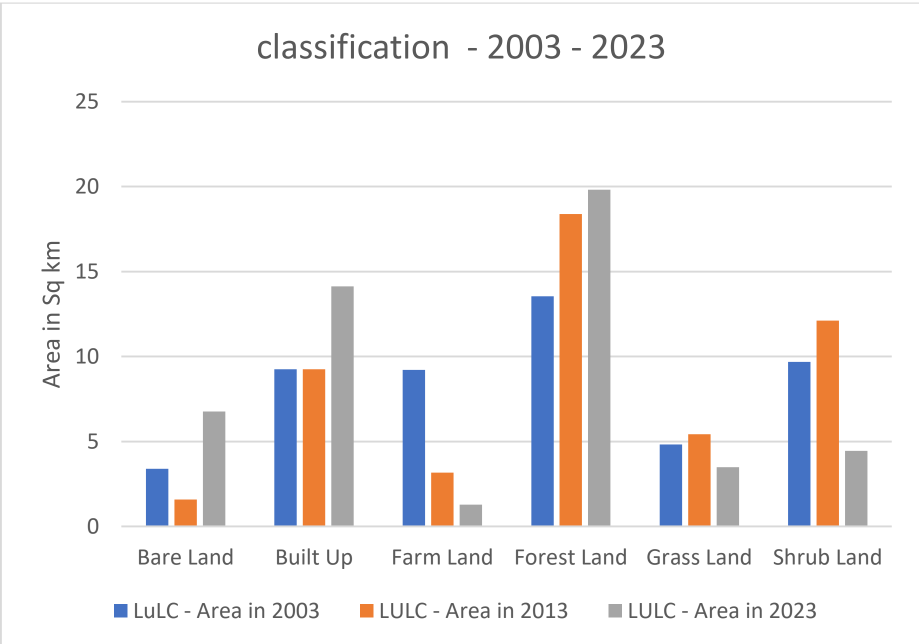


Figure 9 LULC classification2003_2023

4.3 Forest covers gain and loss in year

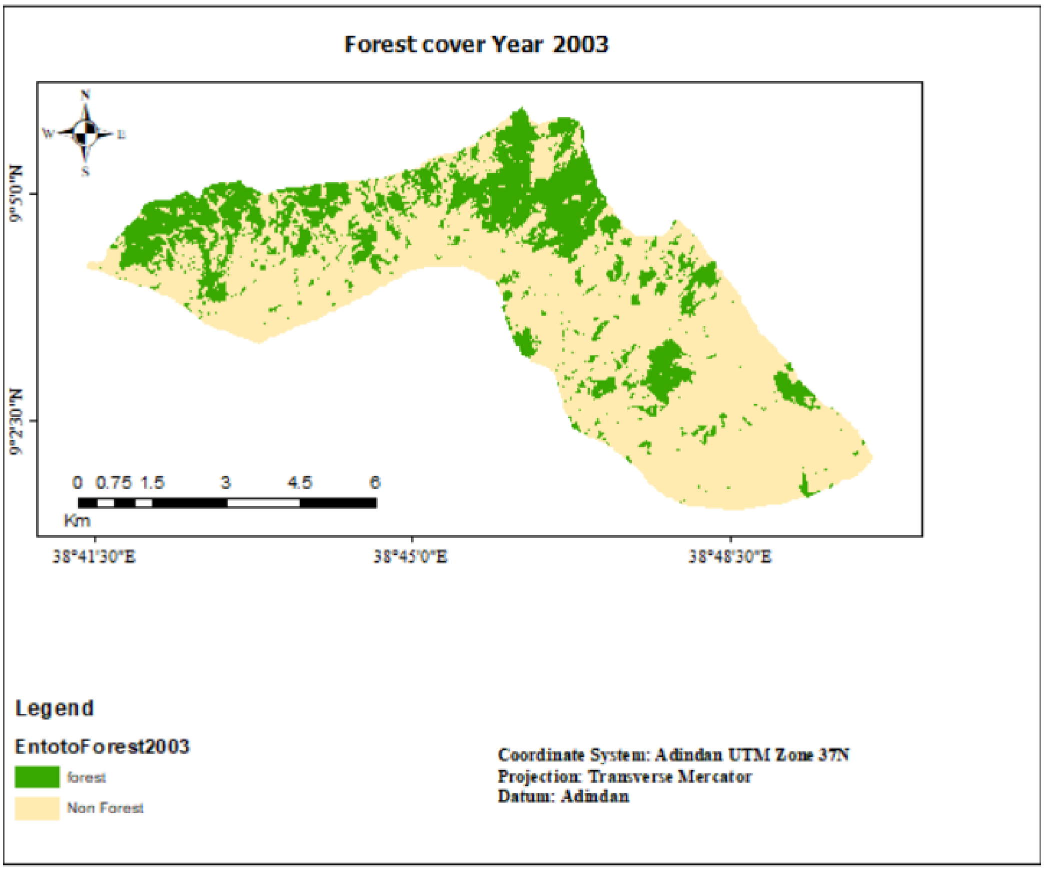


Figure 10forest cover map 2003

Forest cover show in2003

The analysis of forest cover change between 2003 and 2013 important change forested areas of the area. In 2003, the forest cover was 13.541 hectares, an even smaller portion of the land compared to non-forest areas. But, by 2013, the forest area had expanded to 18.39 hectares, an increase of around 4.85 hectares in the forested area. This positive trend is indicative of reforestation over the 10-year period. The increase in forest area most area the reforestation programs conservation efforts it is at restoring degraded land forest growth. The non-forest areas, including built-up, farmland, grassland, shrub land, and bare land, occupied a large portion of 36.3807 hectares in 2013.

The forest gain seen during this period emphasizes the sustainable forest management method in the region, which creates opportunities for ecotourism development. The increased forest cover supports biodiversity, provides more green spaces for tourists, and contributes green ness. It also underlines the growing importance of balancing land use between development and environmental conservation.

This shift in forest cover, illustrated in Figure (12) is a clear indicator of the region's progress toward sustainable land management practices, which benefit both the environment and local communities engaged in eco-tourism and forest-based livelihoods.

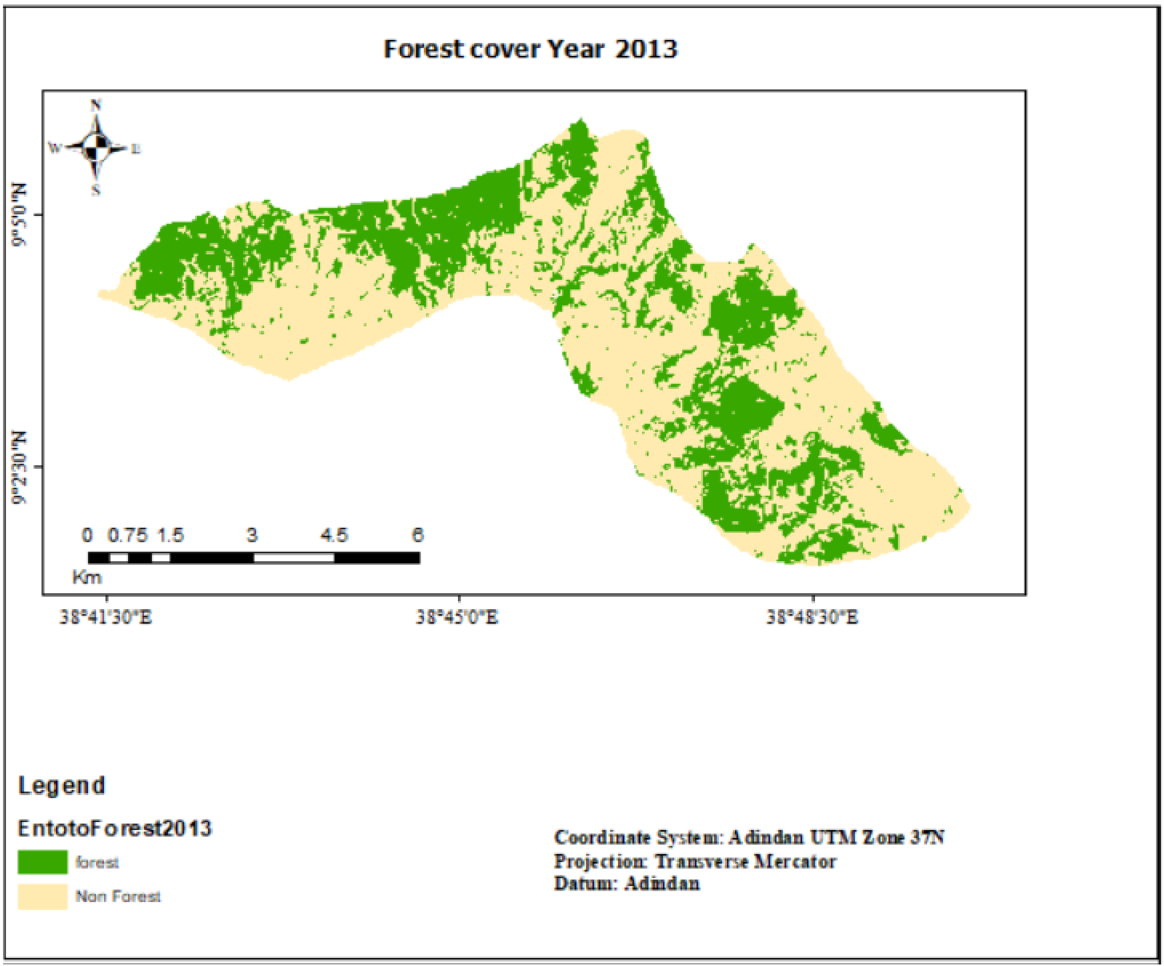


Figure 11forest cover year 2013

Forest cover in year 2023

In the table below (4) comparison of forest coverage up to 2023 shows an increase of 1.7%, which increasing to an additional 1.7163 hectares of forest. This increment reflects a positive trend in forest area expansion over the observed period The forest cover change analysis results of the study show incising comparing to the 2003 forest these my of afforestation of tree.

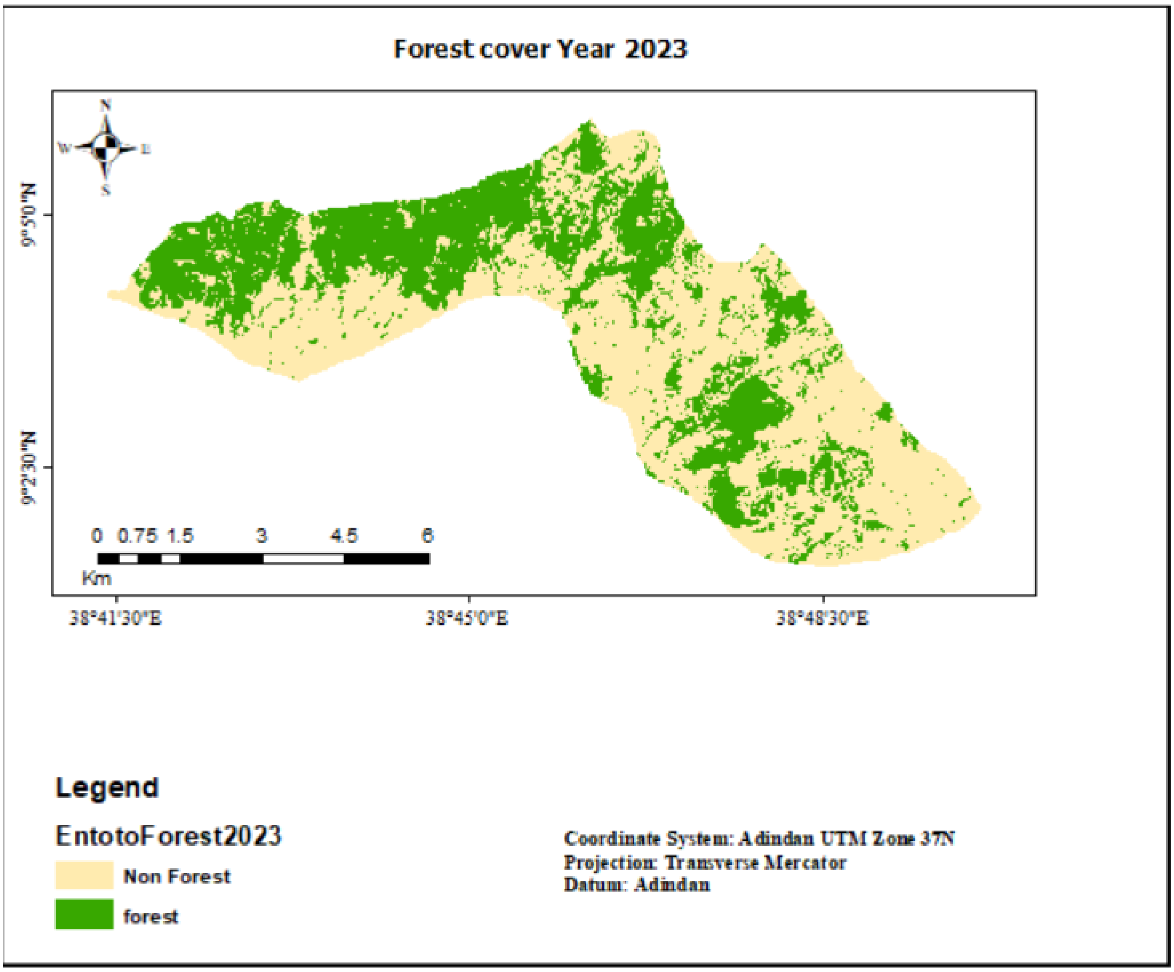


Figure 12forest cover year2013

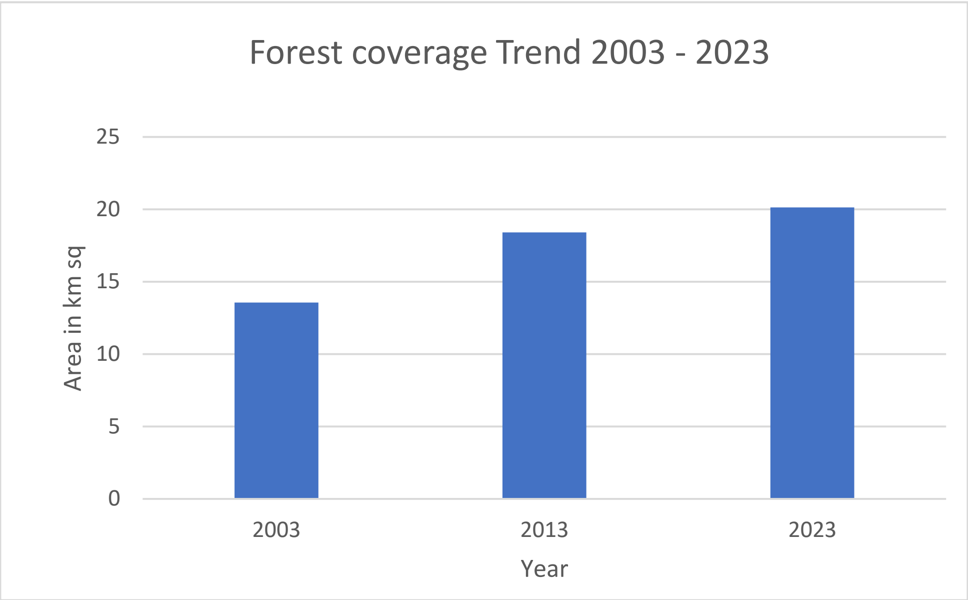
Forest cover 2003, 2013and 2023

Forest cover refers to the land area that is covered by forests, including natural and plantation forests. It is impliedly measured in terms of area hectares or square kilometers and is often expressed as a percentage of the total land area. Forest cover indicates the density or spares distribution of forests within a specific area, and it plays an important role in maintaining biodiversity, regulating climate, and supporting ecosystems. In forest cover Changes can result in deforestation and reforestation. Environmental policies, natural processes, and human activity all play an important role in forest cover gain and loss. Generalized global deforestation is still a major problem, mostly in tropical regions. To preserve biodiversity, slow down climate change, and promote human well-being, forest cover dynamics must be balanced through sustainable management, robust legislation, and community involvement(Zheng et al., 2022)

Forest cover treande2003_2023

Forest cover change analysis indicates that global conservation efforts aimed at reducing deforestation and forest degradation are most impacted by forest conservation practices in recent years. Ethiopia, the government has implemented a forest rehabilitation program, which includes planting millions of trees annually in Addis Ababa and surrounding areas. As a result of these initiatives, Entoto Forest has experienced a notable increase in coverage over time. Between 2003 and 2023, the forest area in Entoto has significantly expanded, reflecting the positive trend of these conservation efforts.

The bar chart (14) shows Forest Coverage Trend 2003-2023, the changes in forest coverage over a 20-year period. In 2003, the forest coverage was approximately 13 km, representing the lowest value within the year. By 2013, the forested area had increased significantly to around 18 km, showing efforts in forest conservation and reforestation contributing to forest growth. The upward trend continued, and by 2023, the forest coverage would grow over 20 km². This consistent increase in forest area is a positive trajectory in forest management and environmental protection over the past two decades.



13 forest cover trend in 2003 _2023

This table illustrates the changes in forest and non-forest cover over time. Between 2003 and 2023, forested areas increased from 13.5477 km² to 20.1141 km², reflecting a substantial growth of 40.29%. Conversely, non-forest areas decreased from 36.3807 km² to 29.8143 km², representing a reduction to 59.71%. The total area remained relatively constant around 49.93 km² throughout the observed period.

Table 5forest cover trend 2003_2023

Forest Cover Trend Analysis (Area in km sq.)					
VALUE	**CLASS NAME**	**2003**	**2013**	**2023**	**Percentage**
6	Forest	13.5477	18.3978	20.1141	40.29
1	Non-Forest	36.3807	31.5234	29.8143	59.71
Total		49.9284	49.9212	49.9284	100

Forest covers gain and Lost- Year 2003_ 2013

In the figure (15), this analysis shows that, over the different periods, Entoto Forest has of gains and losses. Between 2003 and 2013, there was a significant increase in forest cover, with a gain of 9.0126 km². The period from 2013 to 2023 also saw a gain of 6.1218 km², though with more loss compared to the previous period. Over the entire span from 2003 to 2023, the forest cover gained 9.4914 km², while the forest area lost was significantly reduced to 2.925 km², indicating an overall positive trend in forest conservation and expansion.

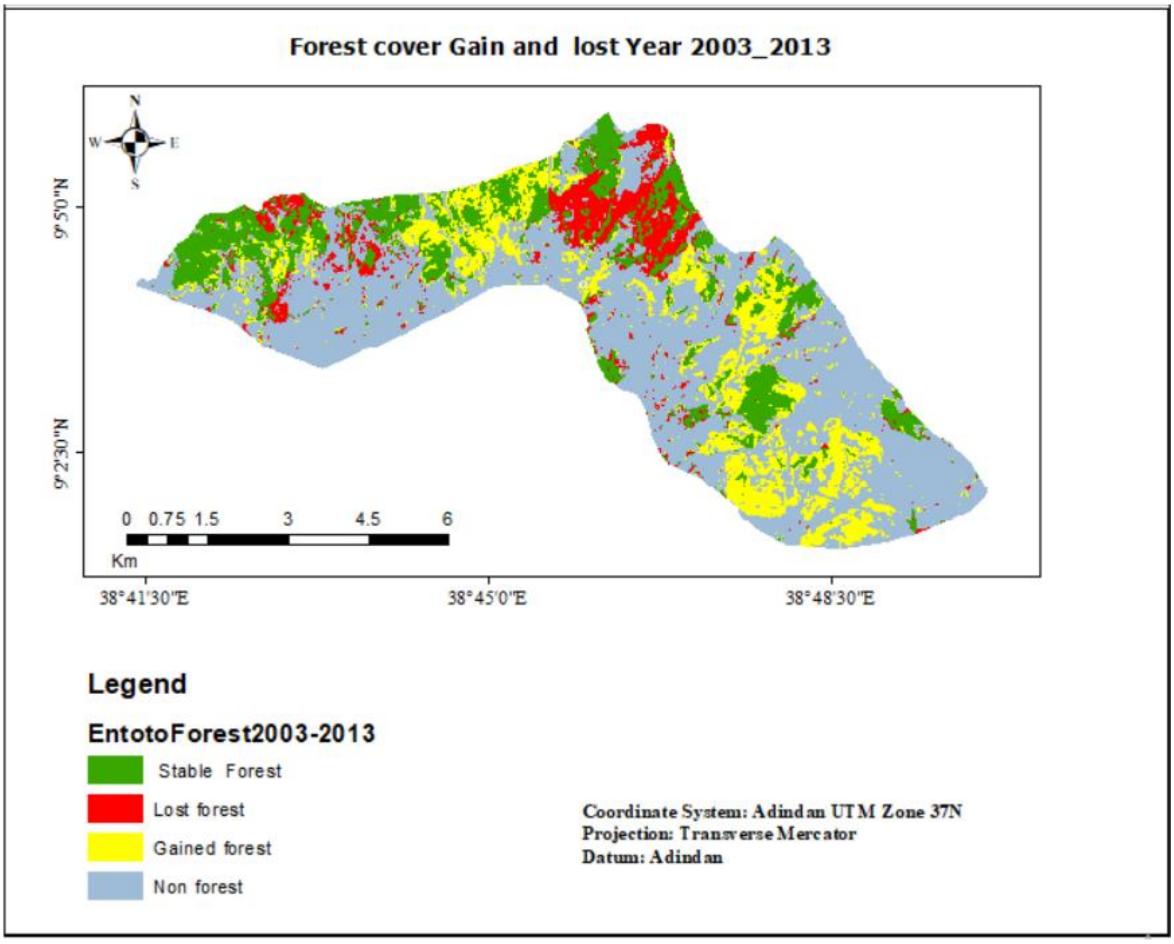


Figure 14forest cover gain and lost 2003_2013

Forest Cover Gain and Lost 2003_1013 the table above illustrates the changes in forest cover between 2003 and 2013; based on the provided data, Entoto Forest has experienced a notable increase in forest cover from 2003 to 2023. In 2003, the forest cover was 1,354.77 hectares. By 2013, this area expanded to 1,839.78 hectares, reflecting an increase of 484.98 hectares, or approximately 9.72%. The trend continued from 2013 to 2023, with the forest cover rising further to 2,141.75 hectares. This represents an additional increase of 301.97 ha, or 2.83%. Overall, from 2003 to 2023, the total increase in forest cover amounted to 786.98 hectares, marking a substantial rise of 12.55% in the forest area.

Table 6forest coven gain and lost 2003_2013

Forest cover gain and Lost- Year 2003 - 2013					
Value	land cover Type	Area (m^2)	Area (Ha)	Area in km sq.	Percentage
1	Non forest	27360900	2736.09	27.3609	54.808
2	Gained forest	9012600	901.26	9.0126	18.054
3	Lost forest	4162500	416.25	4.1625	8.338
4	Stable Forest	9385200	938.52	9.3852	18.800
sum		49921200	4992.12	49.9212	100.000

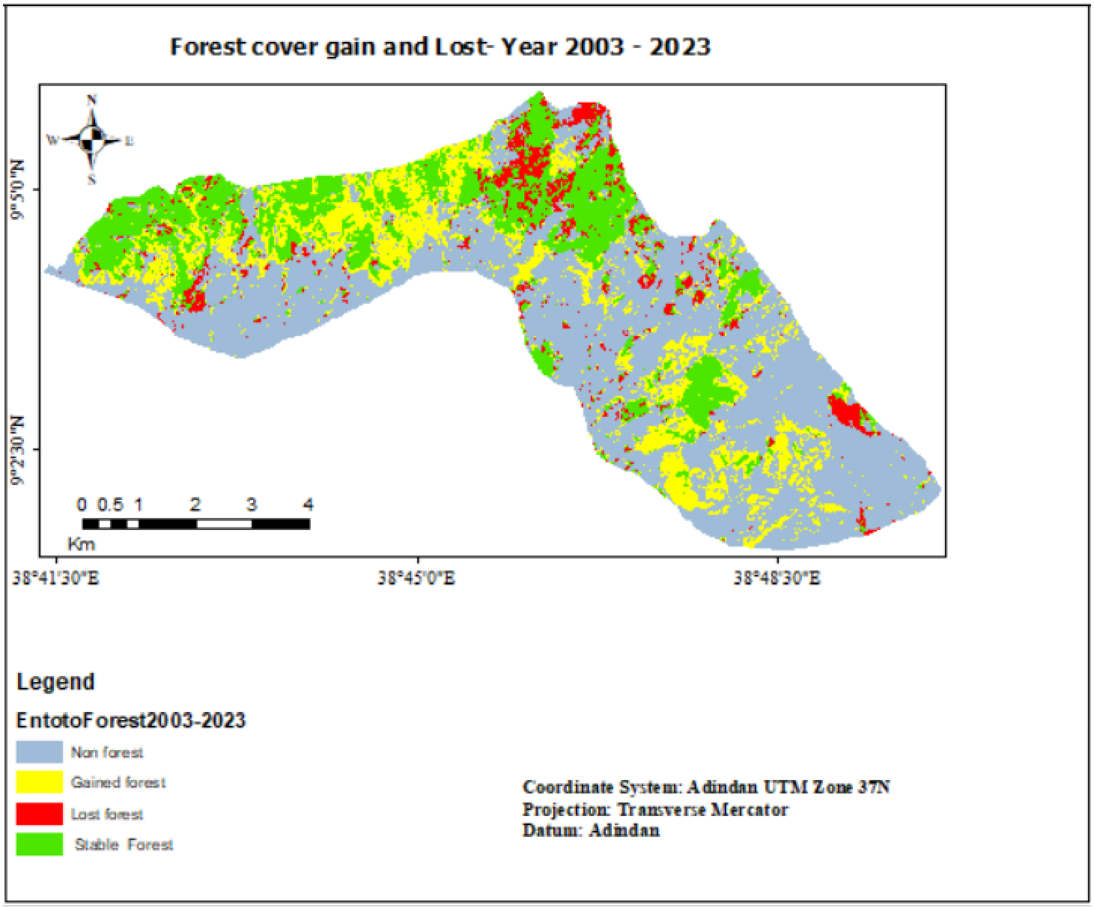


Figure 15forestforest cover gain and lost 2003_2023

Forest cover gene lost 2003_2023

The table presents a detailed analysis of forest cover change from 2003 to 2023. During this period, non-forest land dominated the area, covering 26.89 km², which accounted for 53.86% of the total land. There was a notable gain in forest cover, with 9.49 km² of new forest established, representing 19.01% of the area. However, there was also a loss of 2.93 km² of forest, which made up 5.86% of the total land area. Meanwhile, 10.62 km² of forest remained stable and unchanged over the two decades, constituting 21.28% of the land.

These changes reflect the ongoing dynamics of deforestation, reforestation, and conservation efforts within the region over the 20-year period.

Table 7fores cover gain and lost 2003_2023

Forest cover gain and Lost- Year 2003 - 2023						
Value	land cover Type	Area (m^2)	Area (Ha)	Area in km sq.	Percentage
1	Non forest	26889300	2688.93	26.8893	53.85572
2	Gained forest	9491400	949.14	9.4914	19.01002
3	Lost forest	2925000	292.5	2.925	5.858389
4	Stable Forest	10622700	1062.27	10.6227	21.27587
sum		49928400	4992.84	49.9284	100

Between 2003 and 2023, forest cover experienced significant changes. The largest portion of land, accounting for 53.86%, remains non-forest, which is a substantial area of 26,889,300 m. Over this period, there was a notable increase in forest cover, with 9,491,400 m², or 19.01% of the total area, gaining forest. However, this gain was somewhat offset by forest loss, which amounted to 2,925,000 m², or 5.86%. In contrast, stable forest areas comprised 21.28% of the total land, equating to 10,622,700 m². This suggests that while there have been both gains and losses in forest cover; a significant portion of the forest area has remained unchanged. Overall, these figures reflect a dynamic landscape where forest cover has seen both positive and negative changes, with stable forests forming a crucial component of the total forest area.

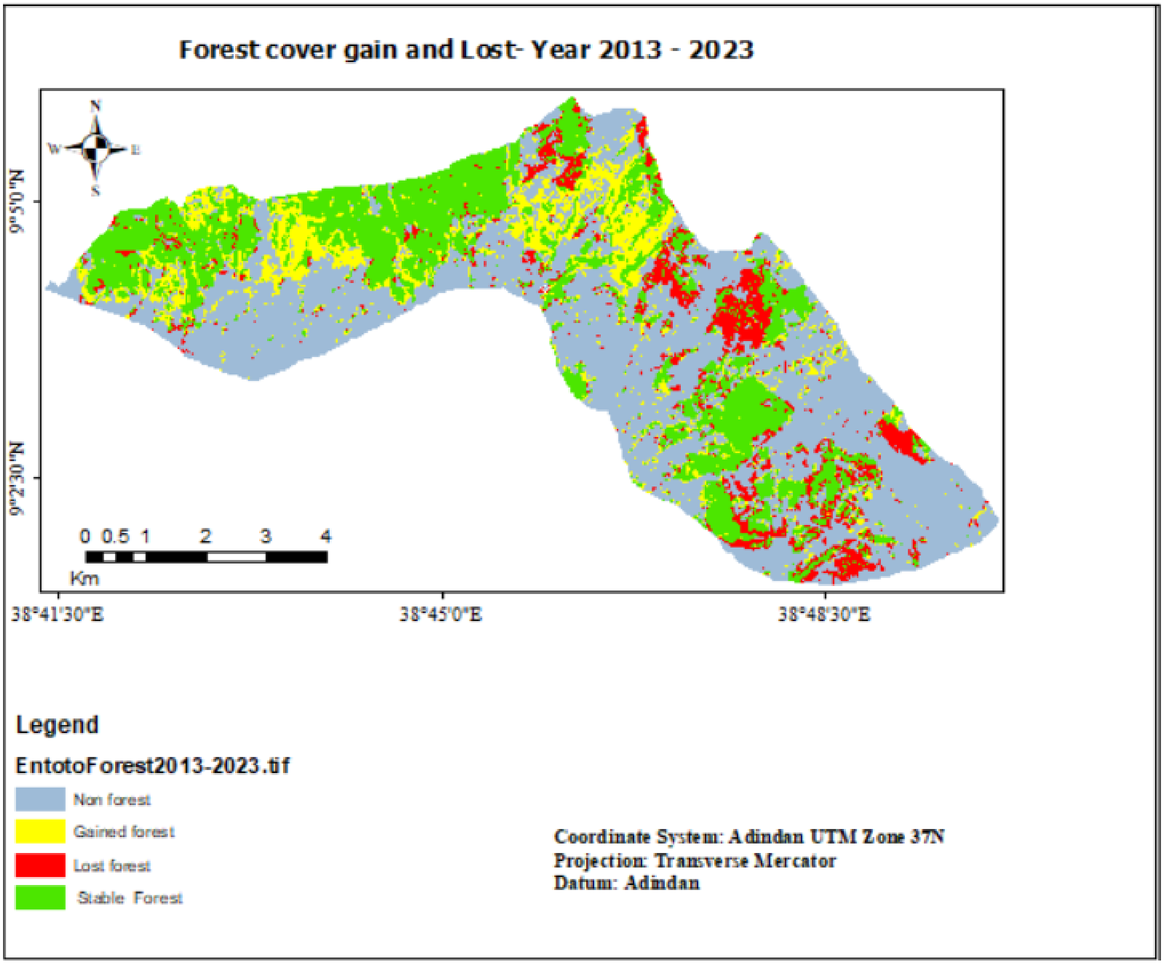


Figure 16 forest cover gain and lost year 2013_2023

Between 2003 and 2023, forest cover experienced significant changes. The largest portion of land, accounting for 53.86%, remains non-forest, which is a substantial area of 26,889,300 m. Over this period, there was a notable increase in forest cover, with 9,491,400 m², or 19.01% of the total area, gaining forest. However, this gain was somewhat offset by forest loss, which amounted to 2,925,000 m², or 5.86%. In contrast, stable forest areas comprised 21.28% of the total land, equating to 10,622,700 m². This suggests that while there have been both gains and losses in forest cover; a significant portion of the forest area has remained unchanged. Overall, these figures reflect a dynamic landscape where forest cover has seen both positive and negative changes, with stable forests forming a crucial component of the total forest area.

Table 8 Forest cover gain and lost year20013_2023

Forest cover gain and Lost- Year 2013 - 2023					
Value	land cover Type	Area (m^2)	Area (Ha)	Area in km sq.	Percentage
1	Non forest	25401600	2540.16	25.4016	50.883
2	Gained forest	6121800	612.18	6.1218	12.263
3	Lost forest	4405500	440.55	4.4055	8.825
4	Stable Forest	13992300	1399.23	13.9923	28.029
sum		49921200	4992.12	49.9212	100.000

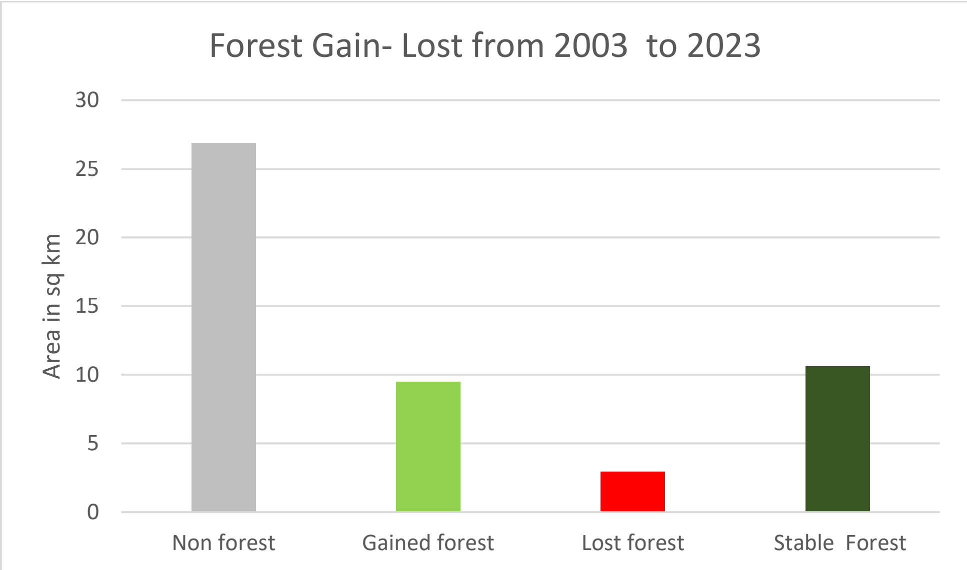


Figure17forest gain lost 2003_2023

Forest cover gain lost 2003_2023

The above figure shows the changes in land use and land cover classes in Entoto Forest over 20 years, from 2003 to 2023. The map displays in the Cause of Entoto Forest area forests cover increased time to time these show the figure (8) the forest gain and loss map in the Entoto forest Based on the data provided, the Entoto Forest has experienced a significant increase in forest cover from 2003 to 2023. In 2003, the forest cover was recorded at 1354.77 hectares. By 2013, this area had expanded to 1839.78 hectares, marking an increase of 484.98 hectares, or approximately 9.72%. From 2013 to 2023, the forest cover further increased to 2,141.75 hectares, showing a continued positive trend with an additional rise of 301.97 hectares, which represents a 2.83% increase. Overall, from 2003 to 2023, the total increase in forest cover amounted to 786.98 hectares, indicating a notable rise of 12.55% in the forest area. The term forest cover gain describes an increase in forested areas as a result of reforestation or natural recovery, whereas forest cover loss refers to a decrease in forested land as a result of land conversion or deforestation. The sustainability and health of forest ecosystems can be evaluated by keeping an eye on these changes

4.4 Digital Elevation Model of Entoto Forest

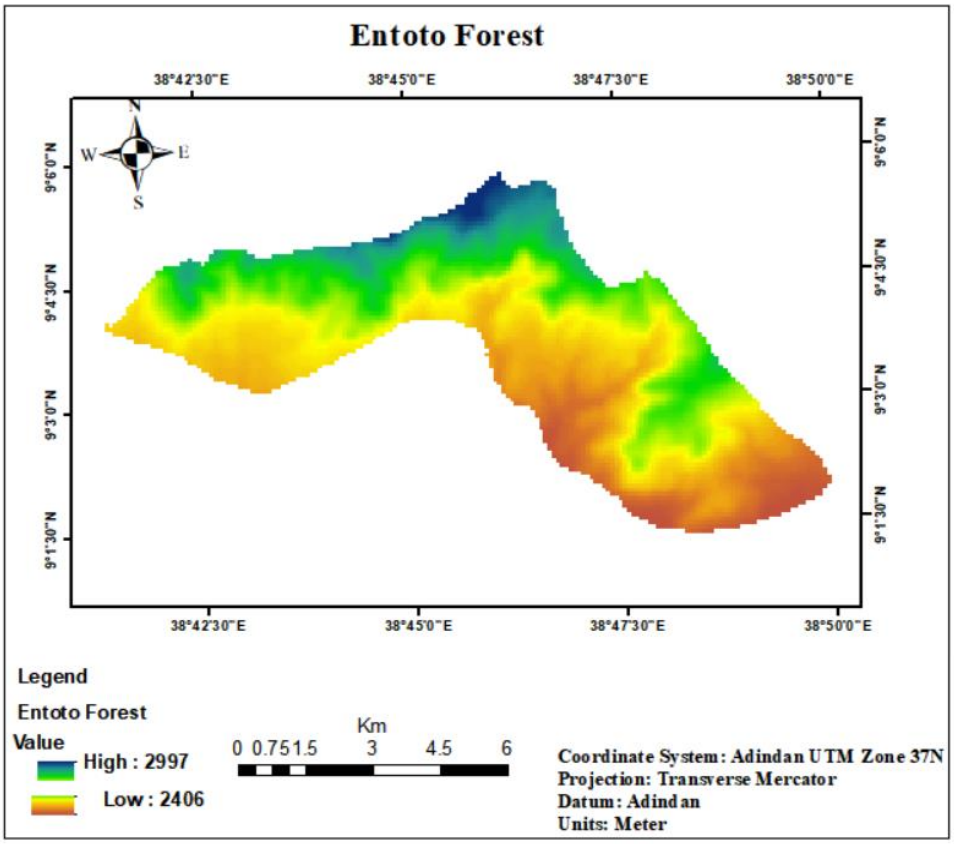


Figure 18 Digital Elevation Model

Entoto Mount, with an elevation ranging from minimum 2,400 to maximum 3000 meters above sea level, is one of the highest points in the Addis Ababa region. Its altitude fosters a cooler climate and supports a unique ecosystem with endemic plant and animal species not found in the lower urban areas. This distinct environment, coupled with the forests rich biodiversity and scenic beauty, makes Entoto Forest a prime eco-tourism destination area. Visitors are offered natural trails for hiking, nature walks, and panoramic views of Addis Ababa and the surrounding area, offering a peaceful destination. The DEM of Entoto Forest is an important tool for understanding the relationship between the forest's physical terrain and its ecotourism areas. It helps identify areas suitable for sustainable tourism development while guiding conservation strategies to preserve sensitive ecological zones.

By integrating the DEM with spatiotemporal forest data, stakeholders can ensure that eco-tourism development aligns with environmental protection goals, fostering long-term sustainability in the region.

Along with its natural enchantments, the Entoto region has developed into an important center for ecotourism and businesses, such as restaurants and recreational areas that encourage environmental conservation. These businesses have been carefully placed to provide magnificent views while leaving as little of an environmental impact as possible. Mount Entoto is a popular destination for ecotourism in Ethiopia due to its natural beauty, biodiversity, and sustainable tourism infrastructure. It draws both domestic and foreign tourists' attraction peaceful surroundings and outdoor activities.

4.5 Map of Ecotourism activity area in Entoto forest

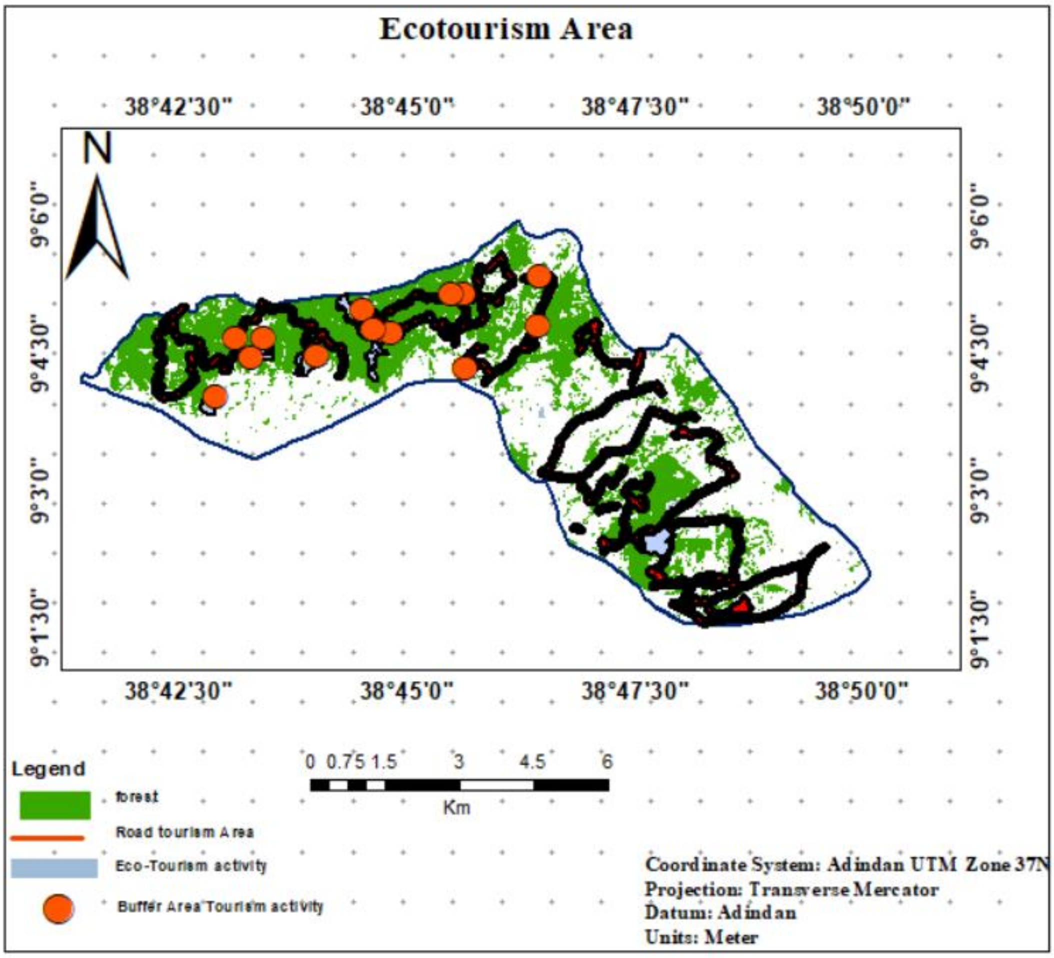


Figure 19 Ecotourism activity area.

Map of Ecotourism Activity Area in Entoto Forest the above finger showed of accordingly to remote sensing data and field verification Buffer Zone of Tourism Activity Key Tourism Activity Locations Entoto Forest visitor centers, cultural sites, roads, and recreation of areas within the forest. Figure 20: Tourism Activity Buffers: A buffer zone is defined by a certain radius (30 meters) of tourism activity. The size of the buffer depends on the expected impact zone for tourism activities, such as foot traffic, noise, or pollution.

By mapping out the road networks, the forest management is ensuring that tourists can enjoy convenient access while reducing the environmental impact through the strategic placement of roads. This infrastructure, however, must be carefully managed to prevent undue damage to the sensitive environment of Entoto Forest.

The purpose of the 30-meter buffer zone: The 30-meter buffer zone withes both sides of the road as a protective strip around the road infrastructure. This buffer is a tourism activity area associated with road construction and use disturbances to local wildlife. Within this buffer, restrictions are likely placed on activities such as logging, land clearing, or construction to preserve the natural vegetation and maintain the integrity of the forest ecosystem. It is a 30-meter buffer zone along roads in the Entoto Forest eco-tourism area. By safeguarding the area surrounding the roads, the forest management effectively balances the needs of infrastructure with the ecological preservation goals central to eco-tourism development.

Entoto area is home to historical and religious sites, including ancient churches and monasteries. Eco-tourism integrates these cultural elements into the visitor experience, allowing tourists to enjoy both the natural beauty and the cultural history of the area in a sustainable manner.

Eco-tourism in the Entoto forest area supports local communities by creating job opportunities and income generated by tourism and related activities. This helps to reduce poverty by reduces the reliance on environmentally harmful practices (Solomon, 2021).

In addition to learning about the value of environmental preservation, eco-tourists can take advantage of recreational pursuits including hiking, bird viewing, and sightseeing in the Entoto Forest. Focusing on education encourages tourists to adopt more sustainable practices and helps spread awareness of the need to preserve natural regions like Entoto. Promoting sustainable tourism that benefits local people and the environment while protecting the park's natural and cultural legacy for future generations is at the heart of the interaction between ecotourism and Entoto Natural Park (Civil et al., 2019).

Increasing forest coverage in Entoto Mountain is the most important benefit for eco-tourism activity by biodiversity and environmental sustainability. Landscapes, wildlife encounters, and immersive nature experiences. As forest cover expands, it supports increased ecosystem benefit, promoting biodiversity conservation, and making the area increase in activities like hiking, bird watching, and nature photography. And also, increased forest coverage contributes to environmental sustainability by improving air quality, balancing local climate, and sequestering carbon, all of which create a more attractive and healthier environment for visitors. The forest ecosystem also benefits local communities by generating income through sustainable tourism activities, where there is a connection between conservation efforts and tourism development.

In addition Entoto Forest, located in the mountainous area of Addis Ababa, Ethiopia, has a lot of significant advantages for eco-tourism. Its high-altitude forest provides a unique and diverse ecosystem, rich in biodiversity, which attracts nature researchers. The forests elevated location advantages panoramic views of the surrounding landscape,

Enhancing additionally the coldest climate environment makes it an ideal destination for eco-tourism activities. And it is promoting sustainable tourism practices; Entoto Forest helps protect its delicate ecosystems while providing economic benefits to local communities, fostering a deeper connection between visitors and natural beauty.

Spatiotemporal forest and ecotourism relation

The Entoto Mountain area used significant potential for developing tourism as part of its broader ecotourism because of its rich biodiversity, proximity to Addis Ababa, and the presence of cultural and historical sites. The relationship between eco-tourism and the Entoto Forest is in promoting sustainable tourism practices that harmonize environmental conservation with cultural preservation and local community involvement. As forest cover in Entoto has expanded over the past two decades, it has provided a better environment for wildlife, including bird species that can draw birdwatchers and nature enthusiasts.

Entoto Natural Park, located in the mountains, offers panoramic views, historical landmarks, and diverse ecosystems, making it a prime location for eco-tourism. The forest plays a crucial role in attracting visitors who are interested in nature, outdoor activities like hiking, and exploring the area's cultural heritage, all while focusing on minimizing the environmental footprint of tourism. The spatiotemporal growth of the forest over the years has enhanced the area's natural appeal, reinforcing eco-tourism as a sustainable development model that balances environmental protection with community engagement and cultural education. This symbiosis of forest growth and eco-tourism helps ensure the continued health of the ecosystem and benefits both local communities and conservation efforts.

Chapter 5 CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This study evaluated spatiotemporal changes in forest cover in relation to ecotourism activities. The advancement of technology is fast growing, and it has a strong impact on eco-tourism and forests. The ML algorithms are powerful tools for classified analyzing huge and large data. The findings, while eco-tourism can play a role in conserving forested areas, show that the spatiotemporal growth of ecotourism areas has both positive and negative impacts on the forest, and temporal analyses show that areas with increased ecotourism activities experience either a positive or negative impact on the forest. Indiscriminate or mismanaged tourism activities cause habitat destruction, whereas implementation of ecotourism has been beneficial for conservation in some regions.

The changing pattern of Entoto Forest from 2003 up to the year 2023 was demonstrated by spatiotemporal analysis, and it enables one to confirm that there is a constructive change in getting larger forest cover; for the last two decades of time, the area of forest land has increased. Forest cover has demonstrated a positive growth of 12.55% from 1,354.77 hectares in 2003 to 2,141.75 hectares in 2023, through the efforts of both reforestation and rehabilitation through natural recovery. The growth of forest area, the decline of bare land, and the developments in other land use categories represent an indication of good management in the region and ecosystem protection.

At the same time, the growth of built-up areas (that expanded by 9.78% by 2023) portrays more improvement of infrastructure that could be due to the demand of tourism services and local development. However, with the increase in built-up areas, there arises a need to strike equilibrium between urban development and environmental conservation so as to maintain the wellbeing of the eco-system.

Meanwhile, the expansion of built-up areas (which grew by 9.78% by 2023) shows more infrastructure improvements. This could be because of the need for tourism services and local growth. Yet, as built-up areas increase, we need to balance urban growth and protecting the environment to keep the eco-system healthy. Overall, considered, the information emphasizes how important sustainable land management is to maintaining the forest ecosystem and advancing ecotourism in the Entoto area. It is crucial to keep striking a balance between conservation initiatives, ecotourism growth, and community involvement in order to guarantee long-term environmental and financial benefits.

5.2. Recommendation

The researcher only covered part of Addis Ababa but the large forest cover surrounding Addis Ababa in Oromia region it is important future studies.

Conservationists and eco-tourism operators in making informed decisions that ensure eco-tourism contributes positively to forest conservation while it is sustainable economic opportunities.

In the spatiotemporal Entoto Forest analysis from 2003 to 2023, a positive trend toward expansion of the forest cover is observed due to efforts of reforestation and natural recovery. At any rate, such growth can only be continued when strict regulations on eco-tourism development are in place. In this case, minimizing environmental degradation may be achieved by restricting the growth of built-up areas and tourism to low-impact areas. Meanwhile, in order to develop responsible tourism that will preserve the forest's natural resources, sustainable eco-tourism which includes eco-friendly services and community-based activities should be promoted.

Encourage Collaboration Stakeholders: To develop a comprehensive strategy for ecotourism that strikes a balance between environmental preservation and economic growth, governments, non-governmental organizations, local communities, and the private sector should work together. This involves having conversations, components, and best practices to increase ecotourism's efficacy.

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