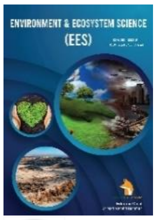
ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2521-0882 (Print)
ISSN: 2521-0483 (Online)
CODEN: EESND2

Environment & Ecosystem Science (EES)

DOI: http://doi.org/10.26480/ees.02.2025.133.141



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RESEARCH ARTICLE

CHANGES IN FOREST COVER AND DRIVERS OF DEGRADATION IN ODO SHAKISO NATURAL FOREST, SOUTHERN ETHIOPIA (1995 – 2025)

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ARTICLE DETAILS

Article History:

Received 13 June 2025
Revised 22 July 2025
Accepted 25 August 2025
Available online 29 September 2025

ABSTRACT

Over the last 30 years, Odo Shakiso's natural forest in Oromia Region has undergone severe fragmentation and vegetation change. By combining multi-temporal Landsat imagery and household surveys, this study examined spatial and temporal patterns of deforestation, identified main drivers of land degradation, and evaluated vegetation health changes over the past 30 years through NDVI trends. Land cover conversion was identified using supervised classification and change detection analyses across Landsat images collected from 1995-2025, and NDVI was used to appraise average canopy density and greenness. The remote sensing analysis was complemented by data derived from structured household interviews, which served to identify perceived socio-economic and policy-related drivers of local forest change. Overall, the forest loss was 29,478.74 hectares or 55.16% of the initial forest cover since 1995, while NDVI analysis indicated consistent decreases in vegetation health, density, and greenness over each decade examined. Despite local efforts of conservation, ongoing forest disturbance occurs due to increasing and overlapping pressures on forest resources. Major Drivers of land degradation include: Agricultural expansion and encroachment, the increasing number of population on the area and socio-economic related resource use, uncontrolled wildfires and climatic variability, the spread of settlements, over-exploitation and grazing, and Ambiguous and limited forest policy. Recommendations include: strengthen and integrate indigenous conservation approaches through community building, develop and enforce distinct, forest-specific forests policy separate from agricultural policy, and establish formal platforms linking scientists, educators, and policymakers to allow for broad, evidence-based decisions.

KEYWORDS

Natural forest, Remote sensing, NDVI, Land-cover change, Forest policy, Community conservation, Odo Shakiso

1. INTRODUCTION

Forests principally constitute valuable resources offering numerous ecological, economic, social, and political benefits, including the ecosystem services required for the sustenance of human well-being, having alternative roles in conserving biological, genetic, and species diversity (Heino et al., 2015; FAO, 2016; Moyra, 2016; Barakat et al., 2018). In contrast, forest cover is diminishing at a high momentum, especially in developing countries of South America, Asia, and Africa, where age-old natural precious forests are disappearing at an alarming rate (FAO, 2016). Deforestation, on the other hand, is greatly affecting the climate change, drought, soil loss, water scarcity, and general life quality of people (Sasaki and Putz, 2009; Islam et al., 2021). Since 1990, about 30 million hectares of natural forest lost, as told by the Global Forest Assessment 2020.

Natural forests with native tree species and multilayered canopy structures are relatively diverse, sustainable, and resilient to environmental degradation and climate change (Franklin et al., 2002; Vancutsem et al., 2021; Hirschmugl et al., 2023). Consequently, naturally generated forests exist with essential ecological and ecosystem services that include pest and disease control, drought resistance, soil and water conservation, and mitigation of climate change (FAO, 2006). On the other hand, the supports the idea that native tree species promote biodiversity (FAO, 2020). Different factors have contributed to land use changes that accelerate the decline of native tree species; these include agricultural expansion, population pressure, poverty, wildfires, illegal timber harvesting, pest and disease outbreaks, frequent grazing, conflicting and inadequate forest policies, and climate change (Wassie, 2020; Keenan et al., 2015; Kewessa et al., 2024).

The worldwide threat to natural forests continues to be of primary concern from both anthropogenic and natural perspectives (World Bank, 2006). An increase in forest degradation, brought about by human and natural causes in the last decades, has had adversarial environmental, social, ecological, economic, and political dimensions and has contributed instead to climate change at the global level (Panigrahy et al., 2010; Reddy et al., 2013; Fokeng et al., 2020). Negative annual net changes in forest cover are being reported from different African countries (Diaz-Delgado et al., 2001; MacDicken et al., 2015; Peñuelas et al., 2017). Hence utmost deforestation has been taking place in Eastern African countries, including Ethiopia, in recent times (Kidane et al., 2012; Nyssen et al., 2014; Keenan et al., 2015; Aerts et al., 2016; FAO, 2020). Indeed in Ethiopia, in the early 20th century deforestation rates were among the highest in the world, a state of affairs that has continued into the 21st century (Jacob et al., 2015; FAO, 2016; Tolessa et al., 2017; Wassie, 2020; Tsegaye et al., 2023).

Over the last decades, Southern Ethiopia's drylands faced multiple severe alterations including fragmentation and vegetation alteration (Markakis,

Quick Response Code	Access this article online	
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Cite the Article: Biruk Birhan Zewde, Nigus Tekleselassie Tsegaye, Deginet Birhanu Shewa. (2025). Changes In Forest Cover And Drivers Of Degradation In Odo Shakiso Natural Forest, Southern Ethiopia (1995 – 2025). Environment & Ecosystem Science (EES), 9(2): 133-141.

2011; Tolessa et al., 2017). Alongside this, the accumulation of long-term baseline data became necessary to understand the patterns, causes, and consequences of deforestation in order to formulate forest policies and strategies that prevent land degradation (Kim et al., 2014; Vieilledent et al., 2018). In all instances, scientific information becomes the key to integrating ideas within decision making and crafting successful policies for conservation, restoration, rehabilitation, and management interventions at a local level like in the natural forest of Odo Shakiso, an invaluable regional asset (Gebrehiwot et al., 2014).

The Odo Shakiso Natural Forest has historically provided a livelihood for local communities and served other cultural and ecological purposes including: regulation provisioning, and support for human and wildlife well-being. It served food, shelter, raw materials, clean water, medicinal plants, and aromatic flora; as a refuge, chief among its uses in natural disasters (Melese et al., 2023). In terms of threats, the forest experiences heavy deforestation due to varied causes such as population pressure, fires, illegal settlements, agricultural expansions, overexploitation for fuel and timber, construction in nearby and small towns, grazing, clear-cutting, and bark removal for traditional hives. These threats become even more aggravated by climate change, weak forest policies, and unstable governance systems (Markakis, 2011).

In the last 30 years, the changes in forested land in the Odo Shakiso natural forest to other land uses underwent transformation without proper scientific documentation. The major causes of changes to the natural forest cover have not been well studied. Cultural beliefs that prevent human entry into the forest combined with a weak district government support for forest management in pastoral areas have allowed the forest to continue providing vital ecological services. However, until a few years ago, no data could analytically justify the general pattern of forest cover change (Jacob et al., 2015). Potential deforestation and consequent potential effects on local livelihoods remains a concern, necessitating an inquiry into forest cover loss and root causation (Gebrehiwot et al., 2014; Jacob et al., 2015; Wassie, 2020).

Hence, the objective of this study was to assess the extent of forest cover change and to identify the primary driving forces over the last 30 years in the natural forest of the Odo Shakiso district. Providing both qualitative and quantitative information concerning the dynamics of forest cover change was aimed at supporting stakeholders and policymakers to put in place proper and adaptable management strategies for forests.

2. Materials And Methods

2.1 Description of study area

The study was carried out in Odo Shakiso district with in the Guji zone of Oromia region, Ethiopia (Figure 1). Odo Shakiso district is located 495 km south of Addis Ababa (latitude: 5°32′0′′ N to 5°60′0′′ N and longitude: 38°38′0′′ E to 39°6′0′′ E), has a semi-arid climate with bimodal rainfall (September-October, March-May) and an elevation of height 1,428 to 2,226 meters above sea level. Rainfall varies from 250 mm to 750 mm and average temperature ranges from 25°C to 31°C and can be considered as drought-prone area.

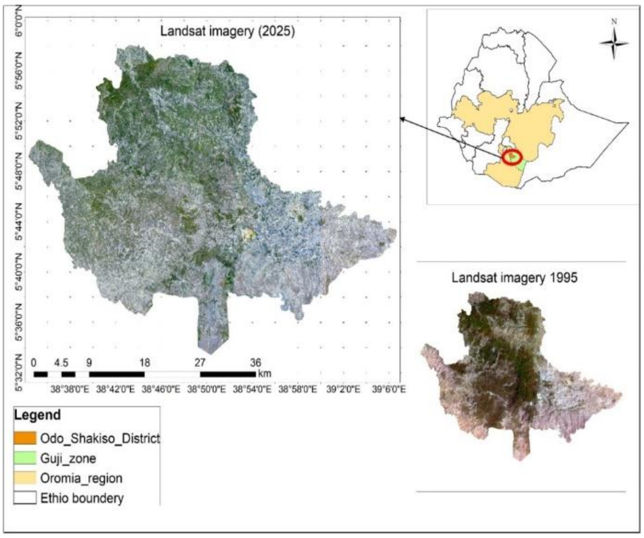

Figure 1: Location map of Odo Shakiso natural forest

2.2 Data Collection

2.2.1 Satellite Imagery Capture

The forest perimeter was systematically assessed over a maximum of 48 hrs by four transects, (North, South, East and West) following a collated methodological approach (Carr, 1994). Approximately 20% of the forest areas were sampled in corners (Sewana, Welebo, and Hangadi) to assign the forest areas to specific forest sections of mapping (Lindsey, 1958; Runkle, 1992; Scott, 1998).

Data were collected and recorded, using the GPS system, in areas of maturity, density and stand structure tree species, land use types, and forest under story level of deforestation (Draijer et al., 2000). Land use was classified into agriculture, shrubs, and deep forest. For the purpose of the ground truthing exercise, settlements, and areas of barren soil and rock observed were classified as agricultural land, while grassland and deciduous woodland were classified as shrubland primarily because under the remote sensing process initiated with satellite images it was difficult to identify them independently (Congalton and Green, 2019). About 200 training locations classified as one of the three land use classes were collected and recorded using GPS coordinates.

Table 1: Techniques for gathering satellite images and the date of image acquisition

No	Image	Sensors	Path row	Spatial Resolution	Cloud cover (%)	Source	Acquisition date
1	Landsat 5	MSS	168/056	(30*30) m	0.00	(USGS)	Jan. 30, 1995
2	Landsat 7	ETM	168/056	(30*30) m	0.00	(USGS)	Feb. 26, 2003
3	Sentinel 2A	MSIL2A	Don't have	(10*10) m	0.00	(Sentinel)	Feb.02, 2015
4	Sentinel 2A	MSIL2A	Don't have	(10*10) m	0.00	(Sentinel)	Feb.21, 2025

2.2.2 Image Classification Methodologies

The Landsat Imagery underwent rigorous pre-processing methodology, which included sub-setting, resampling, geo referencing, stacking of layers, and reduction of geometric and radiometric error, and thus guaranteeing repeatability and integrity of the data. The analysis of land use and land cover changes was performed using supervised classification methodology of satellite imagery, conceiving the maximum likelihood method across all spectral bands (Abburu and Golla, 2015; Manandhar et al., 2009).

Before image processing, a set of 200 ground GPS points, which represented 20% of all forest land, was obtained from the three main land use classes: forest, agriculture, and shrub. These points were located at the corners, or within, forested areas where they could be referred to as classification data (Zumberge et al., 1997). The GPS data and forest cover change data was imported into ArcGIS for image processing (Figure 2).

While recommends a minimum accuracy of 85% with land cover classification based on remote sensing data, we had difficulty in distinguishing agricultural land from shrub land with complete accuracy (Anderson, 1976). The study achieved an average classification accuracy of 94.3%; however, this was limited by land use types such as bare soil, settlements, rocky areas, grasslands, and woodlands that went undifferentiated. Following a false color composite was used to examine forest change in order to determine forest cover change over the past three decades; this included image enhancement, ground truth during the validation process, image filtering, normalized difference vegetation index (NDVI) analysis, and accuracy analysis (Patra et al., 2006; Toet and Walraven, 1996; Huang et al., 2021). After the NDVI image analysis, the most disturbed moments in all four research periods were identified to describe vegetation dynamics for evaluation by greenness, density and amount of plant cover change employing the Landsat NDVI.

Based on the chlorophyll and other pigments absorption characteristics, the NDVI suggests that while healthy vegetation has low reflectance in the visible part of the EMS, it has high reflectance in the NIR part of the EMS due to internal reflection by the mesophyll-spongy tissue in the green leaves (Campbell, 1987). The following is the NDVI calculation:

NDVI = index (NIR-RED) = ((NIR - RED))/((NIR + RED)) Where, NIR - reflection in the near-infrared spectrum

RED - reflection in the red range of the spectrum; for Sentinel-2, the index looks like this:

NDVI = index (Band8, Band4) = ((Band8- Band4))/((Band8+ Band4))

2.2.3 Household Survey

A survey was administered to 150 adults (≥18 years) randomly selected from three Kebeles closest to the forest. Following a group researchers' respondents were interviewed using a structured questionnaire to measure changes in forest cover, indigenous communities' experiences with conservation, and protection against deforestation for the last 30 years (Phellas et al., 2011). The questionnaire was developed in English and translated into the local language, Oromic, for ease of understanding the material. Data was obtained in English and analyzed using standard scientific translation methods. Each interview took about 90 minutes, depending on the degree of understanding and response rate from the respondents.

2.2.4 Focus Group Discussions

The selection of key informants from the community was performed using snowball method in which informants who are mentioned by many farmers were selected (Goodman, 1961). Focus group discussions were conducted with 24 individuals of indigenous knowledge from the Sewana, Welebo, and Hangadi Kebeles in the Odo Shakiso district. Three groups of eight individuals followed a series of open-ended discussions in their native language. The discussions ranged from about two to three hours per group with a series of open-ended questions. The documentations were translated to English by interpreters.

2.3 Data analysis

Image classification and Normalized Difference Vegetation Index (NDVI) calculations were conducted using ERDAS Imagine 2015, and spatial mapping was performed in ArcGIS v. 10.4.1 (Mahmon et al., 2015). The data collected was summarized and analyzed by means of descriptive statistics using Statistical Packages for Social Sciences (SPSS V.26.0). The illustrative tables and graphs were also used to summarize the data in precise form using the software programs.

3. RESULTS

3.1 Respondents' demographic details

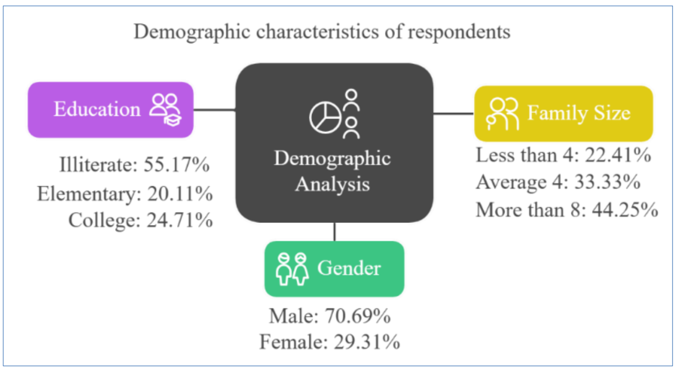

Figure 2: Demographic characteristics of respondents

Demographics of participants exhibited a gender balance with the shown figure 2 meaning a more or less substantial implication towards the cultural norms in Ethiopia that consider males advantageous to hiring along, being more likely to be employed in most sectors, including forestry (Tadesse et al., 2017). Similar to finding, illiteracy was also a noted factor among participants, Those in rural parts still have schools, but a prevailing view may impact education exposure and attainment levels; people reportedly also tend to continue their previous lifestyles (Zikargae et al., 2022).

The family size result possibly indicating some cultural view suggesting families should have larger access to the member workforce (Asfaw et al., 2013). Positive demographic characteristics to note - the member dominated workforce, low education status, lower level of interest to learn/understand, and larger family size reinforce the need for action on family planning, education, gender equity and environmental sustainability.

3.2 Tree species composition in the forest

The forest is mostly covered with indigenous evergreen trees, mainly Ficus vasta, Croton macrostachyus, Olea europaea, Acacia senegal, Jiniperus procera, Pappae capenisis, Acacia hocki, Catha edulis, Combretum molle, Grewia ferrginea, Acacia albidia, Ficus platyphyla, and Cordia africana. Laetadenia hastrtate, Podoccarpus falcatus, Ficus platyphyla, Cordia Ficus sycomorus. Teclea nobilis, Calpumia aurea Verpris Eugeniifolia, Senna occidentalis, Solanum incanum, Myrsine africana, Rhus vulgaris, Dodonea viscosa, Euclea raccmos, Rhus natalensis, Podoccarpus falcatus, Rhamnus prinoides, Indigofera schimperi, Dombeya lngbbracteolata, Tramilalia brownie, Phoenix dactylifera, Osyris quadripartita, and Grewia villosa were all obtained during ground verifications. As a result of severe drought and climate change, the pastoralist and agropastoral societies have transitioned to small-scale traditional agriculture, mainly livestock, and small-scale trading in non-timber forest products like gum and resin, honey, fuel wood, charcoal, and selling timber for building in local markets, along with wood-made artifacts and fodder.

3.3 Primary factors affecting changes to the natural forest cover.

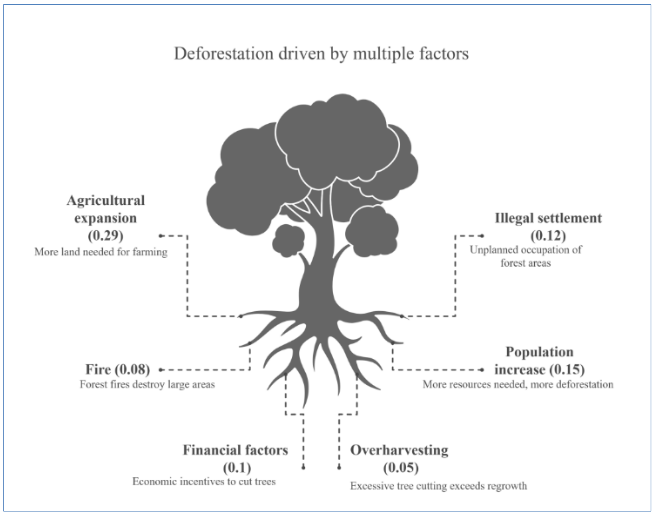

Figure 3: Driving factors of land cover change in the study area

The survey data conducted on rural communities' analysis and findings (recorded from focus groups/interviews) results revealed that the major factors affecting the changes of forestry cover were: population growth, change of climate, overabundance of harvesting, grazing, for settlements, fires, developing agricultural sites, and how ineffective forest policies are targeting changes. The factors around deforestation can further be organized on the amount which each factor is often mentioned (high, medium, low) to identify the major influences of the changes.

The assessment of change in forest cover over the last 30 years, based on respondent responses, shows that agricultural expansion index (0.29), population growth (0.15), and illegal settlements (0.12) contributed the most to the change. Other factors impacting forest cover change included fire (0.08), economic constraints (0.1), overharvesting (0.05), and free grazing (0.07). Climate change (0.06) and inadequate forest policies (0.09) had a somewhat indirect contribution to declines in forest cover. Similar findings were published in different studies (Aerts et al., 2016; FAO, 2016; Tolessa et al., 2017; Negassa et al., 2020; Wassie, 2020; Tsegaye et al., 2023).

The findings from this study support that factors such as agricultural expansion, population growth, illegal settlement, economic constraints, overharvesting, overgrazing, fire, poverty, inadequate policies, and climate change have contributed to changes in Odo Shakiso Forest cover, declining from 390.89 km2 to 96.33 km2 over the past 30 years (FAO, 2016; 2020). Respondents stated that population growth, drought, and poverty were the primary motivators for encroaching forests for agricultural land, shrubland, settlement, and grazing (Lele and Joshi, 1992; FAO, 2016; 2020; Stibig et al., 2014). This finding is supported only if we consider previous studies that cite increasing population density as a primary driver of land-use changes (Meyer et al., 1992; Jacob et al., 2015;

Wassie, 2020).

The findings support the claim that population pressure and agricultural expansion resulted in deforestation (Lele and Joshi, 1992). Droughts continue to severely affect goat and animal populations (Markakis, 2011; Kidane et al., 2012; Yohannes et al., 2021). The FAO (2016) points to: farming, poverty, population growth, inadequate forest policies and climate change as major causes of forest degradation, drought, hunger, global warming and climate variability; this report aligns with those findings. Climate change affects the decline of native tree species and forest fragmentation heavily (Aerts et al., 2016). There are many human-induced forest fires that are recognized in Ethiopia that can contribute to forest degradation, native trees decline and damage ecosystem and while damaged forests may not fall under policy often it is overlooked (Aerts et al., 2016; Tolessa et al. 2017; Wasie, 2020; Tsegaye et al., 2023). This is consistent with evidence based on anthropogenic fires being a major driver of forest degradation across Euro-Asia as both anthropogenic and non-anthropogenic reasons speed up the decline of natural forests in Ethiopia (Achard et al., 2006; Aerts et al., 2016; Tsegaye et al., 2016; Tolessa et al., 2017).

A survey questionnaire was used to gather information about the indigenous people's knowledge and perspectives about the natural forest in Odo Shakiso District. This information is vital to public awareness in the interest of forest conservation and accountability to conserve resources for sustainable management. The intent of recording the Oromo community's knowledge of the benefits trees while obtaining a response is to build involvement in the interest of conservation and sustainable forest resources while also protecting against deforestation. Survey respondents responded that Ethiopian Orthodox churches had provided superior contributions to preserving natural forest in the Odo Shakiso District. The notion of Ethiopian Orthodox churches having a link to natural forest exists established hypotheses that churches and not only provide direct forest protection but they have indirect protection (Mengistie et al., 2022). Respondents mentioned the following arguments that contribute to the conservation of forests: landscape, ownership, historical perspective, traditional beliefs/practices, kind, cultural practice, steward keeper, punishment, education, research, indigenous knowledge, clan systems, socio-ecological, rehabilitation, lead advocate by NGOs. Landscape topography remains essential to track deforestation in Ethiopia (Birhane et al., 2019). Church and landscape form indirect and direct components of forest technology and management which provide real benefits (Aerts et al., 2016). Collaboration of the above has allowed sustained benefits in conserving the Odo Shakiso District's natural forest through generations. The Oromo community implements rules by social leaders to protect tree cover and prevents illegal tree cutting, encroachment and or farming operations by issuing penalty for offenders and or promoting awareness.

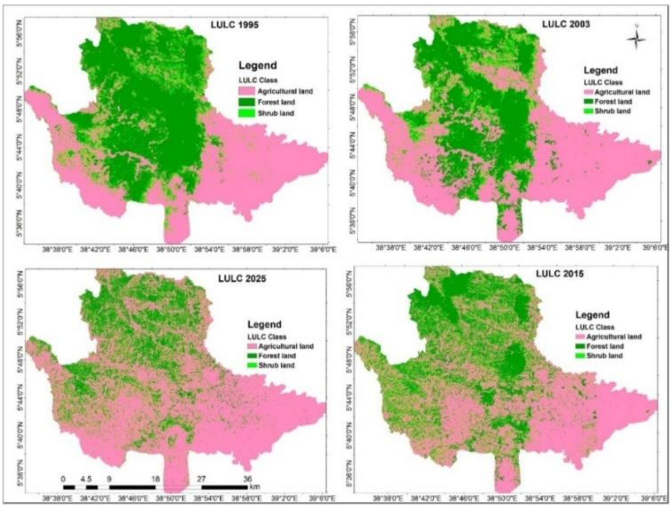

Figure 4: Changes in Odo Shakiso natural forest's forest cover between 1995 and 2025

Table 3: Changing forest cover in the natural forest of Odo Shakiso district's

Class Name	Time (year) 1995		2003		2015		2025	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Agri. land	62258.8	49.04%	73795.8	58.13%	77573.37	61.11%	93085.96	73.33%
Forest land	53444.7	42.10%	41763.2	32.90%	35075.77	27.63%	23965.96	18.88%
Shrub land	11238.7	8.85%	11383.2	8.97%	14293.07	11.26%	9890.28	7.79%
Total land	**126942.2**	**100%**	**126942.2**	**100%**	**126942.2**	**100%**	**126942.2**	**100%**

In order to prevent further deforestation, it is important to work with NGOs, engage with local people, encourage local ownership, provide education and research, and create a stable forest policy that brings in all interest groups and recognizes the impacts of churches, indigenous peoples, and geography on the permanence of the Odo Shakiso District Natural Forest (Markakis, 2011).

An analysis of satellite images shows that agricultural lands have increased significantly from 1995 to 2025 in the Odo Shakiso district. For example, agricultural land has increased from 62,258.8 ha (49.04%) in 1995, to 93,085.96 ha (73.33%) in 2025. Agricultural increase is recognized as one of the major factors of forest cover change (Babiso et al., 2020; Belayneh et al., 2020). On the other hand, forest land decreased from 53,444.7 ha (42.10%) in 1995 to 23,965.96 ha (18.88%) in 2025. The area of shrub land displayed varying results of area, with 11,238.7 ha (8.85%), 11,383 ha (8.97%), 14,293.07 ha (11.26%) and 9,890.28 ha (7.79%) for the years mentioned above.

This study has shown that agricultural expansion has significantly impacted land use change in northern Ethiopia because of population increase, unsupervised free-grazing systems, and over-exploitation of resources (Solomon et al., 2018). Similar points were made by who suggested that native tree populations experienced a detrimental decrease since the 1930's (Nyssen et al., 2014). The increase of agricultural land from 1995 to 2025 to 73.33% reflects the findings of identified a 33% increase in agricultural production, and a 7.7 decrease in natural forest cover between 1985 and 2019 (Tsegaye et al., 2023).

Several studies substantiate this trend by identifying agriculture as a significant driver of deforestation (Feyissa et al., 2018; Derbew and Dalacho, 2019; Kidane et al., 2012; Yohannes et al., 2021). Likewise, the observed 7.79% decrease in shrub lands over the last thirty years is also a response to intensifying agricultural activity. In fact, a group researcher point to the same conditions associated with deforestation in their study, with reference to population expansion, agricultural development, harvesting fuel wood, and demand for building materials based upon urbanization (Yismaw et al., 2014).

This study found 55.16% of a decline in natural forest cover in the Odo Shakiso district over the last thirty years due to agricultural expansion, unsanctioned settlements, population growth, over-consumption of resources, forest fires, economics, and climate change (Betru et al., 2019; Wassie, 2020). The study further confirms the 40% deforestation rate seen in Indonesia from 2000 to 2012 (Margono et al., 2014). The forest loss was calculated on an annual basis for various timeframes at a rate of 2.73% (1995-2003), 1.33% (2003-2015), and 3.17% (2015-2025), for a total loss of 29,478.74 ha (982.63 ha/yr) from 1995 to 2025, with the highest deforestation rates occurring from 2015 to 2025. Importantly, these findings achieved substantial agreement with findings by (Negassa et al., 2020; Debebe et al., 2023). These studies all refer to the same "primary factors" associated with decline in forest cover such as population expansion, harvesting fuelwood, animal grazing, forest fires, and agricultural activities.

This also supports Hansen and De Fries (2004)'s finding of a significant drop in global forest cover during the 1980s and 1990s. The persistence of traditional agricultural practices in forested areas in high densities contributes to deforestation, and the lack of firm forest policies and weak forestry sector compounds the problem. These trends relate to the 17% loss of tropical wet forests between 1990 and 2019 reported and reemphasize the need for effective policy development and leadership in developing countries, as previously observed by (Vancutsem et al., 2021; Potapov et al., 2012; Wassie, 2020; Yismaw et al., 2014; Deribew and Dalacho, 2019). Where there has been severe drought, population movement to mountainous forest areas will occur as rural populations search for more favorable agricultural conditions (Markakis, 2011). Hence, government and non-governmental support is crucial, and traditional agricultural and livestock growing activities alone are unsustainable, especially in regions experiencing environmental degradation, climate change, natural disasters, poverty, and a lack of laws that may threaten rural communities while driving the over-harvest of natural forest resources.

Forest cover changed, significantly, between 1995 and 2025. Forest cover increased by 11,681.5 ha (22%) from 1995-2003; then it increased an additional 6,687.43 (12%) from 2003-2015; and an additional 11, 108.81 ha (21%) from 2015-2025. Despite these increases, total forest cover during the study during the study period was 29,478.74 ha (55.16%) less than the 1995 baseline of 53,444.7 ha. This large loss of forest cover corresponds with findings of a total loss of 54.2% of Ethiopia's natural forest since 1986 until 2015, and it can also be related to findings of a global loss of 172,171 km2 of forest (0.6% of the 2000 total world forest area) from 2000-2010 (Tolessa et al., 2017; Li et al., 2016).

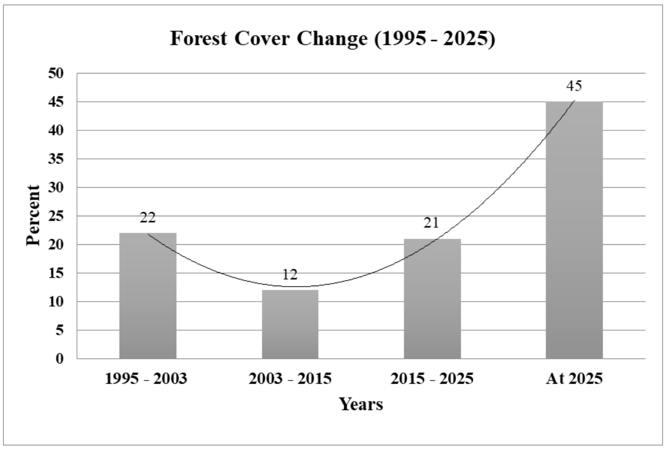

Figure 5: Trends and rates of forest cover change in Odo Shakiso district

Similarly, a study reported a total loss of 44% of the natural forest cover in Madagascar over the time the country has been studied, which dates to 1953 (Vieilledent et al., 2018). Both anthropogenic and non-anthropogenic factors have driven forest dynamics, including an expansion of agricultural land at the expense of forest and shrub land (Figure 3t). This study found the same pattern, reflecting the progression from forestland to shrubland and then ultimately to agricultural land, as noted by both (Betru et al., 2019; Vieilledent et al., 2018). Current reports also highlight the rapid rate of global deforestation (Heino et al., 2015).

3.4 Normalized difference vegetation index (NDVI)

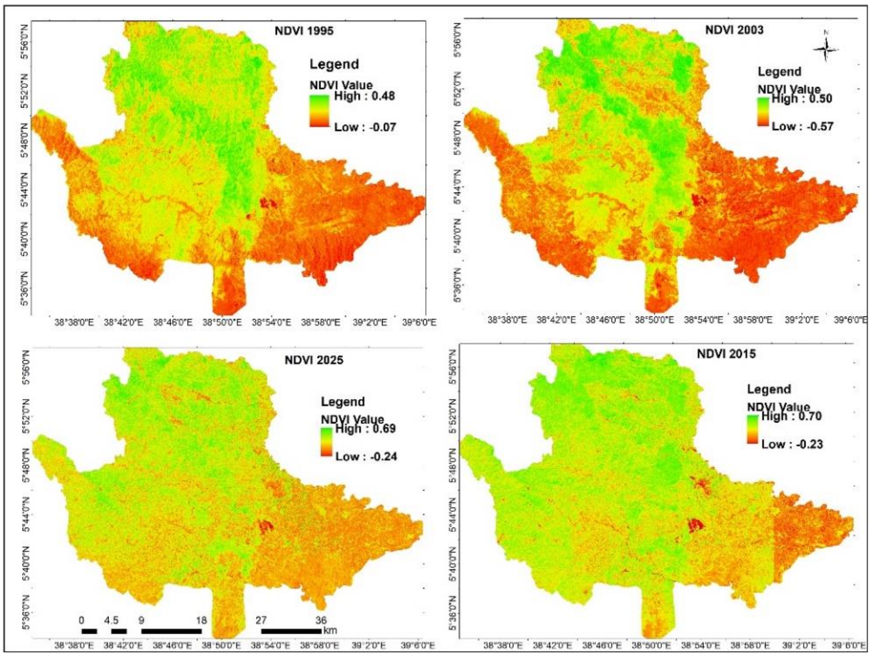

Figure 6: Four study periods (1995–2025) were included in the normalized difference vegetation index (NDVI).

For landscapes without vegetation, NDVI values were negative during each of the four researches time periods. Specifically, for landscapes without vegetation, NDVI values were negative for each research time period, with values declined from 1995 to 2005 and slightly increased (less negative) from 2003-2015 (Figure 4). For landscapes with dense vegetation NDVI data indicated substantial plant cover in 1995 and 2003, a significant drop from 2003 to 2015, and a partial recovery by 2025 in plant cover, but not to the levels of 1995 and 2003. The data indicate ongoing forest disturbances and overall changes in NDVI as demonstrated by vegetation index trends were the result of anthropogenic activities and natural factors in the Odo Shakiso district natural forest over the last 30 years. Our field work also indicated that much of the arid land and deforested land has been transitioned into agriculture. Such results agree with what reported regarding loss of forest land area since 1965 when brush and shrub areas have increased, where community members have been forced to leave degraded agricultural land in favor of productive forest areas, resulting in unproductive land with invasive shrubs (Belay et al., 2015; Markakis, 2011).

This means that strategies like irrigated agriculture, improved livestock production and value addition, ongoing forest protection and conservation, invasive species management, science education and research, and community awareness, all play a role in safeguarding community livelihoods. The results suggest a predominance of agricultural expansion driving land degradation; invasive species distribution and forest cover changes in Latin America (Grau and Aide, 2008). The integration of science, education and research into inclusive policies and decision-making from local communities, researchers, and policy makers, and taking in consideration gender and social wellbeing, will undoubtedly prevent further deterioration of forests and invasive species distribution (Aerts et al., 2016). Our results are similar to those of illustrating that Ethiopian forests converted into grazing land, shrubland, rangeland, and bare cropland due to increased pressures from human activities (Regasa et al., 2021).

4. Discussions

The natural forest in Odo Shakiso district has deteriorated over the last 30 years as a result of the simultaneous occurrence of numerous determining factors, including agricultural expansion, illegal settlements, population increase, poverty, overgrazing, unsustainable use, poor forest policy, fire, and climate change. This is congruent with studies which highlight agriculture as a main driver of forest cover change and the difficulty for rural communities or developing nations to monitor forest resources and establish effective policies (Reddy et al., 2013; Romijn et al., 2015). In particular, poor and inconsistent agricultural and forestry policies in Ethiopia have had negative impacts on forest cover, institutional structure, and adherence to policy (Hu et al., 2014; Wassie, 2020). Poor populations turn to forest resources as building material for housing, cooking fuels, feed for animals, and for sale in markets (Crespo et al., 2017).

The dryland forest types are particularly at risk of losing native tree species due to the complex processes associated with vegetation restoration and the increased pressures of poverty, economic challenges; rising populations and climate change (Marques et al., 2016). Deforestation in Odo Shakiso can therefore be attributed to population growth, climate change, overgrazing, desertification, agricultural expansion, illegal settlements, forest fires, poverty, exploitative wood harvesting methods, and a lack of integrated scientific knowledge, education, effective policy and sound economic considerations. This mirrors the alarming rate of mature natural forest loss observed across East Africa (FAO, 2020).

This study utilized interviews, focus groups, and remote sensing to identify the decline of forest cover as being rooted in both anthropogenic causes and non-anthropogenic drivers (Tolessa et al., 2017; Yahya et al., 2020). Climate changes, and ongoing drought, have forced communities to revert to non-capitalist-subsistence agricultural practices, as crop production follows declines in livestock production (FAO, 2016). All forest loss may be linked to human or natural causes, but to achieve full preservation we must acknowledge that religious institutions, indigenous knowledge, cultural norms, and landscape structure have a significant impact on preservation, and that the role of social and spiritual connection to nature runs deep (Markakis, 2011). Settings that support indigenous societies by recognizing land tenure, valuing ecosystem services, applying indigenous knowledge, developing bio-economies and awareness is critical, as forestry remains the key to mitigate climate change, prevent biodiversity loss, minimize ecosystem disturbance or degradation, reduce land degradation, alleviate hunger, and minimize poverty. Forest fire and climate change can negatively affect native tree physiology and regeneration, causing drought stress, pest outbreaks, disease outbreaks, and invasive species (Markakis, 2011; Kidane et al., 2012; Gebrehiwot et al., 2014; van Lierop et al., 2015).

While the forestry sector is not effectively addressing the concerns posed by forest fires, fires caused by human beings continue to destroy grasslands and forests affecting the population of indigenous tree species and limited by climate change to regenerate through post-fire growth efforts, producing an empty landscape with open land for invasive species. Collectively, around 55.16% of the total forest area in the study areas has been lost due to anthropogenic or non-anthropogenic causes (Jacob et al., 2015). The rate of total forest loss in Ethiopian forests is worrying, which calls for forest policy to be intentionally designed around a framework to address forest loss and establish a sustainable and stable forestry sector that eliminates incurring forest loss (Betru et al., 2019; Yahya et al., 2020; Aerts et al., 2016; Wassie, 2020). Overall, the trend is an increase in degradation of forest cover and deforestation has an approximate annual decrease of 1.84% since 1995 (FAO, 2020; Nabuurs et al., 2023; Potapov et al., 2012). Information from the fieldwork was able to demonstrate an increased land conversion from forested land to agricultural land, accompanied by the decrease in greenness (health) and coverage of other vegetation type on moderate and dense forest coverage (Forkuo and Frimpong, 2012; Pagnutti et al., 2013; FAO, 2016).

5. Conclusions

The natural forests of Odo Shakiso district are significant for species, genetic, and ecosystem diversity as they support biodiversity and habitat, ecosystem functions, and ecosystem services in general. Some drivers of decline were poverty, hunger-related disasters, customary agricultural practices, uncontrolled fire, overgrazing, forest law inefficacies, soil degradation, climate change-related disasters, settlement, fragmentation, institutional instability, negligence, and priorities directed to projects like green legacy at the polity level over conserving natural forest areas that were poorly managed. Literature suggests that these are part of larger systems of forest degradation identified as agriculture, population growth, deficient forest laws, a lack of forest function while at the same time climate change also posed as an additional risk.

There is clear evidence of substantial degradation of approximately 29,478.74 hectares (55.16%, representing 1.84% annually) of Odo Shakiso's forest in the last thirty years focusing on increasing agricultural land use. This supports FAO findings of an increase of +0.3% of forest to shrub land transitions between 2010 and 2015. Therefore, turning floristic areas of the district into agricultural lands and degraded shrublands has also had negative impacts on the natural forests found in the district. This was evidenced by NDVI vegetation dynamics indexes used in this study. The natural forest cover, structure, maturity, vegetation health, and native tree diversity have been meaningfully affected by both anthropogenic and non-anthropogenic actions.

To counteract further deforestation, we need a collaborative journey forward towards comprehensive forest policies that adopt new and smarter ways of addressing deforestation from top down and bottom up. These ways include dramatically reducing poverty, increasing social awareness, establishing a forestry sector that creates certainty, developing talented forestry students into trained professionals, and incorporating science, research, and education into the policies and decisions impacting forest and forestry loss. The best forest future will rely on individuals' equal participation in the decision-making, increased awareness of forestry values and benefits, collaborative commitments.

Effective forest and agricultural policies will clearly identify how a 'forest-positive future' can hasten the transition to 'nature-based solutions', providing solutions to climate change, biodiversity loss, ecosystem disturbance, land degradation, hunger and poverty, increasing the opportunity to build a healthy and resilient environment. The forest future relies on young, innovative, and educated foresters. Young foresters graduating from forestry programs will not always find academic programs to help with the demanding workplace they will enter. In Ethiopia, few higher education institutions facilitate training, development of professional careers, gender-related practices and professional employment opportunities in the forest sectors.

It is also important to address the confusion surrounding agricultural technicians and foresters who do not have an appropriate level of forestry expertise. Hence, it is important to take collective action and develop strong Forest policies, reduce poverty, improve the livelihoods of pastoralists, combine the importance of science, research, and education with the decision-makers work, create consistent institutional approaches to forestry, reduce fragmentation in forestry research, develop bio-economies, e.g. tourism, recognize indigenous and local knowledge, support local communities, and connect global issues of climate change, hunger and poverty through training and awareness of these issues. To prove what trees in the traditional knowledge of the Oromo community in the context of tree fires and forest fires, more research is needed to measure biomass and carbon stock potential.

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