

## Land use land cover change and expansion of Eucalyptus plantations in Senan District, northwest Ethiopia: analysis of potential factors

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### Abstract

Farmers in Ethiopia's highlands are rapidly converting their agricultural land into Eucalyptus plantations, which may have socioeconomic and environmental implications for local communities. This study aims to assess the expansion of Eucalyptus tree plantations at the expense of other land use practices in Northwest Ethiopia, specifically in the Senan district, and the factors that contribute to it. Data was collected from 332 (166 Eucalyptus planter and 166 non-planter) households and analyzed using the binary logit model. Land use and land cover change in the study area were investigated using Landsat satellite images of four periods (1990, 2000, 2010, and 2021). The land use and land cover classes were categorized using a supervised classification method. The findings revealed a decrease in cropland from 58.4% in 2010 to 38.1% in 2021, whereas the vegetation cover, predominantly consisting of Eucalyptus, experienced an increase from 16.8% to 26.5% during the same period. The results of the binary logit analysis indicate that the age of the household head, the size of the farmers' land, and savings had a positive and significant impact on the adoption of Eucalyptus plantation, while the family size of households, educational status, livestock ownership, and the fertility level of farmers' land had a significant negative effect on Eucalyptus plantation. Therefore, it is recommended to conduct comparative studies to assess the impact of Eucalyptus plantations on the livelihoods of farmers, ensuring that their well-being is improved as a result..

**Keywords/Phrases:** Driving factors, Ethiopia, Eucalyptus, GIS, Land-use change

### 1 Introduction

Eucalyptus is the most widely planted tree species in the world (Abebe *et al.*, 2019). Over the last century, it has spread rapidly throughout the world. In the 1890s, it was introduced to Africa, specifically Ethiopia (Jaleta *et al.*, 2016).

Zenebe (2016) noted that in terms of livelihoods, Eucalyptus plays an important role in addressing food security. Besides, according to Elli *et al.* (2019), the availability of fuelwood is one of the most important contributions of Eucalyptus to food security. Cooking, for example, is the most common method of ensuring food utilization through high nutritional

absorption from food, and 2.4 billion people use fuelwood to cook.

Despite the numerous benefits of eucalypt plantations, particularly in East Africa, where most people rely on wood for construction and fuel, there is still some criticism. Eucalyptus tree users, growers, environmentalists, researchers, and policymakers have different views on the economic, social, and environmental sustainability of the species. The majority of concerns raised are related to the environmental impact, particularly concerning soils, water, and biodiversity (FAO, 2011). On the contrary, according to Sembiring *et al.* (2020) and Silenat & Fikadu

(2018), Eucalyptus is a plant that has many environmental benefits, including the ability to reduce the risk of forest fires, floods, and erosion, be more efficient with water use, make nature more natural, restore land degradation or unproductive land, and the growth of these plants has long-term potential for biodiversity. On the other hand, Zenebe (2006) stated that Eucalyptus hurts yield and inhibits undergrowth. However, almost all the firewood, building materials for houses, farm implements, and other materials in the village are made from Eucalyptus. As a result, the benefits outweigh the negative impacts, which can be mitigated by planting Eucalyptus in areas that are unsuitable for agriculture and spacing them widely apart, even in farmlands and borders.

Even though Eucalyptus plantations are generally criticized, farmers in Ethiopia, particularly in the northwest highlands, including the Senan district have converted their cropland into Eucalyptus plantations (Amare *et al.*, 2021). Previous studies have identified various factors associated with the expansion of Eucalyptus plantations in Ethiopia. For instance, the age of the household head (Gebreegziabher *et al.*, 2010; Tegegne *et al.*, 2018), the education level (Kebede, 2017; Asabeneh & Yoseph, 2022), sex of the household head (Zenebe *et al.*, 2020), family size (Setiye & Mulatu, 2016), wood demand (Tola, 2010), land degradation (Berihun & Habtemariam, 2017), the need for immediate cash (Tola, 2010), adaptability to wider agro-ecological zones, affordable cost of production (Gashaw *et al.*, 2023). and low labor requirements for management (Berihun & Habtemariam, 2017) have all been identified as significant factors influencing land use patterns and the expansion of Eucalyptus plantations in Ethiopia. These factors play a significant role in shaping land use patterns and the expansion of Eucalyptus plantations in Ethiopia. However, it is important to acknowledge that these factors may vary in different contexts.

While previous studies have provided some insights

into the conversion of croplands to Eucalyptus plantations in Ethiopia, including the Senan district, there is a lack of adequate research, specifically focusing on the land use and land cover change in this district and the reasons behind the conversion. Amare *et al.* (2022) highlighted that smallholder farmers in the northwestern highlands, including the Senan district, have recently started converting their croplands to Eucalyptus plantations. However, their study was conducted across three districts and did not separately analyze the driving factors specific to the Senan district. Therefore, this study assesses the land use land cover change and the factors that motivate farmers to convert their croplands into Eucalyptus plantations in the Senan district.

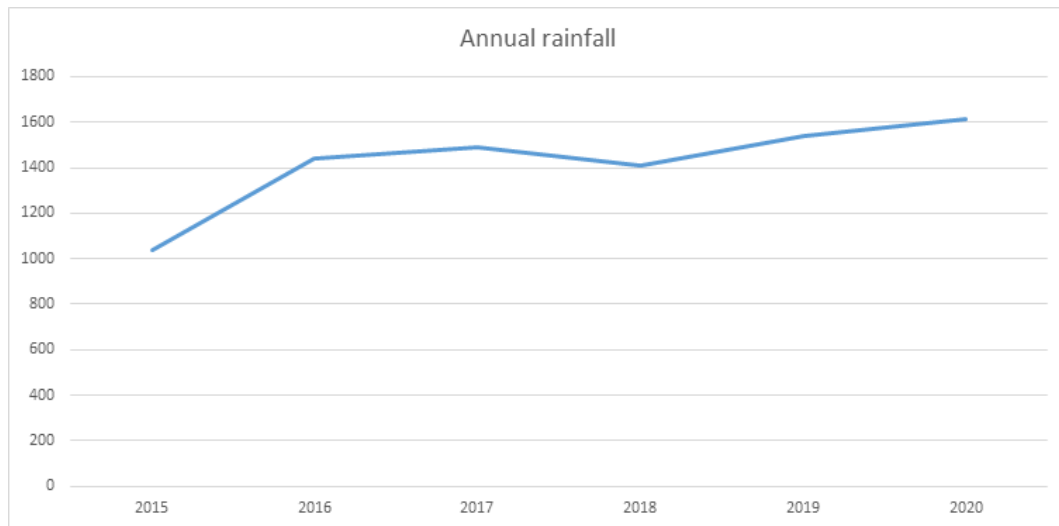
## 2 Materials and Methods

### 2.1 Description of the Study Area

Senan is located in the East Gojjam Zone of the Amhara Region, Ethiopia, which lies within the range of 10°25'13" N and 10°40'30" N latitudes and 37°40' E and 37°50'20" E longitudes (Lakachew, 2022). The district has 19 kebeles; 17 rural and 2 urban kebeles. The altitude within the district varies from 2300 meters to 4154 meters. Notably, Mount Choqe, known as the 'water tower of Ethiopia,' is located in this district, serving as the highest point in the district and the East Gojjam Zone, reaching an elevation of 4154 meters above sea level (Senan District Communication Affairs Office, 2021).

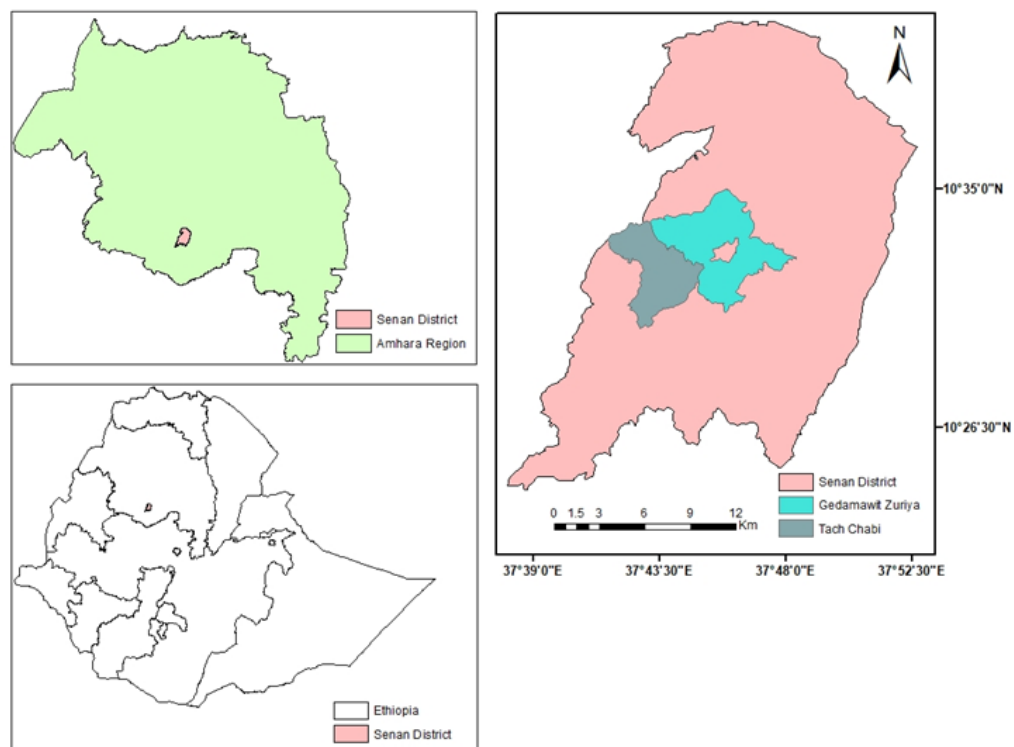
Approximately 25% of the land in the district consists of plateau and plain surfaces, while mountains and hills make up around 60%, and valleys account for approximately 15% of the landform. Eucalyptus globules are the dominant vegetation in the study area (Senan District Communication Affairs Office, 2021).

According to the Central Statistical Agency of Ethiopia's 2007 national census, this district has a total population of 98,939 people.



**Figure 1.** Annual Rainfall of Senan District (2015-2020)(CSA, 2022)

The daily average temperature is 15 degrees Celsius and the annual rainfall in the district is between 900-1500 mm (Central Statistics Agency, 2022).



**Figure 2.** The location map of the study area

## 2.2 Data Sources and Processes

This study used both primary and secondary data sources. The primary data were collected using questionnaires, personal observations, key informant in-

terviews, focused group discussions, and surveys using GPS instruments, whereas the secondary data were collected from satellite images and various organizations' documents and reports.

Questionnaire

The researchers collected quantitative data using a questionnaire from 166 households that had planted Eucalyptus and 166 households that had not planted Eucalyptus. The questionnaire was translated into the local language, Amharic, before being pilot-tested.

Personal Observations

We conducted field observations by walking through the district with agricultural office experts in the area. This method assisted us in comprehending the expansion of Eucalyptus plantations. The observation was also carried out at the district’s local marketplace, where we asked questions and took notes on what we had seen, further enhancing our understanding of the situation.

Key Informant interviews and focus group discussions

To understand the determinants of Eucalyptus plantations from their experiences and opinions, thirteen farmers were interviewed and four focus group discussions were held with purposefully selected elderly farmers and agricultural bureau officers. Saturation was used as a criterion for deciding when to stop collecting qualitative data.

Satellite Image

Landsat satellite images of the study area were acquired from the United States Geological Survey (USGS: <https://earthexplorer.usgs.gov>) for four periods (1990, 2000, 2010, and 2021). 1990, 2000, and 2010 images were Landsat 4-5 Thematic Mapper, whereas the 2021 image was a Landsat 8 Operational Land Image and Thermal Infrared Sensor (OLI/TIRS). The images were extracted in Tiff data format during January. This is the time when there is clear sky season in the study area, and important to detect vegetation. Moreover, this time is important to reduce atmospheric and radiometric problems. The detailed feature of the four Landsat satellite images is indicated in table 1.

Ground Control Points

Data collected by satellite sensors should be validated and compared to reality using reliable ground truth data. Therefore, real-world data were gathered using a hand-held GPS instrument for model validation and accuracy evaluation. To have the proper spectral value for each class, training data from the field was gathered to create a land-use land-cover map. Google Earth Pro image was also employed to validate the land use land cover result.

Table 1. Sources of secondary data

No.	Data Type	Sensor	Date of acquisition	Path/Row	Resolution	Source
1	Landsat image	TM	07/01/1990	169/053	30m by 30m	USGS
2	Landsat image	TM	19/01/2000	169/053	30m by 30m	USGS
3	Landsat image	TM	14/01/2010	169/053	30m by 30m	USGS
4	Landsat image	ETM+	28/01/2021	169/053	30m by 30m	USGS

2.3 Sample Size Determination and Sampling Technique

The choice of the Senan district as the study area was driven by the presence of extensive Eucalyptus plantations within the region. Since the population of the study area is small, the modified formula of Cochran, which is designed for a small population, was used.

$$n = \frac{n_0}{1 + (n_0 - 1)/N}$$

Here,  $n_0$  is Cochran’s sample size recommendation,

$N$  is the population size, and  $n$  is the new, adjusted sample size. Hence, the sample size will be:

$$n = \frac{385}{1 + (385 - 1)/2392} = 331.89 = 332$$

To ensure representative coverage, a multistage sampling technique was employed. First, the seventeen rural kebeles of the district were categorized into two distinct agro-climatic groups: nine woinadega (sub-tropical) and eight dega (temperate) dominated kebeles. Then, the kebeles of Gedamawit and Tach Chabi were selected from each group. Households

within the selected kebeles were stratified based on ownership of Eucalyptus plantations. Employing a proportionate stratified sampling technique, 166 planters and 166 non-planters were selected proportionately from both planters and non-planters within each kebele. Agricultural experts of the two kebeles assisted us in collecting data from households that plant and do not plant Eucalyptus trees.

## 2.4 Data Analysis

Preparing digital images for human interpretation is known as digital image processing (Bakker *et al.*, 2001). Pre-processing procedures have been carried out after downloading and extracting the satellite image. These include atmospheric rectification, layer stacking/merging, gap-filling, image mosaicking, clipping, and other image enhancement pre-processing procedures that were used to enhance the quality and interpretability of the image so that the images are appropriate and prepared for further analysis.

The development of thematic maps involves classifying the satellite image. The subjects could range from general categories to in-depth analyses of specific groups (Schowengerdt, 2007). Images were composed in different ways to identify surface features in the study area. True color composite known by RGB 321 for Landsat 4-5 TM where band 3 reflects red, band 2 reflects green band 1 reflects blue color combination, and RGB 432 combination for Landsat 8 ETM+ were used to conduct the classification.

The land use classifications were conducted by using the maximum likelihood supervised classification. 155 training areas for all spectral classes were developed composing each information class to be identified by the classifier. Based on prior research (Agenagnew *et al.*, 2019; Aramde *et al.*, 2014) in the area and observations (ground truthing) made by the researcher, the following classification schemes were developed as follows.

**Table 2.** LULC classes used for classification

No.	Classes	Description
1	Settlement	Scattered settlements with houses separated from one another.
2	Cropland	This category includes area allotted for annual rain-fed and irrigated cultivation. Lands mostly used for cereal production in subsistence farming. Potato, barley, and beans are the main crops produced in the district. They farm using oxen and horse ploughs in the most traditional way.
3	Grassland	Area predominantly covered by small grasses with a small proportion of shrub and trees.
4	Vegetation	This unit includes a collection of plant species. Eucalyptus is the prominent species in the area.
5	Shrub land	Dominated land with isolated small trees always with a lower range of grass.

Calculation of the area in hectare and percent of the resulting LULC types for each study year and subsequently comparing the results were used as a major data analysis method to identify the change from cropland to vegetation. ERDAS IMAGIN and ArcGIS 10.8 software were used to make this analysis.

## 2.5 The Binary Logit Model

To assess the drivers of Eucalyptus plantations in the study area, the dependent variable was categorized into two qualitative parts: whether or not to have Eucalyptus plantations. Therefore, a binary logit

econometrics model was employed to examine the factors that influence farmers' decisions to plant Eucalyptus trees. In binary logistic regression analysis, the dependent variable must be categorical (it can be coded as 0 and 1) (Cokluk, 2010).

The functional form of logit model is specified as follows, according to Gujarati (2003);

$$P_i = E \left( Y = \frac{1}{X_i} \right) = \frac{1}{1 + e^{-(\beta_1 + \beta_2 X_i)}} \quad (1)$$

For ease of exposition, we write as

$$P_i = \frac{1}{1 + e^{-z_i}} = \frac{e^{z_i}}{1 + e^{z_i}} \quad (2)$$

Where,  $Z_i = \beta_1 + \beta_2 X_i$ .

If  $P_i$ , the probability of owning Eucalyptus plantation, is given by (2), then  $(1 - P_i)$ , the probability of not owning Eucalyptus plantation, is

$$1 - P_i = \frac{1}{1 + e^{z_i}} \quad (3)$$

Therefore, we can write

$$\frac{P_i}{1 - P_i} = \frac{1 + e^{z_i}}{1 + e^{z_i}} \quad (4)$$

Now,  $\frac{P_i}{1 - P_i}$  is simply the odds ratio in favor of owning Eucalyptus plantation - the ratio of the probability that a household will own the plantation to the probability that it will not own it. Finally, taking the

natural log of equation we obtain:

$$L_i = \ln \left( \frac{P_i}{1 - P_i} \right) = Z_i = \beta_0 + \beta_1 X_i + \beta_2 X_2 + \dots + \beta_n X_n \quad (5)$$

$$Z_i = \beta_0 + \beta_1 X_i + \beta_2 X_2 + \dots + \beta_n X_n \quad (6)$$

$\beta_0$  is an intercept;  $\beta_1, \beta_2 \dots \beta_n$  are slopes of the equation in the model;  $L_i$  is log of the odds ratio, which is not only linear in  $X_i$  but also linear in the parameters;  $X_i$  is vector of relevant household characteristics

If the disturbance term ( $U_i$ ) is introduced, the logit model that has been used to analyze drivers of Eucalyptus plantation in this study becomes:

$$Z_i = \beta_0 + \beta_1 X_i + \beta_2 X_2 + \dots + \beta_n X_n + U_i \quad (7)$$

**Table 3.** List of independent variables in drivers of Eucalyptus plantations

Independent variables	Description	Expected Effect
Age of household head (years)	Continuous	+
Sex of Household head	Female = 0, Male = 1	-
Marital status of household head	Married= 1, Otherwise = 0	+
Education level of household head (years)	Continuous	+
Family size (number)	Continuous	-
Farm size (Ha)	Continuous	+
Farm fertility (%)	Continuous	-
Livestock ownership (TLU)	Continuous	-
Membership of cooperatives	Not a member = 0, Member = 1	+
Savings	No savings = 0, Have savings= 1	+
Access to savings and credit service	No access = 0, Have access = 1	+

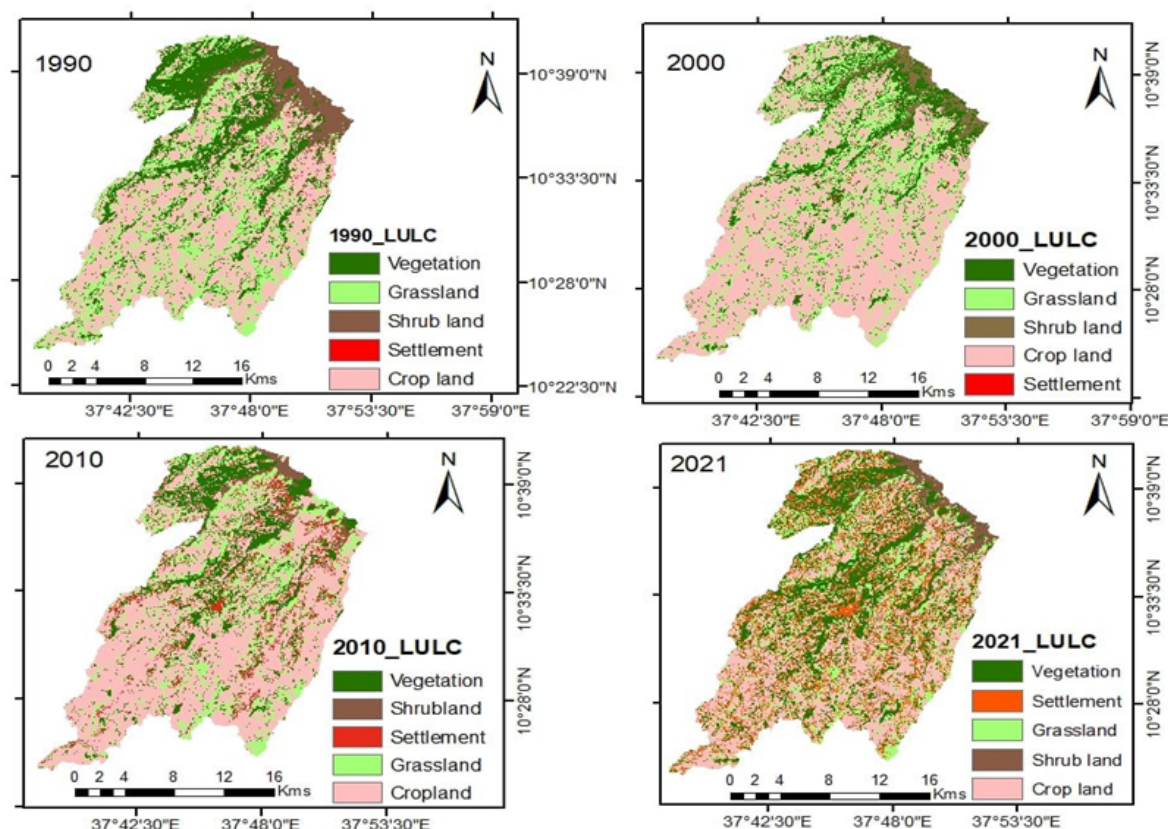
### 3 Results and Discussions

#### 3.1 Land Use and Land Cover Analysis

The analysis comprises the land use land cover analysis and the factors behind the expansion of Eucalyptus plantations. As the classification scheme indicated, cropland, grassland, vegetation settlement, and shrub land area are the major LULC classes of the study periods. The classified images were acquired when crop harvesting had already been

completed, farmlands appeared bare, and grasslands looked relatively bright in color.

Figure 3 shows the land use land cover classes of the study area in 1990, 2000, 2010, and 2021. For 1990, 2000, 2010, and 2021, five major LULC types (cropland, vegetation, settlement, grassland, and shrubland) were classified. The result reveals that there is a recent land-use change, especially in cropland and vegetation cover.



**Figure 3.** Land use land cover map of Senan district (1990, 2000, 2010, and 2021)

**Table 4.** LULC classes and their spatial extent with the observed changes over time

LULC classes	1990		2000		2010		2021	
	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent
Crop land	19750	45.2	25049	57.4	25500	58.4	16647	38.1
Vegetation	10408.5	23.8	7456	17.1	7294	16.8	11558	26.5
Grassland	10151.6	23.3	9406	21.6	6911	15.8	6297	14.4
Settlement	110.9	0.3	128	0.3	2334	5.4	6996	16.1
Shrub land	3215	7.4	1597	3.6	1597	3.6	2138	4.9
Total	43636	100.0	43636	100.0	43636	100.0	43636	100.0

The LULC classification result shows that cropland increased from 45.2 % in 1990 to 57.4 % in 2000 and 58.4 % in 2010, but it decreased to 38.1 % in 2021. On the contrary, the vegetation cover decreased from 23.8 % in 1990 to 17.1 % in 2000 and 16.8% in 2010, but it increased from 16.8% in 2010 to 26.5% in 2021. According to our observation and the focus group discussion result, the highest proportion of the vegetation cover in the Senan district is the Eucalyptus plantation, which has been expanded recently.

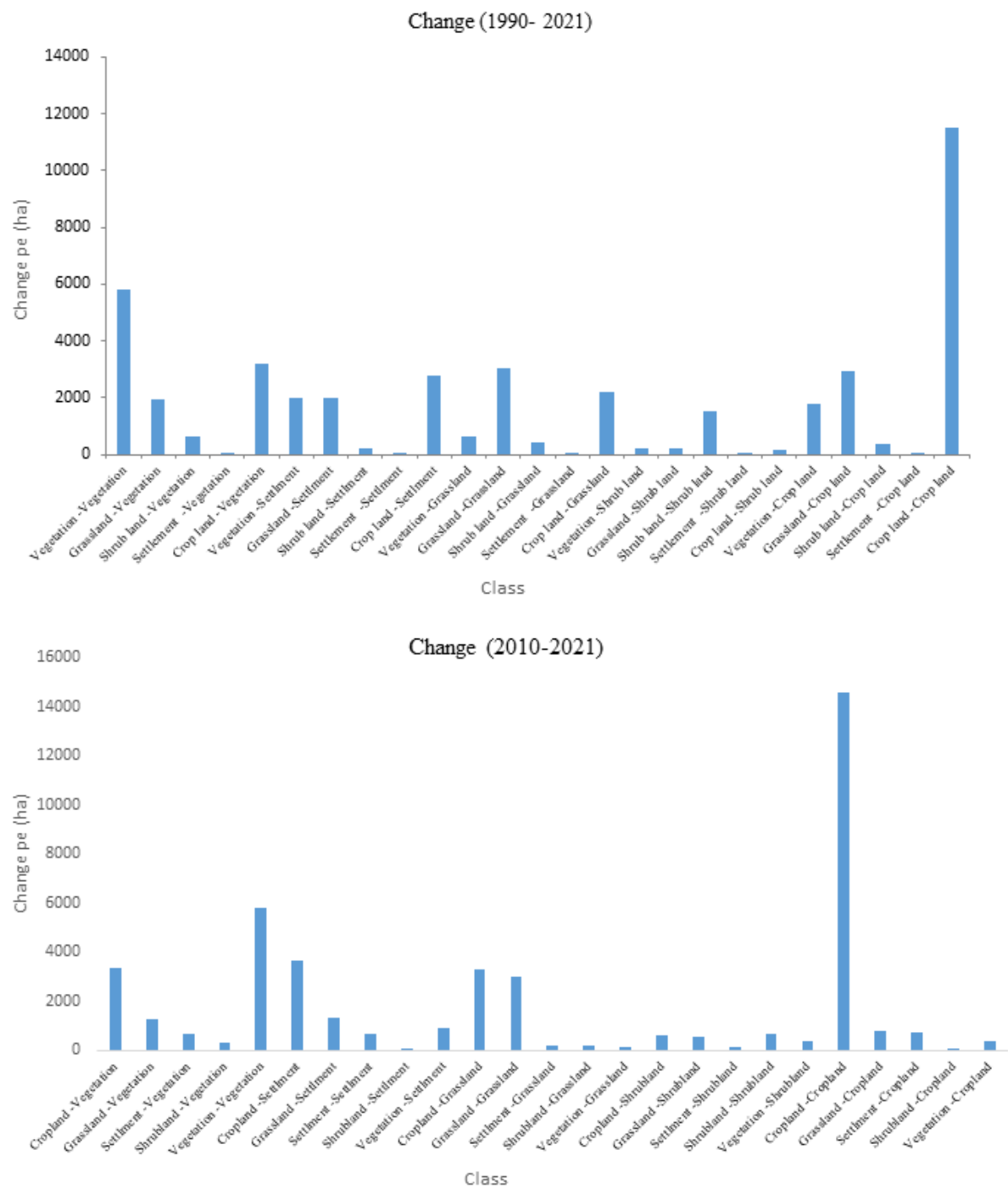
The focus group discussion result also confirmed that a significant number of farmers has been converted their cropland into Eucalyptus plantations during the last 10 years.

The change matrix (1990-2021) shows that the highest proportion of land was converted from cropland to vegetation. This change is mainly because farmers have changed their farmland into Eucalyptus plantations. From 2010 to 2021, the conversion of cropland



to vegetation experienced the most significant rate of change, with a total of 3,353 hectares, equivalent to 13% of the initial cropland, transformed into vegetation. Based on personal observation, almost all

forests of the area are Eucalyptus. The key informant interview also approved that farmers are aware of the economic advantage of Eucalyptus and tried to cover their cropland with this plant.



**Figure 4.** shows the calculated change detection matrix, in percent, covers the change of the whole study period from 1990 to 2021 and from 2010 to 2021



### 3.2 Factors Affecting Eucalyptus Tree Plantation

#### Binary logit model result

**Table 5.** Llogistic regression results

Explanatory variables	B	S.E.	Wald	Sig.	Exp(B)
Sex of household head	-.185	1.091	.029	.865	.831
Age of household head	.169	.031	29.382	.000***	1.184
Marital status	5.701	6.104	.872	.350	299.189
Educational Status	-1.730	.465	13.833	.000***	.177
Livestock ownership (TLU)	-.385	.140	7.601	.006***	.681
Farm size in hectare	3.039	.548	30.766	.000***	20.883
Family size (adult equivalent)	-.957	.203	22.203	.000***	.384
Farm fertility	-2.204	.497	19.665	.000***	.110
Membership of cooperatives	.363	.604	.362	.548	1.438
Having savings	1.453	.432	11.300	.001***	.234
Access to saving and credit service	.850	.449	3.583	.058	2.340
Constant	-8.738	6.409	1.859	.173	.000

Land Use and Land Cover (LULC) are influenced by a variety of factors, encompassing both natural processes and human activities (Terefe *et al.*, 2019). We categorized the driving factors and implications of land use land cover change and expansion of Eucalyptus plantations in the Senan district into four broad categories based on the result of the binary logistic regression model, the focus group discussion, and key informant interview result, as described below.

### 3.3 Socio-demographic Characteristics

Studies by Gebreegziabher *et al.* (2010), Tegegne *et al.* (2018), and Zenebe *et al.* (2020) have all found that age, gender, and education are factors that increase the likelihood and number of trees planted by farmers. However, according to Arragaw & Woldeamlak's (2018) findings, tree-planting activity is negatively influenced by the education level of the household. On the other hand, Tefera & Kassa (2016) noted that household size has a positive and significant influence on the adoption of Eucalyptus plantations by farmers. In relation to this, the binary logit results of this study show that the age of the household head positively and significantly affected the Eucalyptus plantation, while family size of smallholder and educational status

had a significant negative effect on the Eucalyptus plantation. This result means that as the age of the household head increases, the likelihood of adopting a Eucalyptus plantation also increases by a factor of 1.18. The key informant interview also reveals that farmers' motivation and decision to plant Eucalyptus trees increases as their age increases. This is because tree planting does not require much labor force. Therefore, elders prefer to plant Eucalyptus trees to practice crop production. Furthermore, since Eucalyptus plantations do not demand more labor than crop production, female-headed households in the study area prefer planting Eucalyptus to crop production.

According to the binary logistic regression model, the exp (b) value for family size is 0.38, indicating that the odds of adopting the Eucalyptus plantation decrease by a factor of 0.38 for every one-unit increase in family size. The focus group discussions also revealed that farmers with large families are less likely to plant Eucalyptus trees, which negatively affects their decision-making. In contrast, households with fewer family members tend to use their farmlands to grow Eucalyptus because it is less labor-intensive than crop production. However, one of the key informant interviewees noted that even households with large families experience labor con-

straints due to increasing school enrolment rates in the Senan district, which has led to a shift towards Eucalyptus plantations that require less labor. This finding aligns with previous studies, such as Asabneh *et al.* (2023), which found that family size has a detrimental impact on adopting Eucalyptus tree plantations. Based on the results of the focus group discussions and key informant interviews, it was found that female-headed households with smaller family sizes tended to choose Eucalyptus planting over other crops due to its low labor requirements. A widow female-headed household also stated “*My husband was a hard-working farmer who was capable of working day and night. But after I lost him, I turned the cropland into the Eucalyptus plantation because no one can help me on the farm.*”

### 3.4 Economic Drivers

The decision-making process of farmers regarding Eucalyptus tree planting is influenced by resource ownership, including access to land, labor, livestock, agricultural inputs, and market opportunities. Asabeneh & Yoseph (2022) stated that planting Eucalyptus trees offers a considerably better return on investment than growing crops and raising animals. Other previous studies, (Kebede, 2017; Setiye & Mulatu, 2016; Zenebe *et al.*, 2020; Dereje *et al.*, 2011), on the other hand, emphasized that the size of the farmland owned by farmers is a crucial factor in determining their decision to plant Eucalyptus trees. Gebreegziabher *et al.* (2010) found that the number of cattle owned by households had a significant negative impact on the likelihood of participating in Eucalyptus plantations. The findings of the binary logistic regression model in the study area also confirmed that the total land size and savings had a positive and significant effect on Eucalyptus plantations, while livestock ownership had a negative effect. The odds ratio of livestock ownership and farm size indicates that holding all other variables constant, the decision of smallholder farmers to adopt Eucalyptus plantation decreases by a factor of 0.68 times as livestock ownership increases by 1, while the likelihood of Eucalyptus plantation increases by a factor of 20.8 times as the farm size of households' increases by 1. Interviewees also reported that farmers with a large number of cattle do not have Eucalyptus plantations because Eucalyptus trees are not used for animal grazing, unlike

crop residues. As Setiye & Mulatu (2016) described the farmers who have small landholdings prefer to produce crops and other purposes like growing fruits and vegetables than growing Eucalyptus trees. The family who has a large landholding uses their land for diversifying the source of income like growing crops, fruit, tree planting, vegetables, and animal rearing.

Farmers may choose to plant Eucalyptus on marginal land that has limited potential for crop production. The binary logistic regression model and focus group discussions indicate that farmers are less likely to adopt Eucalyptus plantations on highly fertile land. Moreover, one of the interviewees said that:

*“I do have four temad (one hectar) land. The two temad are very fertile but the remaining two temad are not suitable for crop production. That’s why I planted Eucalyptus trees on the plot of land which is not fertile.”*

The findings of the focus group discussion revealed that farmers plant Eucalyptus to make a lot of money at a time so that they will be able to either construct a house, pay school fees to their children, or move to urban areas.

Moreover, Belay *et al.* (2021) also revealed that the growing need for fuelwood, construction, and cash for various purposes are the primary economic drivers behind the planting of Eucalyptus plantations.

### 3.5 Environmental Drivers

Senan is one of the districts in the Amhara Region of Ethiopia, which is predominantly Dega and is not suitable for producing high-value products like Teff. Therefore, the farmers preferred to plant Eucalyptus than to produce low-value products like potatoes.

Moreover, according to Yusuf (2016), Tola (2010), and Dereje *et al.* (2011) land degradation and depletion of natural vegetation are also the driving factors of Eucalyptus plantations. The key informant interviewees described that land degradation is the most common problem in the district, which is usually related to soil acidity. Concerning this, Hailu & Getachew (2011) stated that Ethiopia’s highland areas are experiencing an increase in soil acidity.

These issues are the result of continuous cropping and the use of acidifying fertilizers. The logit result reveals that farm fertility level and Eucalyptus plantation have a negative and significant relationship. According to the interview and focus group discussion, reduced crop yield because of declining soil fertility made farmers convert their cropland into Eucalyptus plantations.

### 3.6 Properties of the Eucalyptus Species

According to Tefera & Kassa (2017), coppicing ability, straight pole growth, quick growth and thus shorter maturity period, multiple uses of the wood, low labor required for management, and drought, disease, and pest resistance are important characteristics of the species. These characteristics are also one of the farmers' driving factors in planting Eucalyptus in the Senan district. One of the interviewees stated that:

*"Eucalyptus is a good species because it saves my time and labor; it teaches me to save a lot of money; it is free from natural hazards; unlike crops, it is not consumed by animals which make it easy to have the plantation."*

The focus group discussion participants also stated that shorter growing seasons and higher biomass, increasing price of farm input such as fertilizer and improved seed, the negative effects of nearby Eucalyptus plantation shades on a crop, and other farmers' successful experiences are some of the factors related to the properties of the species.

In relation to this, an interviewee emphasized that *"the shade of my neighbors' Eucalyptus plantation on my cropland affects its productivity. Hence, I was obligated to convert my cropland into a Eucalyptus plantation even though I did not want to do that."*

Silenat & Fikadu (2018) also stated that Eucalyptus plants are typically taller than other plants of equal age due to their rapid growth, and their shade may affect nearby crops by reducing the sunlight required for growth. Moreover, Gashaw *et al* (2023) described that the detrimental effects that Eucalyptus plantations have on nearby cropland made farmers convert their cropland into Eucalyptus tree plantations.

## 4 Conclusion

The results indicated a decline in cropland area from 58.4% in 2010 to 38.1% in 2021, while there was an increase in vegetation cover, primarily Eucalyptus, from 16.8% to 26.5% over the same time frame. This is mainly caused by socio-demographic characteristics of the household, economic factors, environmental factors, and the characteristics of the Eucalyptus species, such as the availability of large plots of land for ownership, infertile agricultural land, a small labor force, a shorter growing period, the species' shading impacts, and easily accessible market opportunities are responsible for the rapid expansion of Eucalyptus plantation in the study area. As a result, agricultural experts should provide support to farmers through various land-use planning strategies that take into account their socio-demographic, economic, and environmental elements and the country's land-use policy. Moreover, comparative studies should be conducted to make sure the livelihood of farmers is improved due to Eucalyptus plantations.

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### Conflict of Interest

The authors declare that there is no conflict of interest.

## References

- Abebe Birara, Tadie Mirie, & Taye Mekie (2019). Eucalyptus: The popular exotic tree crop in Ethiopia. ACTA scientific agriculture. Vol 3, Issue 9.
- Agenagnew A. Gessesse, Assefa M. Melesse, & Anteneh Z. Abiy (2019). Land Use Dynamics and Base and Peak Flow Responses in the Choke Mountain Range, Upper Blue Nile Basin, Ethiopia. International Journal of River Basin Management. Vol 19, issue 1 (pp. 14-20). <https://www.tandfonline.com/doi/abs/10.1080/15715124.2019.1672700>

- Amare Tesfaw, Dawit Alemu, Feyera Senbeta, & Ermias Teferi (2022). Eucalyptus Succession on Croplands in the Highlands of Northwestern Ethiopia: Economic Impact Analysis Using Farm Household Model. *Resources*. Vol 11, no 71 (pp. 1-3).
- Aramde Fetene, Demelash Alem, & Yosef Mamo (2014). Effects of Land use and Land cover Changes on the Extent and Distribution of Afro-alpine Vegetation of Northwestern Ethiopia: the case of Choke Mountains. *Research Journal of Environmental Sciences*. Vol 8, no 1 (pp. 21-26). <https://scialert.net/abstract/?doi=rjes.2014.17.28>
- Asabeneh Alemayehu & Yoseph Melka (2022). Small scale Eucalyptus cultivation and its socio-economic impacts in Ethiopia: A review of practices and conditions. *Trees forests and people*. Vol 11 (pp. 2-4). <https://www.researchgate.net/journal/Trees-Forests-and-People-2666-7193>
- Asabeneh Alemayehu, Yoseph Melka, & Abje Es-hete (2023). Eucalyptus woodlot adoption and its determinants in the Mecha District, Northern Ethiopia. <https://www.frontiersin.org/articles/10.3389/ffgc.2023.1111301/full>
- Badege Bishaw (2001). Deforestation and Land Degradation on the Ethiopian highlands: A strategy for physical recovery. *International conference on African development*. Western Michigan University. (pp. 1-4). [https://scholarworks.wmich.edu/cgi/viewcontent.cgi?article=1002&context=africancenter\\_icad\\_archive](https://scholarworks.wmich.edu/cgi/viewcontent.cgi?article=1002&context=africancenter_icad_archive)
- Belay Zerga, Bikila Warkineh, Demel Teke-tay, Muluneh Woldetsadik (2021). Land use and land cover changes driven by expansion of Eucalyptus plantations in the Western Gurage Watersheds, Central-south Ethiopia. <https://www.sciencedirect.com/science/article/pii/S2666719321000261>
- Berihun Tefera & Habtemariam Kassa (2017). Trends and driving forces of Eucalyptus plantation by smallholders in the Lake Tana watershed of Ethiopia. *Social and Ecological System Dynamics*. AESS Interdisciplinary Environmental Studies and Sciences Series. Springer, Cham. [https://doi.org/10.1007/978-3-319-45755-0\\_31](https://doi.org/10.1007/978-3-319-45755-0_31)
- Central Statistics Agency (2007). *Census 2007 Report*.
- Dereje Jenbere, Mulugeta Lemenih, & Habtemariam Kassa. (2011). Expansion of Eucalypt Farm Forestry and Its Determinants in Arsi Negelle District, South Central Ethiopia. *Small scale forestry*. Vol 11 (3) (pp. 396-401). [https://www.researchgate.net/publication/257762022\\_Expansion\\_of\\_Eucalypt\\_Farm\\_Forestry\\_and\\_Its\\_Determinants\\_in\\_Arsi\\_Negelle\\_District\\_South\\_Central\\_Ethiopia](https://www.researchgate.net/publication/257762022_Expansion_of_Eucalypt_Farm_Forestry_and_Its_Determinants_in_Arsi_Negelle_District_South_Central_Ethiopia)
- Elli, E. F., Sentelhas, P. C., De Freitas, C. H., Carneiro, R. L., & Alvares, C. A. (2019). Assessing the growth gaps of Eucalyptus plantations in Brazil – magnitudes, causes and possible mitigation strategies. *Forest ecology and management*. Vol 451 (pp. 1-5). <https://agris.fao.org/agris-search/search.do?recordID=US201900334751>
- FAO (2011). *Eucalyptus in East Africa, Socio-Economic and Environmental Issues*, by Gessesse Dessie, Teklu Erkossa. *Planted Forests and Trees Working Paper 46/E*, Forest Management Team, Forest Management Division. FAO, Rome. (pp. 8-20). [https://www.scrip.org/\(S\(351jmbntvnsjt1aadkposzje\)\)/reference/referencespapers.aspx?referenceid=1938879](https://www.scrip.org/(S(351jmbntvnsjt1aadkposzje))/reference/referencespapers.aspx?referenceid=1938879)
- Gashaw Molla, Meseret B. Addisie, & Gebiaw T. Ayele (2023). Expansion of Eucalyptus Plantation on Fertile Cultivated Lands in the North-Western Highlands of Ethiopia. <https://www.mdpi.com/2072-4292/15/3/661>
- Gebreegziabher, Zenebe Mekonnen, Alemu Kassie, Menale Köhlin, Gunnar (2010). Household tree planting in Tigray. *Tree species, purposes, and determinants*, Northern Ethiopia. <https://gupea.ub.gu.se/handle/2077/21995>
- Hailu Regassa & Getachew Agegnehu (2011). Potential and limitations of acid soils in the highlands of Ethiopia: a review. In: Mulat, B. and Grando, S. (eds.). *Proceedings of the 2nd National Barely Research and Development Review Workshop*. HARC, Holetta, Ethiopia. ICARDA. (pp. 104-110).
- Jagger, P., & Pender, J. (2003). The role of trees for sustainable management of less fa-

- vored lands: the case of Eucalyptus in Ethiopia. Forest policy and economics. Vol 5. Issue 1 (pp. 84-86). <https://www.fao.org/forestry/42684-057b8adc0fa549611cf17987f10cff07.pdf>
- Jaleta, D., Mbilinyi, B., Mahoo, H., & Lemenih, M. (2016). Eucalyptus Expansion as Relieving and Provocative Tree in Ethiopia. Journal of Agriculture and Ecology Research International. Vol 6 (3). [https://www.researchgate.net/publication/291688499\\_Eucalyptus\\_Expansion\\_as\\_Relieving\\_and\\_Provocative\\_Tree\\_in\\_Ethiopia](https://www.researchgate.net/publication/291688499_Eucalyptus_Expansion_as_Relieving_and_Provocative_Tree_in_Ethiopia)
- Kebede Gizachew (2017). Expansion of Eucalypt Woodlot and Its Factors in Cheha District, Southern Ethiopia. Southern Agricultural Research Institute, Bonga Agricultural Research Centre. (pp. 173-177). <http://www.worldscientificnews.com/wp-content/uploads/2016/11/WSN-66-2017-163-180.pdf>
- Lakachew Ayenew (2022). Determinants Affecting Lime Technology Adoption on Agricultural Land in Senan District, North West Ethiopia. International Journal of Environmental Chemistry. <https://sciencepg.com/article/10.11648.j.ijec.20220601.13>
- Mesfin, Abebe & Wubalem Tadesse (2006). Eucalyptus in Ethiopia risk or opportunity? Ethiopian Institute of Agricultural Research. (pp. 1-9)
- Schowengerdt, R. (2007). Remote sensing: models and methods for image processing. Third edition. Environmental science. (pp.1-3). <https://www.pdfdrive.com/remote-sensing-third-edition-models-and-methods-for-image-processing-e161061482.html>
- Sembiring, N., Napitupulu, H. Triyana, M., & Wahida, Y. (2021). A review of modeling, and simulation for sustainable replanting Eucalyptus. Proceedings of the 2nd National Barely Research and Development Review Workshop. HARC, Holleta, Ethiopia. Material sciences. Vol 1122. (pp. 4-7). <https://www.semanticscholar.org/paper/A-review-of-modeling%2C-and-simulation-for-replanting-Sembiring-Napitupulu/86a6a016c4f-4985ff19bc1ffc92cd1769ce799c9#citing-papers>
- Senan District communication Affairs Office (2021). The profile of District. Annual report
- Setiye Abebaw & Mulatu Dea (2016). Determinants of Farmers Decision Making for Plant Eucalyptus Trees in Market District, North Willow, Ethiopia. Research on Humanities and Social Sciences. Vol 6, No 13 (pp. 65-68). <https://iiste.org/Journals/index.php/RHSS/article/view/31804>
- Silenat Birhanu & Fikadu Kumsa (2018). Review on Expansion of Eucalyptus, its Economic Value and Related Environmental Issues in Ethiopia. International Journal of Research in Environmental Science Volume 4. Issue 3 (41-45). <https://www.arcjournals.org/pdfs/ijres/v4-i3/5.pdf>
- Sintayehu Ayinalalem & Belay Simane (2016). Development of Community-Based Ecotourism, A Case of Choke Mountain and Its Environments, Ethiopia: Challenges and Opportunities. Journal of Tourism, Hospitality, and Sports. Vol 16. (pp. 14-20). [www.iiste.org](http://www.iiste.org). <https://core.ac.uk/download/pdf/234696842.pdf>
- Tegegne Derbe, Sisay Yehuala, & Genanew Agitew (2018). Factors Influencing Smallholder Farmers Adoption of Eucalyptus Woodlot in Wogera District, North Gondar Zone, Amhara Regional State of Ethiopia. International Journal of Scientific Research and Management. [https://www.researchgate.net/publication/326637313\\_Factors\\_Influencing\\_Smallholder\\_Farmers\\_Adoption\\_of\\_Eucalyptus\\_Woodlot\\_in\\_Wogera\\_District\\_North\\_Gondar\\_Zone\\_Amhara\\_Regional\\_State\\_of\\_Ethiopia](https://www.researchgate.net/publication/326637313_Factors_Influencing_Smallholder_Farmers_Adoption_of_Eucalyptus_Woodlot_in_Wogera_District_North_Gondar_Zone_Amhara_Regional_State_of_Ethiopia)
- Temesgen Alemneh, Benjamin F. Zaitchik, Belay Simane, & Argaw Ambelu (2009). Changing patterns of tree cover in a tropical highland region and implications for food, energy, and water resources. Land Use Dynamics. Vol 7 (pp. 1- 3) <https://www.frontiersin.org/articles/10.3389/fenvs.2019.00001/full>
- Terefe Tolessa, Chala Dechassa, Belay Simane, Bamalaku Alamerew, & Moges Kidane (2019). Land use/land cover dynamics in response to various driving forces in Didessa sub-basin, Ethiopia.

GeoJournal. <https://link.springer.com/article/10.1007/s10708-019-09990-4>

Tola Gemechu (2010). Expansion of Eucalyptus plantations by smallholder farmers amid natural forest depletion: a case study from Mulo district in central Oromia. Proceedings from the congress held Addis Ababa. [https://www.academia.edu/56188031/Expansion\\_of\\_Eucalyptus\\_Plantations\\_by\\_Smallholder\\_Farmers\\_amid\\_Natural\\_Forest\\_Depletion\\_Case\\_Study\\_from\\_Mulo\\_District\\_in\\_Central\\_Oromia](https://www.academia.edu/56188031/Expansion_of_Eucalyptus_Plantations_by_Smallholder_Farmers_amid_Natural_Forest_Depletion_Case_Study_from_Mulo_District_in_Central_Oromia)

Yusuf Bahtimi (2016). Policies, drivers, and land-use trends in industrial forest plantation development in Indonesia. A thesis for Masters of Science in

forestry. Michigan State University. (pp. 120-121).

Zenebe Gebreegziabher, Alemu Mekonnen, Menale Kassie, & Gunnar Köhlin (2020). Household Tree Planting in Tigray, Northern Ethiopia: Tree Species, Purposes, and Determinants. Working papers in economics. Landuse policy. Vol 96 (pp. 1-6). <https://www.semanticscholar.org/paper/Household-Tree-Planting-in-Tigray%2C-Northern-Tree-Gebreegziabher-Mekonnen/2fccccf900ddd6d331ecad95045e2f87176c8b81d#citing-papers>

Zenebe Mekonen (2016). Eucalyptus as alternative source of energy and food security. LAP LAMBERT Academic Publishing (pp. 38-61).