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Original Research

Impacts of Expansion of *Eucalyptus globulus* Plantation on the environment in Horro Buluk woreda, Ethiopia

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Abstract

This study aimed to identify the factors influencing farmers' eucalyptus cultivation practices and to assess the environmental impacts of eucalyptus species proliferation in the Horro Buluk district of western Ethiopia. A rigorous random sampling method was employed to select a total of 161 households. Data collection involved household surveys, focus group discussions, and key informant interviews, supplemented by secondary data obtained from both published and unpublished sources. Qualitative data were analyzed using text summarization techniques, while quantitative data were evaluated using statistical methods, including percentages, means, standard deviations, t-tests, and chi-square tests. The result of the study revealed that 82.6 % of the respondents planted Eucalyptus trees and 49.6 % and 30.8 % of them converted cropland and grazing land to Eucalyptus plantation, respectively. Income, age of the households, and distance to road and market appear to be negatively associated with the expansion of Eucalyptus; whereas family size, landholding size, and distance from natural forest seem to positively influence farmers' decision to establish eucalyptus plantations. The study confirmed that eucalyptus has a significant contribution to the livelihood of the household as well as harmful effects on the environment because of poor silvicultural management. Therefore, further research is needed to balance Eucalyptus farming practices and food crop production and to resolve the land competition problem.

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INTRODUCTION

Eucalyptus, a genus of evergreen flowering trees and shrubs belonging to the Myrtaceae family, encompasses over 800 distinct species (Bayle, 2019). In Ethiopia, around 70 species of Eucalyptus have been identified, with many widely distributed across various regions, particularly in the densely populated central highlands (Bekele, 2015).

The global expansion of eucalyptus plantations has become increasingly common, fueled by the demand for timber, paper, and biofuels, along with its recognized potential for carbon sequestration. Known for its fast growth, drought tolerance, and adaptability, eucalyptus is a preferred choice for commercial forestry (Bekele, 2015). However, the rapid proliferation of eucalyptus plantations has sparked concerns regarding their environmental consequences. While offering economic advantages, these plantations are often scrutinized for their effects on local ecosystems, water resources, soil quality, and biodiversity (Liang et al., 2016). In non-native regions, eucalyptus has posed ecological challenges, such as altering water cycles, exhibiting invasive tendencies, and disrupting native plant and animal populations (Dereje Jenbere et al., 2011). As eucalyptus plantations continue to expand, a balanced understanding of their benefits and environmental trade-offs is essential to foster sustainable land use and forest management strategies.

Eucalyptus plantations are experiencing significant growth in Ethiopia (Yitaferue et al., 2013), fueling an ongoing debate among experts about their environmental and socio-economic impacts (Tadesse and Tafere, 2017). This expansion has also sparked political discourse among environmentalists, foresters, and policymakers (Dereje Jenbere et al., 2011).

In the study area, the rapid growth of the *Eucalyptus globulus* is primarily attributed to favorable agro-ecological conditions that support its proliferation. Despite this notable expansion, limited information exists on its contributions to local livelihoods and the environmental challenges it poses. This study aims to explore the environmental impacts of eucalyptus expansion in Horro Buluk Woreda, West Ethiopia, shedding light on its implications for sustainable development and resource management.

Statement of the Problem

Eucalyptus, a fast-growing exotic tree species in Ethiopia, is known for its high biomass production compared to indigenous tree species (Bekele, 2015). This characteristic has made it a popular choice among local farmers, who cultivate eucalyptus on their agricultural land to meet demands for fuelwood, construction materials, market supplies, and other industrial needs (Zerga, 2015).

The rapid expansion of eucalyptus plantations, particularly *Eucalyptus globulus*, has raised concerns about its environmental and socio-economic implications (Birhanu and Kumsa, 2018). While eucalyptus trees are valued for their rapid growth and adaptability to diverse agro ecological conditions, especially in highland regions, their extensive cultivation often results in significant environmental changes (Zerga, 2015). These include reductions in water availability, degradation of soil quality, loss of biodiversity, and adverse effects on local livelihoods (Abdoulaye et al., 2012). Despite their growing prevalence, there is a lack of comprehensive research examining the long-term impacts of eucalyptus plantations, particularly with respect to ecosystem services and the socio-economic benefits they provide to local communities.

This study aims to address the existing knowledge gaps by investigating the environmental consequences and livelihood contributions of eucalyptus expansion, offering insights that can inform sustainable land-use practices and policy decisions.

Horro Buluk District, located in West Ethiopia, is one of the areas experiencing rapid expansion of eucalyptus plantations. However, scientific data on the environmental impacts and key factors influencing eucalyptus cultivation in this region remain limited. This highlights the need for a detailed examination of local farmers' practices regarding eucalyptus plantations. Consequently, this study identifies the environmental impacts of eucalyptus expansion and analyzes the factors influencing household participation in eucalyptus cultivation within the study area.

RESEARCH METHODOLOGY

Description of the study area

The study was conducted in Horro Buluk Woreda, located within the Oromia National Regional State and part of the Horro Guduru Wollega Zone. Horro Buluk is situated approximately 331 kilometers west of Addis Ababa and 17 kilometers northwest of Shambu, the capital of the Horro Guduru Wollega Zone. Geographically, the Woreda lies between latitudes 9°37′0″N and 9°52′3″N and longitudes 36°58′30″E and 37°21′30″E. Figure 1 provides a map illustrating the location of Horro Buluk Woreda.

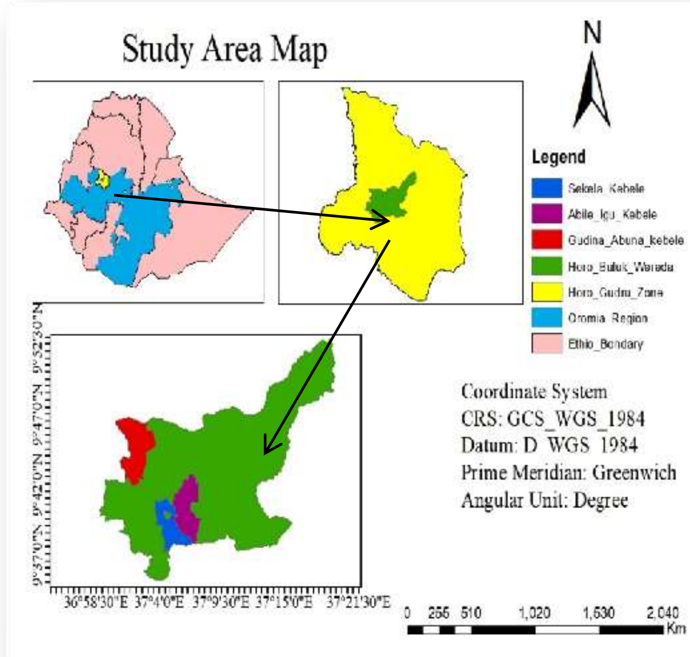

Figure 1: Location map of the study area

Sampling method

A multistage sampling approach was utilized to select households within the study area from Kebeles associated with eucalyptus cultivation. Initially, the districts were categorized into those with potential and those without potential for eucalyptus cultivation. Subsequently, a district with a high concentration of eucalyptus trees was intentionally selected due to its prominence in eucalyptus farming. Lastly, a comprehensive household survey was conducted by randomly selecting three Kebeles from the designated district. Utilizing a stratified random sampling technique, farm households within the selected Kebeles were categorized into two groups: those engaged in eucalyptus cultivation and those not engaged. Subsequently, a simple random sampling method was employed to select households from each group. The names of household heads in each sampled Kebele were assigned numerical identifiers, and the households for the study were selected using a random number table.

A systematic random sampling method was employed to select a total of 161 household heads. The selection process was guided by proportional probability, ensuring representation based on the population size of each of the three sampled Kebeles (Table 1). The sample size was determined following the formula outlined by Kothari (2004) for determining an appropriate sample size in research.

$$n = \frac{Z^2 * p * q * N}{(e^2(N-1)) + (Z^2 * p * q)}$$

Where:

n= the required sample size

Z^2 = is the abscissa of the normal curve that cuts off area α at the tails (1- α equals the desired confidence level. The value of Z is found in statistical tables that contain the area under the normal curve. e.g., Z=1.812 at 93% confidence level; and Z^2 = 3.283).

N= the household size (3088)

P= the population proportion (assumed to be 0.5 since this would provide the maximum Sample size) q= 1-p

e = is the desired level of precision or margin of error (7% error or 0.07).

Thus;

$$n = \frac{3.283*0.5*(1-0.5)*3088}{(0.07^2(3088-1))+3.283*0.5*(1-0.5))}$$

= 161

Table 1: Sample size and sampling distribution by kebele

No	KPAs	Total Households	No. of HHs		Proportional allocation of sample HHs		%
			Planter	Non-planter	Planter	Non-planter	
1	Sekela	1,304	1074	230	56	12	**42.2**
2	Gudina Abuna	901	748	153	39	8	**29.2**
3	Abille Iggu	883	729	154	38	8	**28.6**
	Total	**3088**	**2551**	**537**	**133**	**28**	**100**
			3088		**161**		

Sources and Methods of Data Collection

Both primary and secondary sources provided data for the study. To gain an initial understanding of the study area, a reconnaissance survey was conducted on-site, offering a broad overview. This preliminary assessment was further enriched by key informant interviews (KIIs) with Kebele leaders, development agents (DAs), and experts in agriculture and natural resource management.

For the main phase of data collection, quantitative data were obtained through household surveys, while qualitative insights were derived from KIIs and focus group discussions (FGDs).

Key Informant Interviews(KII):

The KIIs were conducted using semi-structured, open-ended questions that encouraged detailed discussions. A snowball sampling technique was employed to identify a total of 15 participants, comprising 8 agricultural and natural resource management experts, 4 model farmers with extensive knowledge of eucalyptus cultivation and local farming practices, and one Kebele leader from each selected Kebele.

Focus Group Discussions (FGDs):

Three FGDs were conducted in each Kebele, involving separate groups of men, women, and a mixed group of both genders, with each group comprising 8–10 participants. The purpose of these discussions was to gather qualitative insights into eucalyptus plantation activities, their environmental impacts, and the factors driving the expansion of eucalyptus plantations onto farmland, including the conversion of cropland into eucalyptus woodlots. Additionally, the FGDs explored the constraints and challenges affecting eucalyptus farming in the study area.Household Survey:

Household surveys were administered using semi-structured questionnaires, which were translated into the local language, *Afaan Oromoo*, to ensure effective communication. A total of 161 households participated in the survey. The primary goal of the household surveys was to collect quantitative data to analyze farmers' perceptions of the environmental impacts associated with the expansion of eucalyptus plantations. The survey included questions on personal and demographic characteristics (such as age, education level, household size, marital status, landholding size, and income sources) and the participants' views on the environmental effects of eucalyptus plantation expansion.

Secondary Data Collection:

In addition to primary data collection, a detailed review of secondary data sources was conducted. This involved examining published literature, research findings, books, and online resources. Reports (both published and unpublished), official documents, and previous survey results were also reviewed to supplement the study with comprehensive secondary information.

Method of data analysis

Descriptive statistics

The collected data were analyzed using a combination of econometric models and descriptive statistical methods. Statistical software programs, including Microsoft Excel, Stata Statistical Software (version 14), and SPSS (Statistical Package for the Social Sciences, version 25), were utilized for data processing and analysis. Descriptive statistics were employed to compile and interpret the data, providing a concise summary of the key factors and trends observed in the study. Econometric models were applied to explore relationships and draw inferences from the data.

Econometrics model

Binary logit regression analysis was employed to identify the factors influencing farmers' participation in eucalyptus plantations. This method was used to examine the socioeconomic, psychological, institutional, and demographic factors affecting farmers' decisions. Given that the predicted probabilities of the binary logistic function range between 0 and 1, it serves as an effective approximation of the cumulative normal distribution (Gujarati, 2004). In the logit model, farmers with eucalyptus woodlots were classified as "planters," assigned a value of 1, while those without such woodlots were classified as "non-planters," assigned a value of 0.

According to Gujarati (2004), the functional form of the logit model is expressed as follows:

$$Li = \ln\left(\frac{pi}{1-pi}\right) = Zi = B0 + B1.X1 + B2.X2 + B3.X3 \ldots \beta_n x_n \quad (1)$$

Where; Pi = the probability of adopting eucalyptus woodlot ranges from 0 to 1.

L=the natural log of the odds ratio or logit.

$$Zi = B0 + B1.X1 + B2.X2 + B3.X3 \ldots \beta_n x_n \quad (2)$$

β0 = the intercept. It is the value of the log odd ratio, $(\frac{pi}{1-pi})$ when X is zero.

β = β1+ β2+ β3+ β4… βn the slope, measures the change in L for a unit change in X; Thus, if the stochastic disturbance term (Ui) is taken into consideration the logit model becomes Li = β0 +β1 X i +U i.

Multicollinearity test; In the case of using binary logistic regression the multicollinearity of the independent variable was checked. Multicollinearity is the condition in which independent variables are correlated. Therefore the problem of multicollinearity was tested using the variance inflation factor (VIF) and Contingency Coefficient (CC). Accordingly, a method of variance inflation factor (VIF) was employed to detect the problem of multicollinearity between continuous variables. According to Gujarati (2004), variance inflation factor (VIF) is computed as:

$$VIF(xi) = \frac{1}{1 - Ri2}$$

The contingency coefficient (CC) was calculated similarly;

$$C = \sqrt{\frac{x^2}{N + x^2}}$$

In this formula:
χ2 = is the chi-square statistic,
N = is the total number of cases or observations in our analysis/study,
C = is the contingency coefficient.
The decision rule for contingency coefficients is that when p- value of contingency coefficients is non-significant there is no association between discrete variables. The contingency coefficient also shows that there is no problem of multicollinearity between discrete variables.

RESULTS AND DISCUSSION

Characteristics, access, and resources of respondents

Household characteristics and access

Table 2 below presents the demographic characteristics of the respondents, including information on household sex, marital status, educational attainment, and access to credit.

Table 2: Summary of categorical household's socio-economic characteristics

Variables	Indicators	non planter(N=28)		Planter(N=133)		Total(N=161)		χ2	P-value
		F	%	F	%	F	%		
sex	Female	10	35.7	20	15.0	30	18.6	6.522	0.011
	Male	18	64.3	113	85.0	131	81.4		
Education status	Illiterate	16	57.1	31	23.3	47	29.2	12.810	0.000
	Literate	12	42.9	102	76.7	114	70.8		
Credit access	No	6	21.4	34	25.6	40	24.8	0.212	0.645
	Yes	22	78.6	99	74.4	121	75.2		
Marital status	Married	20	71.4	119	89.5	139	86.3	20.403	0.000
	Unmarried	0	0	5	3.8	5	3.1		
	Divorced	0	0	4	3.0	4	2.5		
	Widowed	8	28.6	5	3.8	13	8.1		

The study revealed a strong connection between household demographics and the growth of eucalyptus plantations. Male-headed households were found to dominate, likely driving the expansion of eucalyptus trees, as men are more inclined to engage in tree planting. In contrast, female-headed households were less involved in such activities. A chi-square test confirmed a statistically significant difference in gender-related participation at the 5% significance level (Table 2).

Marital status also played a significant role.The majority of respondents were married, comprising 86.3% of the sample, followed by single (3.1%), divorced (2.5%), and widowed (8.1%) respondents. Furthermore, a chi-square test indicated a statistically significant difference in marital status at the 1% significance level (Table 2).

Education emerged as another influential factor. While 29.2% of respondents reported no formal education, 70.8% had varying levels of educational attainment. The chi-square test again showed a statistically significant difference at the 1% level (Table 2), underscoring the role of education in shaping participation in eucalyptus farming.

In terms of credit access, 75.8% of households reported receiving credit, while 24.2% did not. However, the chi-square test found no statistically significant difference between households that engaged in eucalyptus planting and those that did not.

Table 3: Continuous socio-economic characteristics of households

Variables	Non-Planter(N=28)		Planter(N=133)		Pooled data		t	p-value
	Mean	SD.	Mean	SD.	Mean	SD.		
Age	47.96	7.87	46.69	12.81	46.91	12.08	-.505	.614
Family size	6.89	2.96	6.86	2.85	6.86	2.86	-.060	.952
Livestock owned (TLU)	15.52	7.50	14.82	8.98	14.94	8.72	-.383	.702
Landholding size	1.62	1.16	2.28	0.89	2.16	0.97	3.360	.001
Distance from road	8.78	5.47	3.06	2.93	4.06	4.10	-7.868	.000
Distance from forest	1.70	1.07	4.04	2.64	3.64	2.60	4.601	.000
Distance from market	10.73	4.88	4.38	3.39	5.48	4.40	-8.287	.000
Crop income	67118.18	40294.5	48114.59	41312.35	10,751.36	8,214.90	-2.222	.028
Livestock income	38933.32	29253.9	43840.40	29832.29	4,990.45	3,718.38	.087	.931
Off- farm income	7073.93	10529.2	7650.33	53026.74	2,337.62	2,315.85	.057	.955

Table 3 presents the various continuous socioeconomic characteristics of the respondents. The households had an average family size of 6.86 and an average age of 46.91 years. This age range is conducive to prolonged exposure, and as a result, many respondents appear to be well-informed about the distinct traits of eucalyptus in relation to their local land use practices. According to Table 3, the average number of livestock held by households was 14.94 tropical livestock units (TLU). The average distances from the household to key locations were 2.16 meters to the market, 4.06 meters to the natural forest, and 3.64 meters to an accessible road.

Moreover, a significant difference in crop income between eucalyptus planters and non-planters was observed at the 5% level of significance. Table 3 also illustrates how households diversify their annual income, with average incomes from crops, livestock, and off-farm sources being 9,355.03, 4,990.44, and 2,337.62, respectively. This suggests that income diversification plays a key role in encouraging farmers to plant eucalyptus, offering economic benefits, reducing risks, and enhancing financial stability. This is especially important in regions where agricultural incomes can be unpredictable or insufficient to meet household needs.

The t-test results indicate a statistically significant difference between eucalyptus planters and non-planters with regard to landholding size, distance from the main road, distance from the forest, and distance from the market, all at the 1% level of significance.

Trends in E*ucalyptus* tree planting

Extent of E*ucalyptus* plantation expansion

The survey results indicate a notable increase in the expansion of eucalyptus plantations in the study area in recent times. Particularly eucalyptus planting has increased over the period of 2001 and 2013 E.C in Horro Buluk Woreda (Figure 2). According to the farmer's opinion planting more eucalyptus trees is creating their own green bank and verities of opportunities in their livelihood. However, as indicated in (Figure 2**)** the increase in number of E*ucalyptus* seedlings planted shows the rapid expansion of Eucalyptus plantation. Despite severe blame for the genus and widespread awareness among farmers and its harmful environmental consequences though, this expansion is taking place. Between 1970 and 1980, the average number of Eucalyptus seedlings planted climbed from 467 to 2036 (2001-2013 E.C). Thus, it showed the average expansion of E*ucalyptus* plantations.

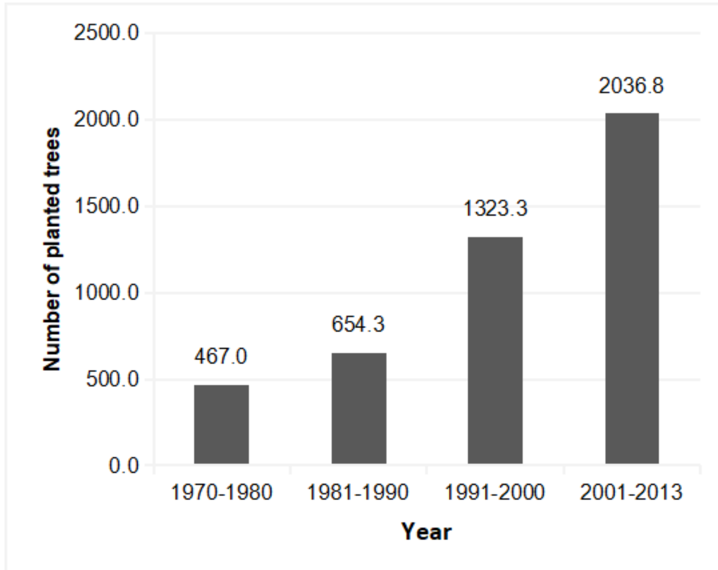

Figure 2: Number of Eucalyptus seedlings planted by households in the last ten years decades (E.C) Source (field survey, 2021)

As natural forests and woodlands continue to rapidly diminish, smallholder farmers are increasingly planting fast-growing tree species to establish their own woodlots(Tefera and Kassa, 2017). The increasing demand for wood products and its significant income contribution to livelihood is invigorating the dramatic expansion of eucalyptus plantations in Ethiopia (Bekele, 2015). Particularly, in the study area, the price increment of eucalyptus poles from time to time encouraged the farmers to plant more eucalyptus. The amount of planted eucalyptus woodlots generally increases throughout the year because once the farmers growing the tree satisfy their substance and cash crop needs like coffee; they prefer to grow more eucalyptus trees. Eucalyptus tree plantation is a well-known emergent activity done by the majority of the farmers in the current research area.

Table 4: The starting year of eucalyptus planting by the planters in the study area in E.C

Period		No of planters	Percentage
Valid	1970-1980	2	1.2
	1981-1990	18	11.2
	1991-2000	42	26.1
	2001-2010	51	31.7
	2011-2013	20	12.4
	Total	**133**	**100.0**

Source (field survey, 2021)

In the study area, eucalyptus is the most commonly planted tree species, with approximately 82.6% of respondents indicating its cultivation. When asked to identify the primary reason for their preference for this species, respondents highlighted the tree's essential role in supporting household livelihoods and its contribution to the production of cash crops. Some of the respondents reported fear of E*ucalyptus* expansion, particularly in its competition with cereal crops and grazing lands. Table 4; shows the beginning of the farmers when started planting Eucalyptus trees. About 31.7% of the respondents started planting during the period of 2001-2010; while 26.1% of respondents started before 20 years (1991-2000). The result showed that the study area appears to have had extensive experience with Eucalyptus farming.

Conversion of other land use to E*ucalyptus* plantation

According to focus group participants, most households convert other land uses to eucalyptus plantations for various reasons, such as when crop productivity declines, the influence of nearby households with eucalyptus plantations, poor yields from cereal crops due to pests and diseases, or the need for fuelwood and building materials.

The survey findings reveal that respondents converted a larger proportion of land previously used for cereal crops to eucalyptus plantations, followed by grazing land. The primary motivation for this shift was the need to secure the intended yield of cereal crops, such as wheat, maize, teff, barley, and nug, in the study area. Approximately 49.6%, 30.8%, and 12.8% of households established eucalyptus plantations by converting croplands, pastureland, and homestead areas, respectively (Table 5).

Table 5: Number of households converted other land use types to E*ucalyptus* plantation

	Number of respondents	
Converted land use type	**Frequency**	**percentage%**
Cropland	66	49.6
Homestead area	17	12.8
Grazing land	41	30.8
Others	9	6.8
Total	**133**	**100.0**

Source (field survey, 2021)

The expansion of eucalyptus plantations has come at the expense of other land-use types, significantly impacting traditional farming practices. Farmers have increasingly allocated substantial portions of their land to eucalyptus cultivation, motivated by the perception of higher financial returns compared to conventional crop farming. Respondents who converted cropland to eucalyptus consistently identified two primary reasons for the shift: declining crop yields due to reduced soil fertility and the superior income potential of eucalyptus over annual crops.

Focus group discussions highlighted that eucalyptus plantations are directly competing with land traditionally used for food crop production. The financial attractiveness of eucalyptus farming has emerged as a key driver of this conversion, as farmers prioritize immediate and higher economic gains. Similar observations were noted in studies by Dereje Jenbere (2012), Tefera and Kassa (2017), Munuyee (2018), and Alemayehu and Melka (2022).

When the productivity of food crops diminishes, as often expected due to soil degradation, farmers are quick to transition the land to eucalyptus plantations. Key informants also emphasized that, in many cases, the land passed down to heirs—whether children or relatives, often living in urban areas—is commonly converted to eucalyptus plantations to ensure a steady, low-maintenance income stream. These findings align with studies by Kebede Gizachew (2017) and Zerga et al. (2021).

However, this growing trend raises concerns. If the replacement of cropland by eucalyptus plantations is not carefully managed, it could lead to a significant reduction in food crop production, ultimately threatening food security in the region (Alemayehu and Melka, 2022).

Figure 3: Different land uses converted to E*ucalyptus* plantation. Source; (own field photo, 2021)

***Eucalyptus* landholding size and niches of E*ucalyptus* plantation**

As indicated table 6, about 31.6 % of respondents were allocated 0.75-1 hectare of their farming land by eucalyptus plantation. The rest of the respondents have less than 0.025 hectare (11.3%), 0.025-0.5 hectare (12.8%), 0.05-0.1 hectare (11.5%), 0.025-0.5 and 0.5-0.75 hectare (11.3% for each) (Table 6).

Table 6: Household's land occupied by *Eucalyptus* tree

Eucalyptus landholding size (ha)	**Number of households**	
	No of planters	**Percentage**
< 0.025	15	11.3
0.025-0.05	17	12.8
0.05-0.1	14	11.5
0.1-0.25	11	8.2
0.25-0.5	15	11.3
0.5-0.75	15	11.3
0.75-1	42	31.6
> 1	4	3.1
Total	**133**	**100.0**

Source (field survey, 2021)

Eucalyptus landholding size in farmers having large land size is greater than those having small landholding. With respect to this land use competition of *Eucalyptus* with cereal crops, grazing land and other land use types is becoming a serious problem in the study area. Therefore, land domination of *Eucalyptus* tree plantation becomes a more important land use practice for small landowners than for large size (Zerga *et al.*, 2021). Farmers' high desire for planting and managing *Eucalyptus* could be shown in their allocation of limited land for *Eucalyptus.*

Niches	No planters	Percent
On degraded land	90	67.7
On farmland with crops	2	1.5
As farm boundary	30	21.6
Along roadside	11	8.2
Total	**133**	**100.0**

Table 7: Niches of *Eucalyptus*

Source (field survey, 2021)

The study reveals that approximately 67.7% of farmers prefer planting eucalyptus on degraded land. This choice reflects the species' popularity in the region, as it helps farmers recover income, ensure food security, and alleviate rural poverty. Consequently, both households and government-led afforestation programs have prioritized degraded lands for eucalyptus plantations to curb further land degradation and promote land rehabilitation.

In addition, 21.6% of respondents reported planting eucalyptus along homestead boundaries and around farmlands. This trend is likely influenced by the small and fragmented nature of landholdings, which encourages boundary expansion under the new land tenure system.

Smaller proportions of eucalyptus growers—8.2% and 2%, respectively—have established plantations along roadsides and within farmland alongside crops. While planting eucalyptus on degraded lands and roadsides is generally encouraged for its environmental and economic benefits, its expansion along farm boundaries and into cropland warrants caution due to potential negative impacts on cereal crop productivity (Table 7).

Farmers adopt diverse planting strategies, including establishing eucalyptus woodlots around homesteads, using degraded or low-productivity lands, planting along roadsides, and integrating it with farm boundaries. These findings are consistent with previous studies by Zerga (2015), Tefera and Kassa (2017), Tesfanesh Ababu Kebede (2021), and Degefu et al. (2023).

Environmental impacts of the *eucalyptus* plantation Expansion

Perceived changes within *eucalyptus* plantation

The study shows that approximately 48.8% of respondents observed a significant reduction in soil erosion in and around eucalyptus plantations, while 42.2% reported a minor decrease (Table 8). Similarly, 24.2% of respondents noted a major decrease in gully formation, and 42.9% observed a minor reduction.

These findings contrast with those of Zerga (2015), who argued that eucalyptus plantations exacerbate soil erosion and contribute to gully formation rather than mitigating it. In stark opposition, the current study reveals that 65.2% of farmers plant eucalyptus trees for environmental conservation purposes, particularly to control soil erosion and reduce gully formation. This highlights a divergence in perspectives, potentially influenced by local environmental conditions or differences in plantation management practices.

Table 8: Perceived changes from expansion of *Eucalyptus* expansion

	Response (%)				
Expected change	**Major decrease**	**Minor decrease**	**No change**	**Minor increase**	**Major increase**
Gully formation	24.2	42.9	17.3	4.3	1.2
Soil Erosion	48.8	42.2	6.8	1.2	1.2
Adverse effect on undergrowth	0	0	8.1	11.8	80.1
Change in presence of birds	0	0	3.7	62.1	34.2
Change in presence of wild animal	0	0	29.2	68.9	1.9
Total	**73**	**85.1**	**65.1**	**148.3**	**118.6**

Source (field survey, 2021)

Although eucalyptus plantations offer significant socio-economic and environmental benefits, they have also sparked some public concerns due to their potential negative impacts. Environmental implications such as effects on the water cycle, soil erosion, nutrient depletion, pest and disease proliferation, biodiversity loss, soil quality degradation, and hydrology disruption have been noted (Alfred, Zaiton, and Norzanalia, 2020).

Interestingly, the survey results indicate that farmers perceive a reduction in soil erosion and gully formation around eucalyptus plantations. This suggests that eucalyptus can play a positive role in controlling soil erosion and mitigating land degradation. However, the effectiveness of well-managed eucalyptus plantations in reducing soil erosion and gully formation depends on several factors, including rainfall intensity, soil quality, slope length and angle, and the presence of ground vegetation and litter cover (Bayle, 2019).

One of the most debated issues surrounding eucalyptus is its negative impact on the undergrowth of other plant species. When eucalyptus is planted on unsuitable sites, replaces existing natural forests, or is poorly managed, it can exacerbate these adverse effects (Dessie, Abtew, and Koye, 2019). Eucalyptus plantations often inhibit the growth of colonizing woody species and nearby crops due to competition for water and nutrients.

Field observations during data collection revealed very low levels of undergrowth in eucalyptus plantation areas. This was corroborated by survey findings, where 80.1% of respondents reported a significant increase in the negative effects of eucalyptus on undergrowth plants (Table 8). These results align with Zerga (2015), who found that undergrowth in eucalyptus plantations is often sparse or entirely absent.

The population of wild animals and birds has increased in the areas designated for eucalyptus plantations. Hence, *Eucalyptus* is used as their habitat, and hiding birds destroying crops and wild animals eating domestic animals. However, regarding biodiversity conservation, an increase in number of birds and wild animals are positive environmental impacts of *Eucalyptus* plantations. Furthermore, certain wildlife species utilize eucalyptus plantations as a habitat. These plantations, particularly those established in treeless areas, provide refuge for wildlife. With appropriate management practices, eucalyptus plantations can serve as a beneficial environment for animals, supporting the creation of the intended habitat (Bayle, 2019). The key informants also reported that the presence of birds and wildlife increased excessively with the expansion of eucalyptus plantations.

Litterfall effect and shading on crops

During data collection, the researcher observed significant shading effects of eucalyptus plantations on nearby cereal crops across all sampled Key Production Areas (KPAs). Focus group discussions revealed that the shade from eucalyptus trees negatively impacts food crops, primarily due to reduced sunlight under the canopy of mature eucalyptus trees.

As a fast-growing species, eucalyptus typically towers over other plants of the same age, casting dense shade that limits the sunlight essential for crop growth. This shading, combined with competition for water, often leads to lower yields in agricultural crops near eucalyptus plantations compared to those farther from the plantation edges (Zegeye, 2010).

Key informants, including agricultural experts, highlighted additional concerns regarding eucalyptus leaves. The leaves release allelopathic chemicals that negatively affect surrounding crops. Allelopathic compounds disrupt vital physiological processes in plants, including changes in cell wall structure, inhibition of cell division, and suppression of enzymatic activities (Singh et al., 2021).

Furthermore, the decomposition of eucalyptus leaf litter suppresses the germination and growth of undergrowth vegetation and cereal crops. During the decomposition process, allelopathic substances are gradually released, impacting receptor plants by inhibiting photosynthesis, reducing environmental adaptability, and ultimately stunting growth. Research by Abdoulaye et al. (2012) confirmed that high doses of eucalyptus litter have depressive effects on the growth and yield of cereal crops.

Figure 4 illustrates the adverse effects of eucalyptus litter on noug (*Guizotia abyssinica*), further highlighting the potential challenges posed by eucalyptus plantations on surrounding agricultural systems.

Figure 4: litter fall effect on Noug *(Guizotia abyssinica)*
Source: (own field photo, 2021)

Farmers' Perceptions of Eucalyptus' Impact on Food Crops

While eucalyptus contributes significantly to the local economy, it is also widely regarded as having negative environmental effects. In the study area, all respondents (100%) acknowledged the environmental drawbacks of eucalyptus plantations. However, the high economic benefits associated with eucalyptus have led farmers to overlook or tolerate these negative impacts.

Respondents unanimously agreed that the expansion of eucalyptus plantations adversely affects crop production, indicating that they possess indigenous knowledge regarding the consequences of eucalyptus on food crops. According to the farmers, cereal crops grown near or under the shade of eucalyptus trees do not yield as well as those grown farther away from the trees.

Nonetheless, some crops seem to be more tolerant of eucalyptus' effects. For example, 35.4% of farmers reported that wheat and barley could withstand the impacts to some extent, while 27.3% noted the same for maize. In contrast, other common crops in the area, such as teff (96.3%), noug (90.7%), and peas and beans (90.7%), were found to be highly susceptible to the negative effects of eucalyptus (Table 9).

Farmers identified several reasons for these detrimental impacts, including the effects of eucalyptus litter fall, shading, and competition for water and nutrients.

Table 9: Response of cereal crops to the effect of eucalyptus

	(%) of respondents				
Response of Cereal Crops	**Teff**	**Maize**	**Wheat and barely**	**Noug**	**pea and bean**
Resisted	3.7	27.3	35.4	9.3	9.3
Susceptible	96.3	72.7	64.6	90.7	90.7
Total	**100**	**100**	**100**	**100**	**100**

Farmers' responses (multiple responses) indicate that eucalyptus trees have three primary effects on crops: competition for moisture (90.7%), competition for nutrients (96.9%), and shading (91.9%) (Table 10). Furthermore, farmers expressed concerns that eucalyptus could potentially dry out nearby natural streams (97%) and affect soil properties by inducing sterility (91.3%) and depleting soil moisture (95%) (Table 10). This observation aligns with the findings of Bayle (2019), who reported that eucalyptus consumes more water than any other tree species or crop. Given these negative effects and the competition with food crops, the expansion of eucalyptus plantations may pose a threat to farmers' future food security.

Table 10: conditions by which *eucalyptus* plantation affects the environments

Impacts of eucalyptus	Types of effect	N	Proportional (%)
Effects on crop	shading effect	148	91.9
	nutrient competition	156	96.9
	moisture competition	146	90.7
Water resource	sucking much water	155	96.3
	no idea	6	3.7
Causing alteration of soil	causing infertility	147	91.3
	changing color	3	1.9
	drying out	153	95.0

The results were supported by different studies, and the adverse effects of E*ucalyptus* on crop production were reported by many researchers (Feyisa, Kissi and Kebebew, 2018), (Liang *et al.*, 2016). Additionally, according to Bayle (2019), eucalyptus consumes more water than any other tree species or crop.

Farmers' Views on Eucalyptus Expansion

The debate surrounding the expansion of eucalyptus plantations and its impact on food security remains complex. In areas where cereal crop production is critical to food security, the income generated from eucalyptus may not be sufficient to replace the loss of crop yields or maintain food security for farmers.

Farmers in the study area expressed concerns about the potential consequences of continued eucalyptus expansion. Approximately 56.5% of respondents warned that if the expansion of eucalyptus plantations continues at the current rate, cereal crop productivity will decline, thereby threatening farmers' food security. Additionally, 14.3% of respondents indicated that the farming structure, which currently combines livestock and cereal crop production, may shift to other forms of agriculture (Table 11).

Some farmers, however, remain optimistic, believing that they can offset the loss in crop revenue by generating income from eucalyptus plantations, and therefore, do not feel that their food security will be compromised.

Table 11: Future views of the farmers on *Eucalyptus* plantation

Future fear of farmers	Number of households	
	Frequency	Percentage (%)
There will be a shortage of cattle feed	20	12.4
Production of cereal crops will be decreased	91	56.5
The Food security situation of farmers will be adversely affected	27	16.8
Livestock-based and cereal crops farming structure will be transformed to other	23	14.3
Total	**161**	**100.0**

Source (field survey, 2021)

Factors Influencing Households' Decision to Establish Eucalyptus Plantations

The model's goodness of fit is assessed using various measures, with the Hosmer-Lemeshow chi-square test indicating a strong fit to the data. The Hosmer-Lemeshow statistic was chi2 = 8.53, and the associated p-value was 0.3835, which suggests that the model fits the data well, as the p-value is not statistically significant.

As shown in Table 12, out of the ten predicted explanatory variables , three variables were found to have a positive and significant impact on the likelihood of a household deciding to establish a eucalyptus plantation. In contrast, four variables had negative and significant effects, while the remaining three variables were found to have no significant influence on the decision to establish eucalyptus woodlots.

The effect of the independent variables on the log odds of planting eucalyptus is reported as odds ratios, alongside their respective parameter estimates. For continuous independent variables, the odds ratios indicate the extent to which the odds of planting eucalyptus increase or decrease with a change in that variable. For categorical variables, the odds ratio reflects the likelihood of choosing to grow eucalyptus if an event occurs (i.e., if the variable equals 1) compared to when the event does not occur (i.e., the variable equals 0). In all cases, it is assumed that the levels of all other independent variables remain constant.

Table 12: Factors influencing the decision of households in the establishment of *Eucalyptus* plantation, the binary logit model regression results**.**

Variables	Coef.	Std. Err.	Z	Odds Ratio	P>z
SEX	3.352	2.557	1.31	28.565	0.19
AGE	-0.346	0.100	-3.46	0.707	0.001***
EDU	0.306	0.841	0.36	1.358	0.716
FAMISIZE	0.644	0.273	2.36	1.904	0.018**
LANDSIZE	4.491	1.332	3.37	89.170	0.001***
LIVSTLU	-0.062	0.111	-0.56	0.940	0.578
DISTROAD	-0.456	0.234	-1.95	0.634	0.051*
FORESTDIST	1.572	0.618	2.54	4.815	0.011**

MARKTDIST	-0.369	0.211	-1.75	0.692	0.081*
CROPINCOM	-0.001	0.000	-2.96	1.000	0.003***
_cons	8.598	4.066	2.11	5422.874	0.034

Number of observations = 161
Hosmer-Lemeshow chi2 (8) = 8.53
Prob > chi2 = 0.3835
Note: ***, ** and* significant at 1%, 5% and 10% probability level respectively

Age of Household Head (AGE): At a significance level of less than 1%, the binary logit model results revealed that the age of farm household heads had a negative and significant effect on the establishment of eucalyptus plantations. The odds ratio and estimated coefficient for this variable were 0.707 and -0.346, respectively. This suggests that holding all other factors constant, the likelihood of farmers planting and allocating land for eucalyptus plantations decreases by a factor of 0.707 for each additional year of age. Younger farmers, with longer planning horizons and lower risk aversion, may be more inclined to invest in long-term assets such as eucalyptus. The age-related findings of the current study are consistent with those of numerous other researchers. Older farmers, who tend to be less adaptable and less inclined to adopt modern agricultural practices, may face age-related barriers to tree planting (Asfaw *et al.*, 2013). However, this conclusion contrasts with previous studies, which have demonstrated that age and farm experience have a positive effect on the number of trees planted on the farm (Gebreegziabher *et al.*, 2020).

Family Size (FAMISIZE): Family size has a positive and significant impact on the likelihood of planting eucalyptus trees. The results revealed that, at the 5% significance level, family size significantly influences the probability of establishing eucalyptus plantations. According to the odds ratio, the likelihood of planting eucalyptus increases by a factor of 1.904 for each additional family member, while holding all other factors constant. This effect may be attributed to the increased need for wood or the greater availability of labor for eucalyptus planting in larger households. Larger families were more likely to engage in eucalyptus cultivation compared to smaller families. In Ethiopia, there has been discussion on how family size positively affects agricultural tree planting by enhancing the availability of labor (Gebreegziabher *et al.*, 2020).

Furthermore, the increased reliance on plantations as family size grows can be attributed to the various benefits trees offer to local communities, including the provision of wood and non-wood products such as fuelwood, building materials, and income from product sales. This is particularly significant when family expenses rise due to larger household sizes, making the cultivation of eucalyptus plantations a valuable resource for meeting growing needs(Woldie and Tadesse, 2019). Additionally, as household sizes increase, tree_planting initiatives provide additional employment opportunities for household members.(Kasahun Gashu & Omer Aminu, 2019; Solomon Ayele and Solomon Mulu, 2017; (Woldie and Tadesse, 2019); Solomon Ayele & Demel Teketay, 2020). In return, the increase in the family size of households results in an increase in the dependencies of local communities on plantations.

Landholding size (LANDSIZE): the size of own landholding had a positive and significant impact on the likelihood of growing eucalyptus. The total land holding of the household displayed statistically significant ($p < 0.01$) and had a positive relationship with farmer decision in planting and land allocation for *Eucalyptus* plantation (Table 12). This variable was statistically significant at a 1% significance level. The positive sign of the coefficient for total landholding implies that an increased land holding increases the plantation of eucalyptus. Keeping other factors constant, the estimated odds ratio shows that increased in total land holding of households by 1 hectare, increases the probability of farmer decision for planting and land allocation of eucalyptus by the odds of 89.17 (Table 12). In general, the results regarding land size indicated that farm households with larger land holdings tended to maintain more eucalyptus trees than those with comparatively smaller land plots.

According to Zeleke Ewnetu (2009), who identified a positive and significant relationship between farm size and tree count, an increase of one hectare in landholding is associated with an addition of 934 trees per household in the Guraghe highlands of Ethiopia. Similar positive effects of farm size on tree planting have been observed in other regions of Ethiopia as well. Similar reports of positive effects of farm size on tree planting were also reported in Ethiopia (Zenebe Gebreegziabher *et al*., 2010; Alemu Mekonnen, 2009; Dereje Jenbere *et al*., 2011; Solomon Ayele & Demel Teketay, 2020)

Distance of accessible road (DISTROAD): the distance of household from the nearest accessible road was associated negatively with the household decision to establish *Eucalyptus* at less than 10 % level of significance level. The model result indicated that the farmers who are far away from nearest road were less likely to establish and allocate the land for eucalyptus plantation. The odds ratio shows that keeping other variables constant, as the distance of households from accessible roads increase by one kilometer, the probability of farmers' decision to plant eucalyptus and allocate land for it decreases by the odds of 0.633. This is most likely attributable to the fact that farm households near a main road facility prefer eucalyptus species since they have a higher market value as fuelwood and building poles. This finding is consistent with the work of Kebede Gizachew (2017), who noted that households located near accessible roadways find it easier to acquire seedlings and sell woodlot products without incurring significant transaction costs. As the distance between households and the nearest access road decreases, individuals are better able to transport eucalyptus wood products—such as poles, building materials, and fuelwood—to market areas(Tadesse and Tafere, 2017).

Distance to the forest (FORESTDIST): The association between distance to the forest and the probability of farmer's decision to plant eucalyptus is positive and significant at a 5% level of significance. This shows that as the forest distance increases by 1 kilometer the probability of farmers' decision to plant eucalyptus increases by the odds of 4.81. This indicates as the farmers get far from natural forest or community plantation, they obligated to plant optional tree species that could meet their wood demand for fuelwood, construction, and others.

Distance to market (MARKTDIST): The model result confirmed that the variable market distance had been associated negatively and significantly with the establishment of eucalyptus by farmers at less ($P<0.1$) significance level, keeping other variables constant (Table 12). The result shows that as the distance from the nearest market increased by 1 kilometer the establishment of eucalyptus approximately decreased by the odds of 0.691 (Table 12). This may be due to the fact that as the distance to the market center increases transportation cost and labor force increases; since eucalyptus products are bulky products supplied to the market. The result is congruent with the finding of Tegegne Derbe, (2018) who indicated that the farmers who have access of market, could sell eucalyptus products at the right time at reasonable price, which positively influence the decision of smallholder farmers to adopt *Eucalyptus* woodlots on their land that allows them to improve their livelihood.

Crop income (CROPINCOM): The association between crop production and farmers decision to plant *Eucalyptus* was negative and statistically significant ($p < 0.01$). As observed from the model result, the odds ratio estimates showed that all other factors were kept constant, with an increment in crop production, the probability of farmers' decision to plant *Eucalyptus* plantation decreased by the odds of 0.99. The possible reason behind this is that farmers covert their farm lands to *Eucalyptus* when the productivity of land starts to decline since they cannot afford to spend agricultural inputs to improve the productivity of the land as well as when the family food security is affected. This finding also parallels with Kebede Gizachew (2017), planting eucalypts is an alternative to households when the productivity of land is getting low and for its low cost to invest but the return is attractive without any fertilizer application. Therefore, the farmers are already begun to change unproductive farmland to *Eucalyptus* plantation as trees demand fewer nutrients and due to economic reasons.

CONCLUSION

Eucalyptus planting in rural areas is increasingly perceived as a safeguard against unexpected economic challenges. In the study area, eucalyptus cultivation has become a common agricultural practice, alongside traditional crops like teff, maize, wheat, barley, noug, peas, and beans. Farmers often convert various land-use types—such as grasslands, croplands, and homesteads—into eucalyptus plantations, driven by the promise of higher returns compared to crop farmingDegraded fields are frequently repurposed for eucalyptus planting as cereal crop yields decline. This rapid expansion of eucalyptus plantations is displacing the production of food crops, thereby threatening the food security of farmers. The primary driver of eucalyptus proliferation is its economic value, particularly in addressing shortages of fuelwood, construction materials, and alleviating financial challenges faced by farmers. Despite the substantial socio-economic and environmental benefits, there have been notable public concerns regarding the expansion of eucalyptus plantations. The negative environmental impacts, including land degradation and reduced food crop production, are becoming increasingly apparent but often receive less attention than the immediate economic gains. Eucalyptus plantations present both positive and negative environmental consequences. While they offer advantages such as rapid carbon sequestration and timber production, they also pose significant risks to local ecosystems, including water depletion, soil degradation, and biodiversity loss. To mitigate these adverse effects, sustainable management practices should be adopted, including careful selection of planting locations, the use of mixed-species plantations, and water conservation strategies.

It is recommended that relevant authorities, particularly the Ministry of Environment, Forest, and Climate Change, support tree growers with proper silvicultural guidance to reduce the negative impacts of eucalyptus cultivation and ensure more sustainable practices in the future.

Competing Interests Statement

The authors declare that they have no competing interests

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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