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NEW CHALLENGES FOR XXI CENTURY CITIES:

Global warming, ageing of population, reduction of energy consumption, immigration flows, optimization of land use, technological innovation

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Farmers decision on land use land cover change from agriculture to forest and factors affecting their decision: the case of Gurage Zone, Central Ethiopia

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Abstract

Land use and land cover change determined by numerous situation specific factors at different locations and times. In Ethiopia inappropriate land uses land cover changes become pressing challenges. Similarly, in the Gurage zone, there is a significant change from agriculture to *Eucalyptus* plantations. Therefore, this study investigates the direct and indirect drivers of the change, as well as factors affecting farmers' decisions regarding the conversion to provide important policy input. The data collected from 311 households through household surveys, key informant interviews (KIIs), and focused group discussions (FGDs). Descriptive statistics and a binary logit model used for analysis. The result indicated that the direct driver for this land conversion included the ability to generate high income from forest, soil infertility, and increasing demand for forest products. On the other hand, the allelopathic effect of neighboring plantations, lack of adequate agricultural technology and increased accessibility to forest products market were the top indirect drivers. The binary logit results show that farmers' decision to convert agricultural lands to forestland is significantly influenced by land size, forest income, education level, and years lived in the area. The findings suggest creating awareness about appropriate land use techniques to sustain the development.

Keywords

Land use dynamics; Drivers; Impact; Forest land; Cropland.

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1. Introduction

The factors influencing land use land cover change are complex and dynamic and vary from one place to another (Li et al., 2018). These changes are primarily driven by natural and human-induced factors (Kleemann et al., 2017; Zengin et al., 2018, Poudel et al., 2023). Globally, the identified reasons for land use conversion are specific to each case and differ across regions due to the unique socioeconomic and biophysical influences present in each area. Munthali et al. (2019) and Kariuki et al. (2020), stated that the main underlying causes of global land cover change are people's responses to economic opportunities influenced by institutional factors, emphasizing that the drivers of land cover change and land use change are specific to each time.

Similarly, the different landforms, agro-ecologies, socio-economic, cultural, and related settings of Ethiopia contribute to a diversified and complex land use land cover change (Kassa et al., 2017; Belayneh et al., 2020; Mengistu, 2024). Most Ethiopians live in rural and marginalized areas and rely entirely on natural resources for subsistence and household income. Ethiopia's land use system has undergone rapid and extensive changes in recent decades due to significant transformations caused by human and environmental interactions (Fasika et al., 2019). Previous studies in Ethiopia mainly focused on land use and land cover change from forest land to agricultural land (Ariti et al., 2015; Tolessa et al., 2020). However, after the expansion of plantations especially rapid Eucalyptus plantation practices, there has been a change from agricultural land to forest land via smallholder and forest enterprises (Jenbere et al., 2012; Kassa et al., 2017).

Among the different parts of Ethiopia that have experienced land use land cover change the Gurage zone is notable for containing 20% of natural forest land in 1930 (Zerga et al., 2021). However, this forest cover has been steadily declining. Since the 1960s, households in the area have been planting *Eucalyptus* trees at a rapid rate due to their fast growth, high economic benefits, and value as a source of forage for bees (honey production) under poor management (Kerbo et al., 2024; Sahle et al, 2018).

Formerly, farmers grew trees on lands not fertile for crop production, along farm borders, and in their home gardens (Desta et al., 2023). However, the conversion of fertile croplands to *Eucalyptus* has become common in various regions of Ethiopia especially in the Gurage zone (Alemayehu et al., 2022; Jenbere et al., 2012; Tefera & Kassa, 2017). This shift is because *Eucalyptus* provides better income for farmers than other alternative livelihoods such as annual agricultural production, livestock raising and other non-agricultural activities (Desta et al, 2023; Kaur & Monga, 2021; Kassie et al., 2017; Tesfaw et al., 2022). It is evident that farmers allocate their land use based on the potential benefits and costs they can derive from it. Although farmlands are crucial for food security throughout the country, many farmers have converted their fertile farms to *Eucalyptus* to diversify their income (Debie, 2024; Kassie et al., 2017; Stratton et al., 2021). Therefore, land use planning and policy development are essential for managing land allocation of different land use types to ensure sustainable development (Briassoulis, 2019; Liu et al., 2018; Salata & Yiannakou, 2016; Xie et al., 2020; Zucaro & Morosini, 2018). Comprehensive research on the drivers of land use dynamics is crucial for understanding the inter-relationships between societies and natural resources in Ethiopia (Ayele et al., 2016; Kamwi et al., 2015; Reid et al., 2000).

The concept of the drivers is focused on economic, technological, policy, and social factors. This classification explains how communities with locally available resources can respond differently to the interaction of variables, manifested as changes in land use. Community responses are not only limited by local resources but are also influenced by external factors that influence economic growth, the state of natural resources, and human well-being in that area.

Therefore, this study aims to:

1) assess direct and indirect drivers of land use land cover change from agriculture to the forest;

2) examine the pressure, state, impacts, and responses of the land use change from agriculture to the forest;

3) explore the factors affecting the decision of farmers to convert their land use from agriculture to the forest.

The results of this study will be fundamental in forming a solid understanding of the land use changes, helping planners, environmentalists, policymakers, and other stakeholders to develop strategies and sound land use management practices to conserve and sustainably use natural resources in Ethiopia.

2. Materials and methods

2.1 Study area

The study area is located in *Gurage* zone which is found in the Southern Nation Nationalities and People Regional State of Ethiopia. It lies between $7^{0}40'$ and $8^{0}30'$ North and $37^{0}30'$ and $38^{0}40'$ East with area coverage of 5,932 km^2. It is bordered by the Oromia Region in the west, north, and east; *Yem* Special District in the southwest; and *Hadiya* zone in the south. *Gumer* and *Cheha* are the districts among thirteen districts of the *Gurage* zone (Fig.1). The area lies at altitudes between 1000 and 3638m above sea level**.** Afro-Alpine (*Wurch*), Temperate (*Dega*), Sub-tropical (*Woina-Dega*), and Tropical (*Kolla*) agroecological zones are found in the Zone. However, *Woina Dega* dominates.

The average temperature varies between 3 °C and 28 °C. The annual range of rainfall varies between 600 and ,1900 mm. *Cheha* and *Gumer* districts were selected for our study due to their dense populations and high coverage of *Eucalyptus* under expansion. Though there have been reported increases in *Eucalyptus* plantations, land use in the Gurage Zone is primarily oriented toward subsistence agriculture, grains and crops like chat (Zerga et al., 2021). The Gurage people are perhaps best known for their heavy dependence on *enset* (*Ensete ventricosum*). Population levels within the Gurage zone reached approximately 1.3 million people according to 2007 Population Census Commission.

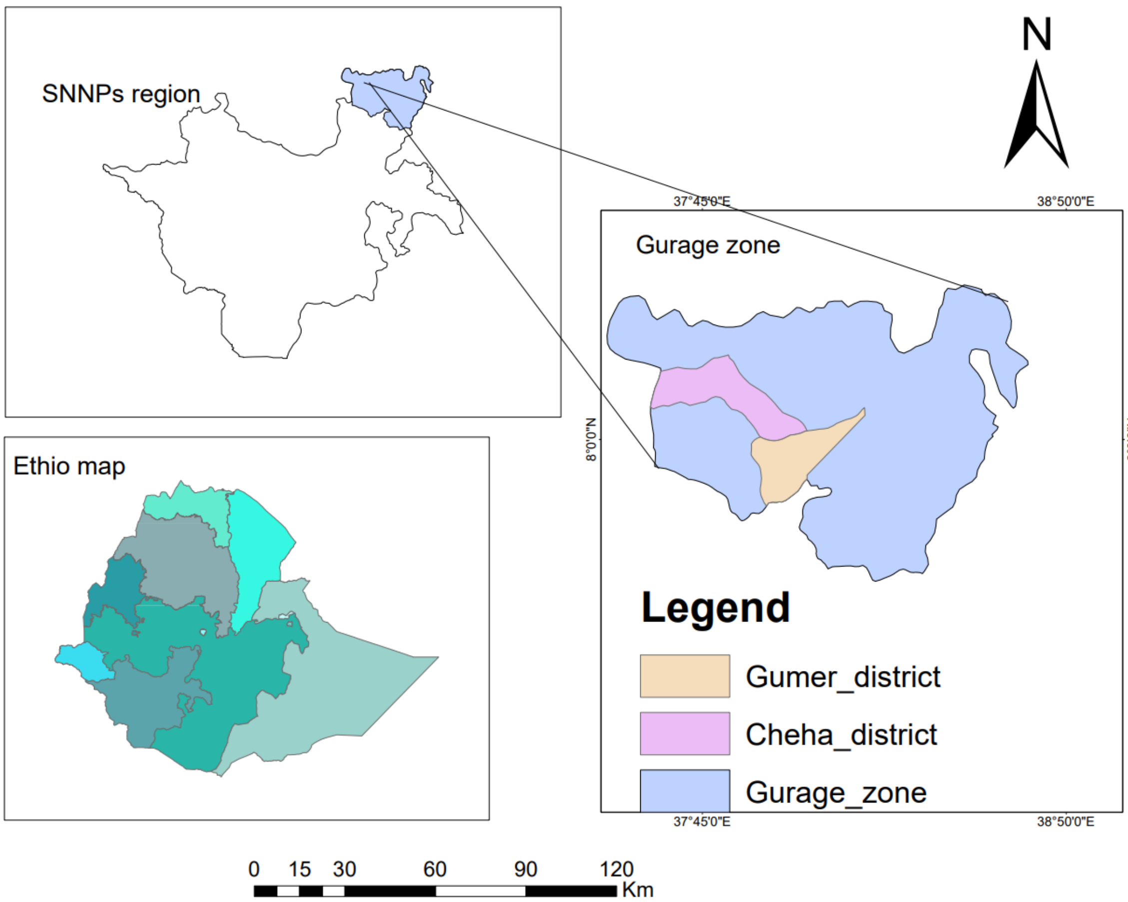

Fig.1 Study area map

2.2 Sampling methods and sample size determination

This study used a multi-stage sampling method. First, two potential districts (*Cheha* and *Gumer*) were selected from the *Gurage* zone based on plantation potential with the consultation of Zonal and *Woreda* (district) agricultural and natural resource offices. In the second stage, two potential *kebeles*[1] were purposively selected per sample district, taking into account the extent of land use change from agriculture to forest. *Degag* and *Worerber* were picked from *Cheha* district and *Bercher* and *Arekitsheleko* were selected from the *Gumer* district. Then, sample farmers were chosen from selected *kebeles* using a simple random sampling technique. The sample size of the two selected districts was determined using the sample size determination formula of Cochran at a 5% precision level cited by Wikidan & Tafesse (2023).

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

$$n = \frac{1640 * (1.96)^2 0.5 * 0.5}{0.05^2(1640-1) + (1.96)^2 * 0.5 * 0.5} \quad n = 311$$

Where: n = Sample size of household heads; P = 0.5, the maximum level of variability taken when previous population variability is unknown; q = 1-0.5. i.e., 0.5; e is the precision level and N=Total population size of the selected villages, obtained from an administrative office of the selected district. The total number of households in the study area was 1640. Therefore, the sample size is 311 households.

2.3 Data collection methods

Semi-structured questionnaires were used to gather information from sampled households in the study area. The questionnaires were administered to respondents 20 years of age and older who had lived in the area for at least 10 years and were the implicit decision-makers in the household. The questionnaires included questions aimed at assessing general information about the respondents, farmers, and the land cover history of the household parcels. Additionally, the farmers' opinions on the drivers, pressures, conditions, impacts, and responses to changes in land cover were requested. Focus groups were also organized using a checklist of questions to guide discussion. The discussion included different groups from the administrative part, community and women. A total of 2 focus group discussions were carried out for each of the selected districts with each focus group consisting of 10 people. Key informant interviews (KIIs) were also conducted to gain an in-depth and detailed understanding of the local people's perceptions of the land use changes that had taken place in the study area and the associated underlying causes perceived to contribute to the changes. The key informants were agricultural and natural resource officers as well as district managers of the study area.

2.4 Data analysis

Before conducting data analysis, data management, data transformation, and diagnostic tests such as multicollinearity and correlation were performed. Both descriptive and econometric models are applied for the analysis of qualitative data. The questionnaire results were complemented with qualitative results gained in FGDs and KIIs. The socioeconomic data derived from the questionnaire were entered, processed, coded in

[1] Kebele is the smallest administration unit in Ethiopia

SPSS, and analyzed using STATA version 17. Descriptive statistical analysis was used to describe the socio-economic variables of the households, summarize the responses and rank drivers of land use change.
The DPSIR model is used to integrate household perceptions of the drivers of land use change. In addition, the ranking of drivers of land use change perceived by the respondents was computed using the principle of weighted average using the ranking index adopted by Solomon et al. (2017).

$$Index = \frac{R_n C_1 + R_{n-1} C_2 \ldots\ldots\ldots + R_n C_1}{\sum R_n C_1 + R_{n-1} C_2 \ldots\ldots\ldots + R_1 C_n} \quad (2)$$

Where R_n = value given for the least-ranked level (for example, if the least rank is the 10th, then $R_n = 10$, R_n-1 = 9, $R_1 = 1$; C_n = counts of the least ranked level (in the above example, the count of the 10th rank = C_n, and the count of the 1st rank = C_1).
The binary logit model is used to examine the factors affecting farmers' decisions to change their land use from agriculture to forestland. The dependent variable, land use change from agriculture to a forest, is a dummy variable and is given 1 for those households that have changed and 0 otherwise. Various demographic and socioeconomic variables were used as independent variables and are summarized in Table 1.
According to Gujarati (2004), the functional form of the logit model is presented as follows:

$$Li = \ln\left(\frac{pi}{1-pi}\right) = Zi = \beta 0 + \beta 1x1 + \beta 2x2 + \beta 3x3 + \beta 4x4 \ldots \beta nxn \quad (3)$$

Were; *pi* = probability of farmer's land conversion ranges from 0 to 1.
L= the natural log of the odds ratio or logit.

$$Zi = \beta 0 + \beta 1x1 + \beta 2x2 + \beta 3x3 + \beta 4x4 \ldots \beta nxn \quad (4)$$

β0 = the intercept. It is the value of the log odds 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

$$Li = \beta 0 + \beta 1\, Xi + Ui.$$

To analyze factors influencing land use change decisions, target farmers were classified into two groups. The first group includes smallholder farmers who have converted their land use from agriculture to forest and others who have not converted their land. Households that change 0.25 hectares or more are considered to change land use and those below 0.25 hectares do not change.

3. Results

3.1 Socio-economic characteristics of households

Among the respondent households, 87% were headed by males and 13% were headed by females. The vast majority (93%) of the respondents were married with only 7% being single. The age of the respondents ranged from 20 to 65 years, with a mean age of 47 years. The average family size of the respondents was 5, with the maximum and minimum family sizes being 11 and 1, respectively. The education status showed that the majority (66.9%) of respondents were illiterate, while only 33.1% were educated. The average number of years that households had lived in their current location was 47.18 years. Respondents owned land with a maximum size of 1.41 hectares and had an average of 2.26 TLU. The maximum forest income gained by the households was 11,000 Ethiopian Birr (ETB) per year. The average distance from the nearest town to their place of residence was about 3.09 km, while the average distance from the nearest forest to their place of residence was 7.03km. The primary income-generating activity in the study area was agricultural production, with an average family income of ETB 39,212.11 per year (Tab.1).

				Number of observations (N=311)			
Variable	**Measurement**	**Description**	**Expected sign**	**Mean**	**Std. dev.**	**Min**	**Max**
Sex (1=Male)	Categorical	1 if the respondent is male, 0 if female	+	0.87	0.34	0	1
Age	Continuous	Respondent age in years	-	50.58	13.86	20	65
Family size	Continuous	Number of persons in the household	-	5.00	2.05	1	11
Education	Categorical	Respondent's educational status	+	0.33	0.47	0	1
Marital status(1=married)	Categorical	1 if the respondent is married, 0 otherwise	–	0.93	0.26	0	1
Years lived in the area	Continuous	Number of years the respondent lived in the area	+	47.18	16.02	10	60
Total land holding size	Continuous	Landholding size in hectares	+	1.41	0.96	0.09	10
TLU	Continuous	Livestock holding in tropical livestock unit (TLU)	-	2.26	1.71	0	10.5
Forest related income	Continuous	Amount of income in birr	+	1,071.70	2,099.58	0	11,000
Distance to town	Continuous	Distance traveled to a town in km.	-	3.09	6.72	0	30
	Continuous	Distance traveled to the forest in km.	+				
Distance to the nearest forest	Continuous	Total crop value in birr	-	7.03	10.10	0.05	75
Total crop value	Categorical	1 if the respondent is male, 0 if female	+	39,212.11	59,080.16	0	412,500

Tab.1 Summary statistics of socioeconomic variables and hypothesis

For the first analysis of the relationship between dependent Variables (decisions to change land use land cover) and socioeconomic Variables (sex, educational status, holding size, educational status, years lived in the area, TLU and forest related income) correlation analysis was applied before modeling continued. Those major socioeconomic variables were analyzed to determine the relationship with decision to land use land cover change or not. According to Belete et al. (2023) before conducting modeling analysis, Pearson correlation analysis can be used to explain the correlation between the dependent variable and the independent variables. Similarly, the Pearson correlation coefficient indicates positive and negative correlations. A positive correlation indicates that the dependent variable increases with the value of the independent socioeconomic variable, while a negative correlation indicates that the dependent variable increases with the value of the independent socioeconomic variable decreases as the value increases the values of socioeconomic independent variables that are the main causes which push for land use land cover change decision. Independents variables (i.e., Sex, Educational status, Total land holding size, Forest related income) have positive Pearson correlations with the drivers of land use land cover change; this means that when these independent variables increase, the decision to change land use and land cover from agriculture to forest also increase. However, when the independent variable of education status is negatively correlated with Livestock holding (TLU) and the number of educated population increases, the land use land cover change decision increase, while the status of livestock holding increases, the driving forces of land use and land use dynamics decline. Number one (1) correlation shows that the value of one variable can be accurately determined by knowing the value of the other variable, which is a perfect correlation (Tab.2).

		ISRSEV dlulcc	**Sex**	**Educational status**	**years lived in the study area**	**TLU**	**land holding size**	**Forest related income**
Is there a relationship between Sev and decisions in land use land cover change	Pearson correlation	1.000						
Sex	Pearson correlation	0.069	1.000					
Educational status	Pearson correlation	0.191	0.0569	1.000				
Years lived in the area	Pearson correlation	-0.170	0.0897	-0.3185	1.000			
TLU	Pearson correlation	-0.081	0.033*	-0.006**	0.111	1.000		
Total land holding size	Pearson correlation	0.310	0.086	0.053	-0.012**	0.0913	1.000	
Forest related income	Pearson correlation	0.177	-0.042*	-0.0484	0.247	0.232	0.1387	1.000

*Correlation is significant at the 0.05 level **Correlation is significant at the 0.01 level.ISRSEVdlulcc =is there a relationship between socioeconomic variables and decisions in land use land cover change. Sev =socioeconomic variables

Tab.2 Correlation coefficient values between socioeconomic variables and decisions in land use land cover change

More than half (74.6%) of respondents own the land through inheritance from their parents. Another 11.9% received it from local leaders. However, 8.68% of them own land as a gift, while the remaining 3.2% of respondents acquired the land through other means, such as being given by the local government, buying and donating, both inheriting and being given by the government, or both buying and inheriting (see Tab.3).

Ways of land acquisition	**Frequency**	**Percent**
Bought	5	1.61
Inherited	232	74.60
Donation	27	8.68
Given by the local leader	37	11.90
Others	10	3.2
Total	311	100.00

Tab.3 Means of land acquisition in the study area

The main crops in the study area are barley, wheat, *enset* (*Ensete ventricosum*), and maize (Zea mays), as confirmed by the respondents. The mean annual income obtained from barely is 11,090.84 ETB and 1,1024.76, 8,070.09, and 2,384.44 birr per year, respectively (Tab.4).

Crop type	**Number of observations (N= 311)**	
	Mean value in birr	**Std. dev.**
Maize	2,384.44	7,510.34
Wheat	11,024.76	35,094.55
Barley	11,090.84	13,658.42
Enset	8,070.09	14,929.56
Potato	1,901.22	3,416.13
Bean	2,543.01	6,467.02
Apple	3,426.05	17,082.34

Tab.4 Total crop production and its value the households received per year

Households in the study area also derived income from alternative sources other than crop production. These sources included full-time employment in the public sector, selling forest products, selling charcoal, remittances, and harvesting edible wild fruits. Remittances were the main alternative source of income for households, with a mean of ETB 5,630 per year, followed by non-farm businesses' income mean of 4,228.33 birrs (Tab.5).

Types of alternative income sources	**Number of observations (N=311)**	
	Mean	**Std. Deviation**
Full time government employment	2,856.71	1,965.17
Selling forest product	2,800.96	2,356.19
Charcoal	3,871.43	3,745.98
Non-Farm business	4,228.33	3,331.38
Remittance in Birr	5,630.00	3,604.33
Wild edible fruit	618.52	591.43

Tab.5 Annual income derived from alternative income sources of households in the study area

3.2 Perception of households for the status of crop production and forest cover change in the study area

According to the majority (75.3%) of respondents, crop yields have decreased over the past 10 years. More than half (64.21%) of households confirmed the decline in land allocation for crop production due to the loss of soil fertility, which is mainly affected by the allelopathic effect of neighboring plantations. Regarding the status of forest cover change, KIIs indicated that the forest cover change had increased over the past 10 years in the study area. Furthermore, the majority (89.47%) of respondent households perceived an increasing rate of afforestation in the area (Fig.2).

The perceptions of households in the study area indicate that the primary reason for the decline in crop yields was unreliable rainfall (35.4%), followed by repeated cultivation due to limited area, soil infertility, high cost of agricultural inputs and the emergence of new pest diseases 26.4 %, 15.2%, 11.9% and 10.8% respectively (Tab.6). The cost of fertilizers has become too high and the arable land cannot receive enough of it, leading to decreased yields in the study area.

The farmland in the study area was increasingly becoming unsuitable for crop production, a concern identified by key informants, discussants, and households. In response to this issue, farmers attempted various actions to meet their subsistence needs and increase their cash income. The majority of respondents (36.6%) reported trying to enhance fertility to boost crop yields, followed by fallowing (34.5%), seeking additional land (17.2%), and transitioning to plantation farming (8%) in the study area (Fig.3).

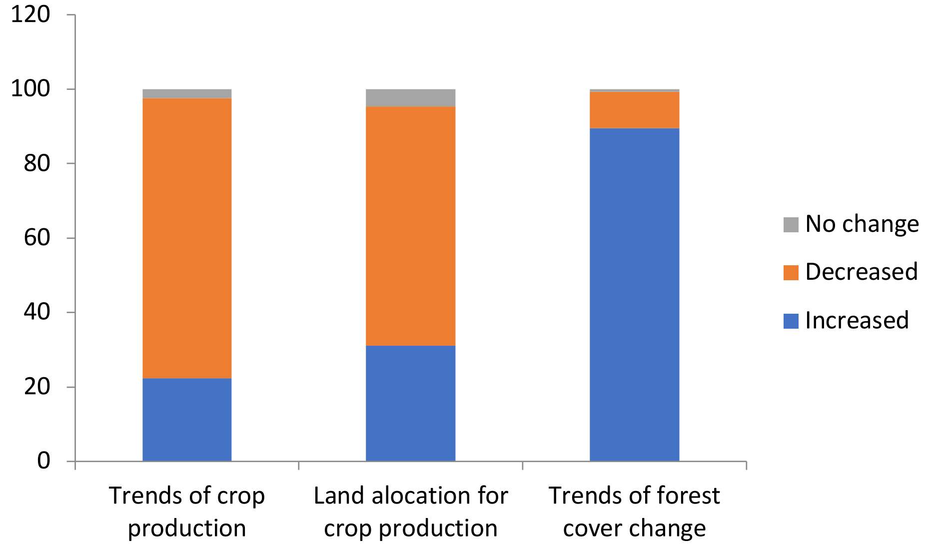

Fig.2 Trends of crop production, land allocation for crop production, and trends of forest cover change

Cause of crop production change	Frequency	%	Proportion (%)
Unreliable rainfall	98	28.0	35.4
Repeated farming due to limited land	73	20.9	26.4
Soil infertility	42	12.0	15.2
High cost of agricultural input	33	9.4	11.9
Occurrence of new pests and disease	30	8.6	10.8
Shortage of agricultural input	27	7.7	9.7
Lack of knowledge	22	6.3	7.9
Lack of improved seed quality	17	4.9	6.1
Inadequate labor	8	2.3	2.9

Tab.6 Cause of crop yield reduction as households' perception in the study area

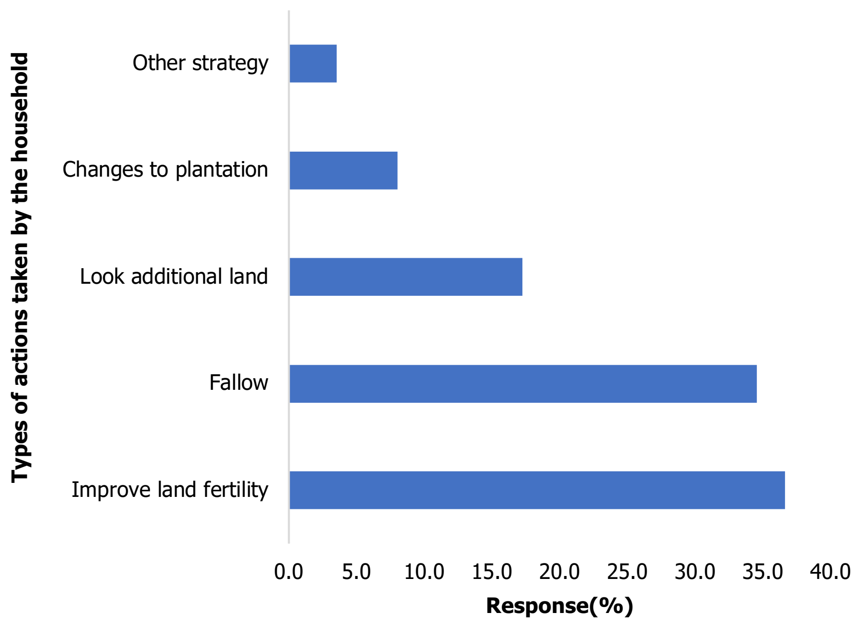

Fig.3 Households' action in response to crop yield reduction

3.3 Drivers of land use land cover change from agriculture to forest

The drivers of land cover change from farmland to forestland were ranked and presented in Tab.7. According to the respondents' responses, the top five causes of cropland changing to forest land were identified as income-generating activities from trees, declining soil fertility, increasing demand for forest products, extreme weather events, and the absence of natural forests in the area (Tab.7).

Key informants and participants in the focus group discussions also noted that the increasing demand for wood products, both for wood fuel and construction materials, has led to a rise in prices. This has motivated farmers to convert their productive agricultural plots to *Eucalyptus.*

Variables	**Weighted frequency**					**Index**	**Rank**
	1	**2**	**3**	**4**	**5**		
Use of the tree for income generation	191	55	28	4	11	0.13	1
Decline soil fertility	156	49	30	29	18	0.12	2
Increasing demand for forest products	156	59	18	17	37	0.12	3
Extreme weather events	118	51	29	15	44	0.10	4
No natural forest	93	41	42	31	55	0.09	5
Education and Awareness	76	55	39	46	56	0.09	6
Fragmentation of farmland	77	37	53	42	42	0.09	7
Expected future return	68	50	46	30	56	0.08	8
Biological property of species	64	51	53	20	48	0.08	9
Labor intensity	76	30	35	32	66	0.08	10
Others	24	7	4	29	29	0.03	11

Tab.7 Proximate causes of land use land cover change from agriculture to the forest

Furthermore, the increasing price of wood-based products, high agricultural input costs, the allelopathic effect of neighboring farmer plantations, lack of motivation for other agricultural practices, lack of adequate technology to improve agricultural practices, increased market accessibility, and unemployment were the top-ranked underlying causes for the conversion from agriculture to the forest (Tab.8).

Indirect drivers	**Weighted frequency**					**Index**	**Rank**
	1	**2**	**3**	**4**	**5**		
The increasing price of wood-based products	147	52	26	14	14	0.13	1
High cost of agricultural input	143	49	24	16	33	0.12	2
Externality	90	42	71	29	37	0.11	3
Lack of motivation to agriculture practice	85	73	37	23	49	0.11	4
Lack of adequate technology for agriculture	109	40	33	36	34	0.11	5
Increased accessibility of the market	90	50	50	17	40	0.10	6
Unemployment	129	18	10	31	63	0.10	7
Presence of soil and land degradation	70	52	51	21	76	0.10	8
Social demographic change	83	47	40	17	39	0.09	9
Others	27	11	5	27	7	0.03	10

Tab.8 Indirect drivers of land use land cover change from agriculture to forest

3.4 Pressures exerted, states, impacts, and response due to land cover change from agriculture to the forest in the study area

Pressures resulting from the change in land cover from agriculture to forest included decreased crop production (82.7%), a lack of crop residue for livestock feed (65.1%), over-grazing of land (64.2%), food insecurity (63.3%), and changes in soil moisture (59.4%) as reported by household farmers (Fig.4). The study by Meshesha et al. (2014) found that the conversion of cropland to forest leads to overgrazing due to scarcity of crop residues for livestock fodder.

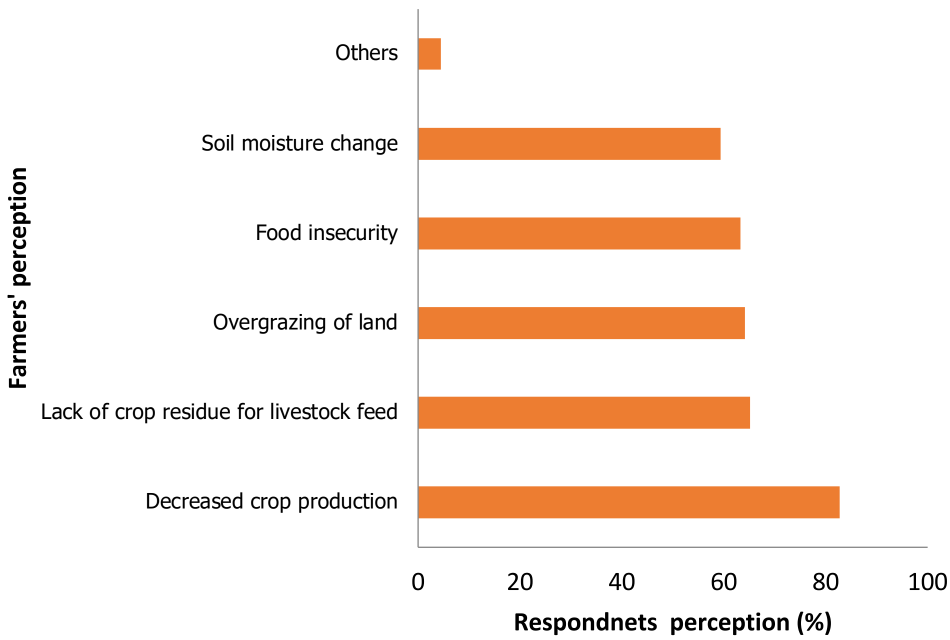

Fig.4 Farmers' perception of pressures exerted due to land cover change from agriculture to forest

In the study area, current observations show that land cover change from agriculture to forest by household farmers has led to increased land fragmentation as confirmed by the majority of respondents (70.1%). This change has also resulted in reduction of grazing land (64.5%), reducing land for agriculture (63.3%), improving biodiversity (53.4%), change of landscape (49.6%), improved soil fertility (42.4%), and (31.3%) of them reported as water quality improvement in case of plantation expansion (Tab.9).

State	Frequency	Proportion (%)
Reduced land for agriculture or increased forest cover	213	63.0
Increased land fragmentation	235	70.1
Reduced land for grazing	216	64.5
Soil fertility improved	142	42.4
Biodiversity improved	129	53.4
Water quality improved	105	31.3
Change of landscape	166	49.6
Other	11	3.3

Tab.9 State/ conditions existed due to land cover change from agriculture to forest farmers' perceptions. The total number of cases was 311 due to multiple-response questions multiple counts are possible

In the study area, the main impacts reported by household farmers were a reduction of fodder for animals (75.5%), scarcity of land for agriculture (73.4%), an increase of rural to urban migration (69.3%), a reduction of crop production (68.7%) and (58.2%) of respondents perceived that difficulty to revert plantation land to agricultural land were the major impacts of land conversion from agriculture to the forest (Fig.5).

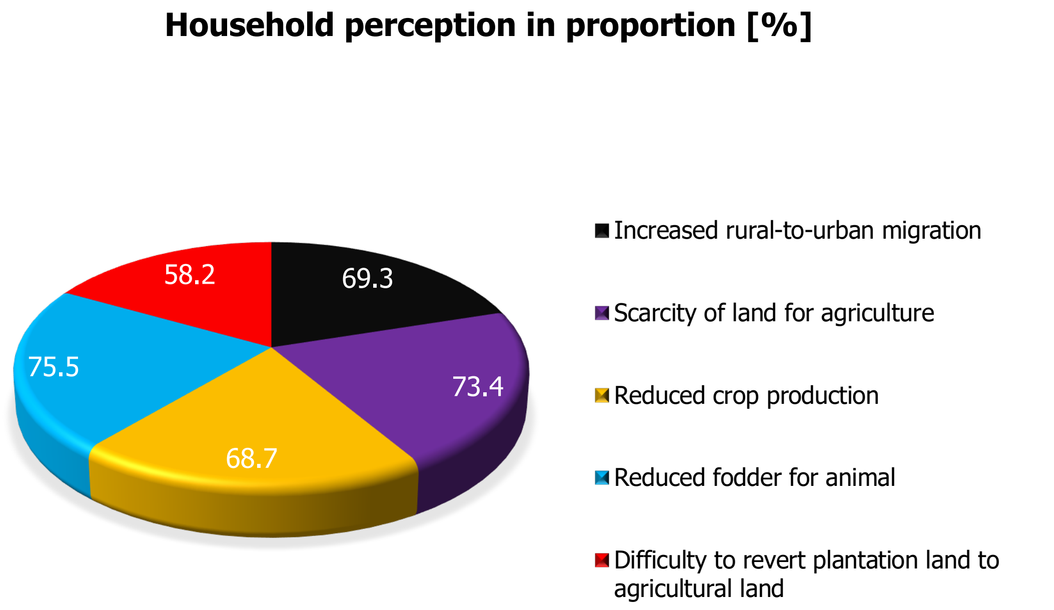

Fig.5 Impacts of land cover change from agriculture to the forest in the study area

The actions taken by households and stakeholders in response to the impacts of land cover changes were as follows; planting multipurpose trees (71%), implementing appropriate land use planning (69.3%), raising farmers' awareness of sustainable land management (66.9%), promoting sustainable agricultural intensification (64.8%), developing specific policies (60%), enforcing existing forest laws and regulations (56.7%), diversifying livelihood activities (47.8%) and utilizing renewable energies (43.3%) (Tab.10).

Responses	**Frequency**	**Proportion (%)**[2]
Planting multipurpose trees	238	71.0
Implementing appropriate land use planning	232	69.3
Raising awareness of farmers in land management	224	66.9
Diversification of livelihood activities	160	47.8
Sustainable agricultural intensification	217	64.8
Developing specific policies	203	60.6
Enforcement of the existing forest laws and regulations	190	56.7
Use of renewable energy	145	43.3
Others	33	9.9

Tab.10 Perception of farmers towards land use land cover change from agriculture to forest

Based on households' responses on their perception of various factors related to the conversion of agricultural land to forest land, the DSPIR model was developed. All the responses received from household farmers during

[2] The total number of cases was 311 and due to a multiple-response question, multiple counts are possible

household surveys and also the idea mentioned by the focus group discussants and key informants were included (Fig.6).

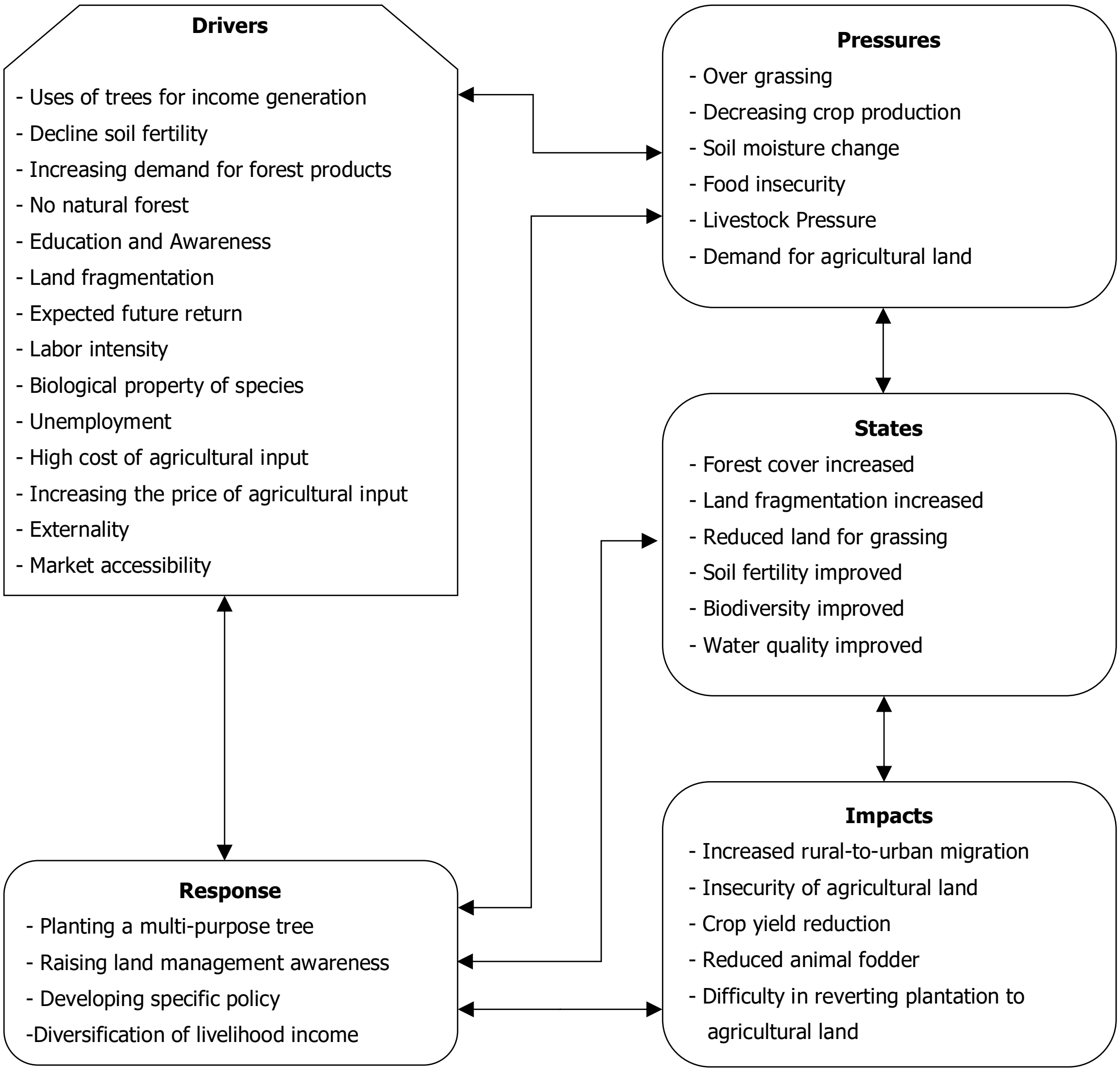

Fig.6 Driver, state, pressure, impact and response model

4.5 Factors affecting farmers' decisions to convert agricultural land to forest

The results of the logistic regression analysis regarding factors influencing farmers' decisions to convert their agricultural lands to forest land are presented in Tab.11. The total land holding size of farmers and their forest-related income have a significant and positive effect on their decision at a 1% level of significance. The number of years lived in the area and the tropical livestock unit (TLU) had a negative and significant influence on households' decisions to convert their farmland to forest land at a 5% level of significance. Furthermore, educational status and livestock holding had a significant and positive effect on farmers' decisions to convert their agricultural lands to forestland at a 5% level of significance. The result suggests that with each additional year of educated farmers, the likelihood of cropland being converted to forest land increases by 1.9%, assuming all other factors remain constant.

The positive and significant effect of farmers' land holding size on the conversion of cropland to forest indicates that land size is crucial in allocating land for different functions.

Number of obs = 311
LR chi2(12) = 67.00
Prob > chi2 = 0.0000
Pseudo R2 = 0.174
Log-likelihood = -158.34358

Parameters	Coefficient	Std. err.	Z	P>z	Marginal effect
Sex	0.608	0.464	1.31	0.190	0.107
Age	0.010	0.020	0.52	0.604	0.002
Family size	-0.070	0.075	-0.94	0.347	-0.014
Education status	0..632	0.322	1.90	0.057**	0.13
Marital status	-0.265	0.562	-0.47	0.637	-0.055
Years lived in the area	-0.034	0.017	-2.01	0.044**	-0.007
Total landholding size	0.686	0.168	4.08	0.000***	0.135
TLU	-0.195	0.091	-2.14	0.032**	-0.038
Forest related income	0.000	0.000	3.76	0.000***	0.000
Distance residence town	0.013	0.022	0.56	0.575	0.002
Distance nearest forest	0.006	0.014	0.45	0.653	0.001
Total crop value	0.000	0.000	0.43	0.666	0.000
_Cons	-1.116	0.903	-1.24	0.216	-

*** and ** indicates 1% and 5% levels of significance, respectively

Tab.11 Factors influencing farmers' decisions to convert agricultural land to forest

The result also showed that forest-related income correlated positively and significantly with farmers' decision to convert cropland to forest. This implies that if farmers gained more income from forests, the probability of their decision to convert agricultural land to forest increased to optimize their economy and cover their livelihood expenditures as well. The tropical livestock unit has a negative relation with the conversion of cropland to forest and shows a significant association.

4. Discussions

4.1 Perception of households for the status of crop production and forest cover change

The qualitative findings revealed that the trends of land allocation for crop production declined over the past 10 years in the study area. The households perceived that the crop yield had a declining trend. The major reasons for the decline in crop yields were unreliable rainfall, repeated cultivation due to limited land, soil infertility, high cost of agricultural inputs, and the emergence of new pest diseases. The cost of fertilizers has become too high and the arable land cannot receive enough of it, leading to decreased yields in the study area (Alebachew et al., 2015; Bizimana & Hategekimana, 2024). Similar results from a study by Ngoune and Mutengwa (2019) showed that the main constraints on agricultural yields are inadequate rainfall, declining soil fertility (Liliane et al., 2020), and biotic factors such as diseases and pests. Therefore, there is a declined land allocation for crop production in the study area. A similar study by Molla et al. (2023) and Worku et al. (2021) revealed that crop yields declined over time due to soil degradation. On the other hand, the forest cover became increased over time due to a rapid expansion of *Eucalyptus* plantations. The probable reason behind this is the households' ability to drive maximum income from forest products, they are going to convert the crop land to forest. This result is in line with Molla et al. (2023), which indicate a dramatic increase in plantation forests, especially *Eucalyptus* plantations, at the expense of fertile land due to farmers' anticipation of a better income source, and the manageable cost of production. A similar result was also revealed in the study by Phimmavong et al. (2019), indicating an increasing trend of forest cover associated with the rapid expansion of *Eucalyptus* plantations. Another study in Gozamin district of Ethioia (Gedefaw et al., 2020) shown that households are planting eucalyptus trees around homestead and farmland to get cash income.

4.2 Drivers of land use land cover change from agriculture to forest

The result of the study indicated that the to five direct drivers of cropland changing to forest land were the ability to generate maximum income from trees, declining soil fertility, increasing demand for forest products, extreme weather events, and the absence of natural forests in the area. This result aligns with the studies by Derbe et al. (2018), Worku et al. (2021), and Desta et al. (2023) which emphasized the economic potential of converting cropland to plantation forest for better return. Similarly, a study by Molla et al. (2023) in the northwestern highlands of Ethiopia found that the higher price of forest products compared to crops was the main factor driving farmers to plantations for increased income. This is also supported by a study in the *Tigray* region of Ethiopia, which highlighted that households chose to plant *Eucalyptus* trees due to its their low-cost requirements and ability to yield high returns when planted on croplands (Jagger & Pender, 2003). Furthermore, the farmers were motivated to convert their productive cropland to *Eucalyptus* plantations due to the increasing prices and the increasing demand for wood products, both for wood fuel and construction materials (Biziman et al., 2024). A similar finding was reported by Tefera & Kassa (2017) and Derbe et al. (2018).

Moreover, the increasing price of wood-based products, high agricultural input costs, the allelopathic effect of neighboring farmer plantations, lack of motivation for other agricultural practices, lack of adequate technology to improve agricultural practices, and increased market accessibility were the top-ranked indirect drivers for the conversion from agriculture to the forest based on the respondents' perceptions. This finding was consistent with the finding of Alebachew et al. (2015), Kidanu et al. (2005) and Worku et al. (2021), who found that the farmers converted to forests due to the rising prices of forest products and their income-generating potential. This result is also supported by the study of Tadesse et al. (2019) which showed that farmers convert their farmland to plantations when the land becomes unproductive for crop production and fertilizer prices increase.

4.3 Pressures exerted, states, impacts, and response due to land cover change from agriculture to the forest in the study area

The study findings revealed that the pressures, states, and impacts existed due to the land use land cover change from agriculture to forest. Based on the respondents' perception the pressure resulting from this land use change included decreased crop production, a lack of crop residue for livestock feed, over-grazing of land, food insecurity, and changes in soil moisture. The study by Meshesha et al. (2014) found a similar result that the conversion of cropland to forest leads to overgrazing due to scarcity of crop residues for livestock fodder. This conversion also leads to different states observed in the area like land fragmentation, reduction of grazing land, improving biodiversity, reduction of land for agriculture, change of landscape, and improved soil fertility (Liang & Zhang, 2024; Woldegebriel & Girma, 2023). Furthermore, the study findings of Lai et al. (2021) stated that forest areas are associated with low flood and landslide hazard which contributes for enhanced soil fertility. Likewise, the main impacts reported by household farmers were a reduction of fodder for animals, scarcity of land for agriculture, an increase of rural to urban migration, and a reduction of crop production, difficulty in reverting plantation land to agricultural land as respondents' perceptions. A similar result was revealed in a study by Gedefaw et.al., (2020) which indicated the high conversion of agricultural land to forest land in the *Gozamin* district, and identified that rural-to-urban migration, a decline in the fertility of land, and food insecurity were the major consequences of converting agricultural land use. Furthermore, the informants confirmed that land use land cover changes affected local communities' economic activities. Similarly, its social impact including changes in employment and agricultural production, equity, relocations of populations were reported by Francini et al. (2021).

According to the residents' perception, responses to revert and mitigate those impacts as well as the actions that should be taken by the government bodies and respected stakeholders were planting multipurpose trees, implementing appropriate land use planning, raising farmers' awareness of sustainable land management, promoting sustainable agricultural intensification, developing specific policies, enforcing existing forest laws and regulations, and diversifying livelihood activities.

4.4 Factors affecting farmers' decisions to convert agricultural land to forest

The farmers decide to convert their agricultural land to forest due to different socioeconomic factors as shown in the results of the logistic regression analysis. The total land holding size of farmers and their forest-related income had a highly significant and positive effect on their decision, which means when their land size and income from forest increased they made a strong decision to convert. This finding contradicts the study by Mulu et al. (2022) which revealed that total land holding size was significantly and negatively correlated with farmers' decisions on land use for plantations in *Guna Begemidir* District. This discrepancy is likely because decision-making regarding land use change is highly context-dependent. The number of years lived in the area and the tropical livestock unit (TLU) had a negative and significant influence on households' decisions to convert their farmland to forest land.

Furthermore, educational status and livestock holding had a significant and positive effect on farmers' decisions to convert their agricultural lands to forestland. Similarly, studies by Bekere et al. (2023) and Hailu et al. (2020) have shown that education plays a significant role in land use and land cover change. The educated individual has the opportunity to work in sectors beyond agriculture, leading them often to convert their agricultural lands into forest land. This is why education status has a positive effect on farmers' decision-making. This finding aligns with previous studies (Tsani et al., 2018) which found that a farmer's education is linked to the conversion of agricultural land to forest land. The result suggests that with each additional year of education of farmers, the likelihood of cropland being converted to forest land increases by 1.9%, assuming all other factors remain constant.

The positive and significant effect of farmers' land holding size on the conversion of cropland to forest indicates that land size is crucial in allocating land for different functions (Fei et al., 2021). However, this conclusion contradicts the findings of Tsani et al. (2018), who found that land-holding size does not influence the decision regarding agricultural land to forest conversion. The results show that farmers have an opportunity to convert some cropland into forest to meet their cash income needs (Zhang et al., 2018). Therefore, if their land size increases by one hectare, the probability of converting agricultural land to forest increases by 13.5%. On the contrary, the number of years lived in the area is negatively and significantly associated with the decision of farmers to convert their land from agriculture to forest. This indicated that as farmer lives in the area for an additional year, the probability of converting their land from agriculture to forest decreases by 0.7%. The probable reason for this could be farmers live more years in the area, they become more stable in their land tenure and therefore prefer to produce crops rather than convert to forest.

The result also showed that forest-related income correlated positively and significantly with farmers' decision to convert cropland to forest. This implies that if farmers gained more income from forests, the probability of their decision to convert agricultural land to forest increased to optimize their economy and cover their livelihood expenditures as well. The tropical livestock unit has a negative relation with the conversion of cropland to forest and shows a significant association. This means that if there is an increasing number of livestock in households their decision may be influenced to remain low due to the demand for fodder for their livestock (Hettig & Sipangule, 2016). This pushes them to prefer crop production as they can obtain more crop residuals for their livestock feed.

5. Conclusions

The *Gumer* and *Cheha* districts of the *Gurage* zone have been experiencing land use conversion for various reasons. The main finding of this study revealed that the use of trees for generating income was identified as a key direct driver of land cover change from agriculture to forest. Declining soil fertility, increasing demand for forest products, extreme weather events, and the absence of natural forests in the area were also identified as the top major causes for cropland changing to forest land. Similarly, the results show that the increasing price of wood-based products, high cost of agricultural inputs, allopathic effect, lack of motivation to other agricultural practices, lack of adequate technology to improve agricultural practices, lack of adequate technology for agriculture, increased accessibility to markets and unemployment were the top-ranked underlying causes of land conversion. The current major issues that exist due to land conversion from agriculture to the forest were an increase in land fragmentation followed by reduced land for grazing, reduced land for agriculture, and improved biodiversity as identified by respondent households.

The results further indicated that changes in land use land cover change affected households' livelihoods by reducing animal fodder, causing a scarcity of land for agriculture, increasing rural-to-urban migration, reducing crop production, and making it difficult to convert plantation land to back agricultural land. Farmers have implemented various remedies to mitigate the impact of land use land cover changes such as planting multipurpose trees, implementing appropriate land use planning, raising awareness among farmers about land management, promoting sustainable agricultural intensification, and developing local practices like planting *Eucalyptus* trees 100m away from cropland to avoid its allopathic effect on crop production. The results of the binary logit model showed that land ownership and forest-related income were significant factors influencing farmers' decisions to convert their agricultural land to forest land, while the number of years lived in the area and the TLU had a negative and significant influence. Based on the result of this study, it is recommended to raise farmers' awareness of appropriate land use techniques as well as soil and water conservation measures to enable them to effectively manage the land and balance the increasing rate of cropland conversion to forest land in the study area.

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