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Driving Forces of Farmers' Decision towards Monoculture of Eucalyptus Plantation and its Trends in North Mecha District, North-West, Ethiopia

[*1]Melsew Nibret Mazengiya, [2]Assefa Abelieneh Berhanu and [3]Girmachew Seraw Misganaw

[*1]Instructor in the University, Department of Rural Development and Agricultural Extension, College of Agriculture and Natural Resource, Mekdela Amba University, Tuluawilya City, Ethiopia.

[2, 3]Assistant Professor, Department of Rural Development and Agricultural Extension, College of Agriculture and Environmental Sciences, Bahir Dar University, Bahir Dar City, Ethiopia.

Abstract

Eucalyptus is the most commonly grown tree species at farm level of rural households in Ethiopia. Despite its importance in the study area eucalyptus is expanding by expensing crop land with its alleged ecological effects. Likewise, there was no sufficient information about extent of eucalyptus growing and the driving forces of farmers' decision to plant eucalyptus. Therefore, the objective was to analyze the trends of eucalyptus growing and identify the driving forces of farmers' decisions towards eucalyptus growing. A multi-stage sampling technique was employed reaching from household survey to remote sensing data processing. The collected data was analyzed through the GIS software package. The remote sensing result confirmed the rapid increment of eucalyptus plantation in the study area while cropland declined. The remote sensed information verified that eucalyptus plantation expanded from 3864ha to 6491ha in the years 2000 and 2019 respectively. While cropland declined from 5027.9ha to 3541ha. The major drivers of farmers to decide from diversified agriculture to monoculture of eucalyptus plantation were; competition from neighboring eucalyptus growers, demand for low labor, the high price of agricultural inputs, the low selling price of crop products, low risk, disease and pest and rising current market demand on domestic and export (Ethio-Sudan) on eucalyptus. The study concludes that due to the existence of the above driving forces, the farmers' plantation expansion continues. Therefore, it is recommended that the ministry of agriculture shall work on awareness creation about its side effect and the introduction of highly productive and market value agricultural technology.

Keywords: Driving forces, monoculture, north Mecha district, remote sensing

1. Introduction

Farm forestry is the incorporation of trees into agricultural systems through private initiatives, such as planting, regeneration, or conservation forestry, either as part of a crop production system or as a planned succession of field cropping systems by trees (EFAP, 1991; Tenaw, 2007). Since Ethiopia is the birthplace and epicentre of diversification, farmers are looking for new ways to make a living. So, the current practice is showing farmers are shifting to the monoculture of eucalyptus plantation than a practice which is diversified agriculture in many parts of Ethiopia. Empirical pieces of evidence identified the reason that drives farmers' decision from diversified agricultural practice to monoculture of eucalyptus plantation as technical, biotic, abiotic, socio-economic and institutional drivers (Saraswati *et al.* 2011) [9].

Ethiopia is the largest growing eucalyptus country in East Africa. The planting of enormous areas of eucalyptus has caused heated debates, and today there are two camps of opinion: advantages (as economists see it) and disadvantages (as ecologists see it) (Dereje, 2009) [5]. Despite the ongoing disagreement among scientists, Ethiopian farmers have continued to plant eucalyptus on their farmlands, homesteads, grazing fields, and other suitable spaces in various parts of the country (Zenebe, 2007) [13].

Likewise, farmers in north *Mecha* district, where the present study was carried out, have been expanding eucalyptus plantation as a major tree species on their irrigated fertile lands and grazing lands are converted to this plantation. Eco-friendly trees, which add soil fertility, are not planted in and around the crop fields of the farmers. Regardless of the above facts, the eucalyptus is extremely expanded in the study area and neither from the NGO, research centre nor have government development policies given attention to the expansion of the eucalyptus in the study area (NMDARDO, 2020) [8]. This practice is ongoing, in Amhara region in general and the study area in particular in rural areas nearer to the town.

In this regard, there is little research conducted about the trends of eucalyptus in the study area. Hence, this lack of empirical data leads to mismanagement and practices of

***Corresponding Author:** Melsew Nibret Mazengiya

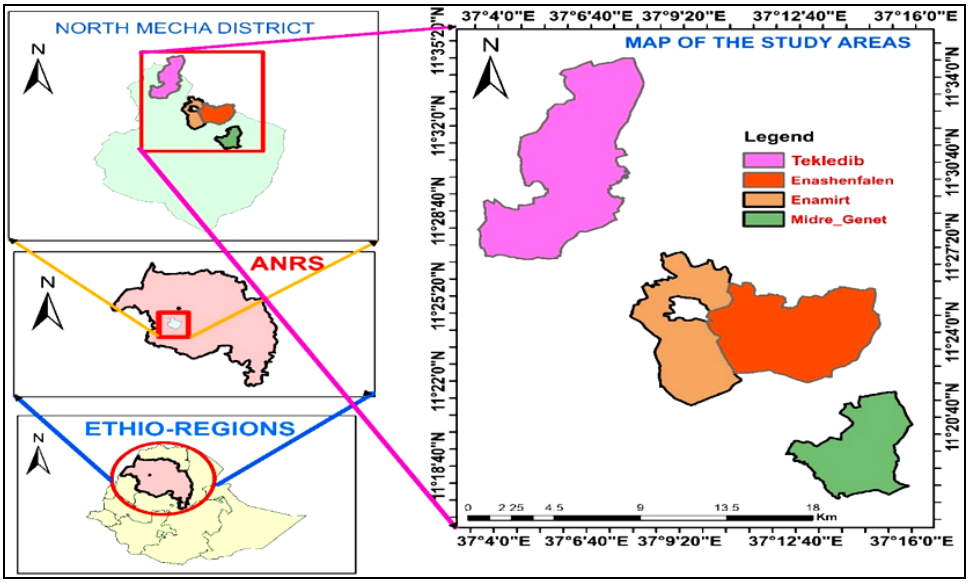
farmland. Therefore, the objectives of the study were to analyze trends of eucalyptus plantation and identify driving forces of farmers' decision towards a monoculture of eucalyptus plantation in North Mecha District, north-west Ethiopia.

2. Methods and Materials

The study is conducted in 2020 in North Mecha District, about 525 km northwest of Addis Ababa the capital city of Ethiopia. The research area is purposefully selected because eucalyptus is the major important livelihood strategy of local people in the area (NMDARDO, 2020) [8]. The total of 33 *kebeles* in the district was classified into two groups based on the eucalyptus cover that have high eucalyptus cover (17 *kebeles*) and low eucalyptus cover (16 *kebeles*) by using stratified probability sampling within the guidance of the district expert and professional observation. The two *kebeles* were chosen from the 17 *kebeles* that have high eucalyptus cover and two *kebeles* were chosen from 16 that have low eucalyptus cover by using simple random sampling. Because random sample drawing does not only help to depict the target population with sufficient accuracy but also enable the researcher to establish a statistical relationship between the sample and the population. Both primary and secondary data were collected. Primary data were collected from sampled households using a Semi-structured questionnaire, Focused Group Discussion (FGD), and key informant interviews. Secondary data have been collected from published and unpublished documents. To examine trends of eucalyptus plantation enhanced thematic mapper (TM) and operational land imagery satellite images were accessed from the United States geological survey (https://earthexplorer.usgs.gov). The selection of satellite image was foremost considered free access available and the dry season was chosen where the eucalyptus was more separable than other features as well as to enhance image quality when there was cloud effect cover exists for data reliability.

Table 1: Time series land satellite images detection

No.	Image	Sensor	Acquisition date	Path/Row	Resolution	Cloud cover
1.	Landsat 7	EM+	06/02/2000	170/52	30×30	0.40%
2.	Landsat 8	OLI	24/01/2019	170/52	30×30	0.000%



Source: (Ethio Geospatial data)

Fig 1: *Location map of the North Mecha District*

- **Remote Sensing Data Analysis**

ERDAS imagine 9.1 was used for image processing and classification and ArcGIS software was used for raster and vector analysis and mapping. Satellite image and shapefile of sample *Kebele* were imported to ERDAS software to create the layout for each year. To detect the extent of eucalyptus plantation of the two period's successive combinations of Normalized difference vegetation index and on-screen digitizing approaches were employed. At the first stage,

i). Raw Red and Near-Infrared bands were clipped in the study area;
ii). NDVI were calculated with the formula of NDVI= (NIR-Red)/(NIR+Red) and
iii). GTP were used to fix NDVI ranges for eucalyptus plantation and correct errors or excluding other vegetation. Thus, the NDVI value range 0.221-0.234 (2000) and 0.12-0.26 (2019) was fixed as the area of the eucalyptus plantation.

At the second stage,

i). The NDVI values were re-classed into eucalyptus plantation and non-eucalyptus plantation cover (crop land, grazing/shrub land and water area),
ii). The re-classed NDVI raster were converted to vector and
iii). Then on-screen digitizing were used to correct errors (including pixels obtaining eucalyptus plantation and removing pixels holding non-eucalyptus plantation areas) using the false-colour composite and support data for each period. In addition to those ancillary data, editing of eucalyptus NDVI vector map has been operated by the aid of GTPs collected for each year;
iv). Finally, the edited map showing the spatial distribution eucalyptus plantation were generated for each year.

LULC change detection analysis was computed in three different ways:

i). Total LC Change in Hectare Calculated as:

Total LC = Area of a final year-Area of initial year

Positive values suggest an increase whereas negative values imply a decrease in extent.

ii). Percentage LC Change Calculated Using the Following Equation:

$$\text{Percentage of LC} = \frac{\text{Area of a Final Year} - \text{Area of Initial Year}}{\text{Area of Initial Year}}$$

iii). An Annual Rate of LC Change: Computed Using the Following Formula

$$r = \frac{Q2 - Q1}{t}$$

Where: r, Q2, Q1and t indicates the rate of change, recent year LC in ha, initial year LC in ha and interval year between initial and recent year, respectively.

3. Results and Discussion

3.1. Trends of Eucalyptus Plantation

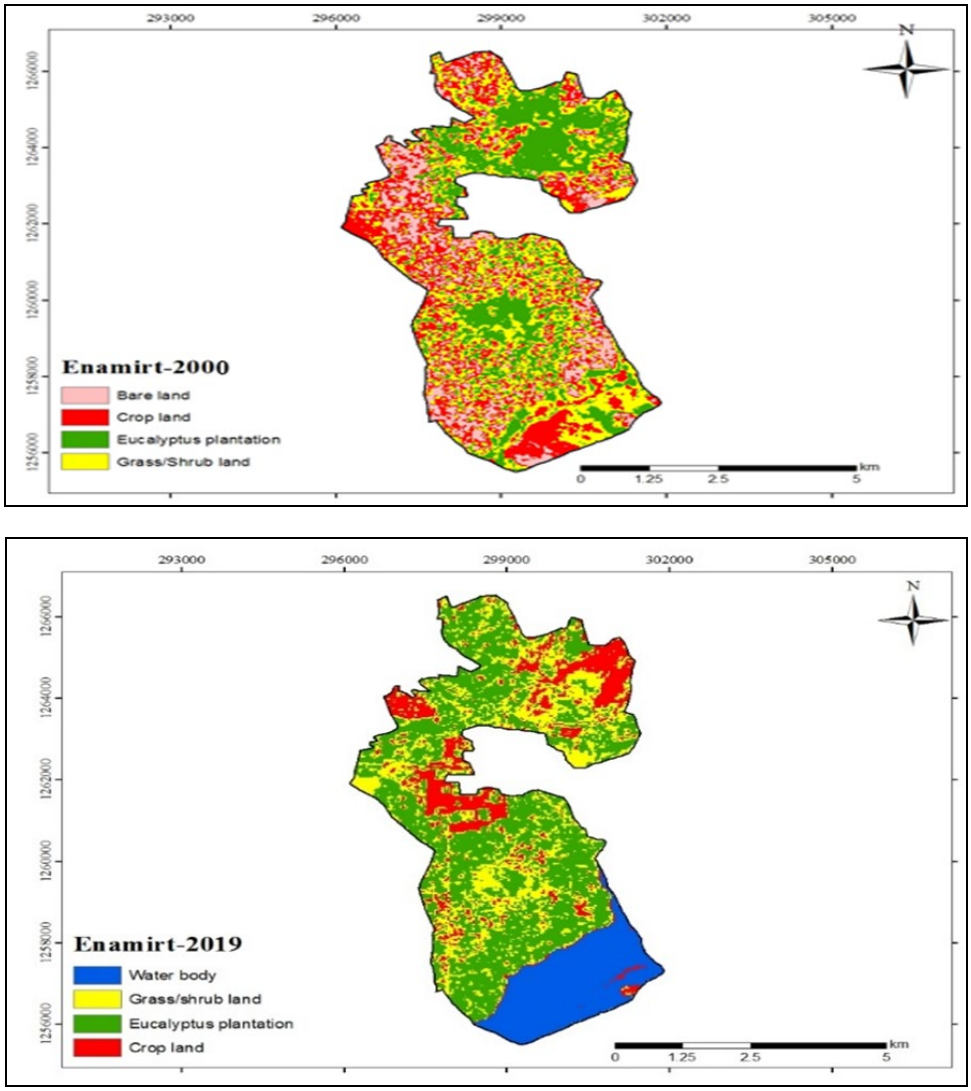


Fig 2: Eucalyptus and other land use/cover type in Enamirt Kebele

Table 2: Distribution and confirmation by remote sensing analysis in *Enamirt Kebele*

Enamirt							
	2000		2019				
LC type	Area (ha)	%	Area (ha)	%	Change in ha (2000-2019)	Rate of annual change (2000-2019	% change
Eucalyptus plantation	899.64	26	1514.97	46	615.33	32.3858	20
Grass/shrub land	1059.75	32	905.76	26	-153.99	-8.1047	-6
Crop land	951.39	28	470.43	13	-480.96	-25.314	-15
water body	0	0	524.97	15	524.97	27.63	15
Bare land	505.35	14	0	0	-505.35	-26.5974	-14

According to remote sensing data, the eucalyptus plantation in *Enamirt Kebele* has increased from 899.64 to 1515 hectares or a shift in percentage coverage of eucalyptus plantation from 26% to 46%. *Enamirt Kebele's* grass/shrub land has been reduced from 1059 ha to 905.76 ha, with a percentage cover shift of grass land from 32% to 26% and an annual average of

8.10. Crop field cover changed from 951 to 470 hectares, with a percentage cover change of 28% to 13% and a 25% annual rate of decrease in crop land. The water body in *Enamirt Kebele* was changed from 0 to 524.97ha, and the percentage coverage of the water body was changed from 0% to 15%, with an annual rate of increase of 27.63 units. *Enamirt Kebele's* bare land has been reduced from 505 to 0 hectares, with an annual percentage cover shift of bare land of 14 to 0 and an annual rate of bare land reduction of 26.6.

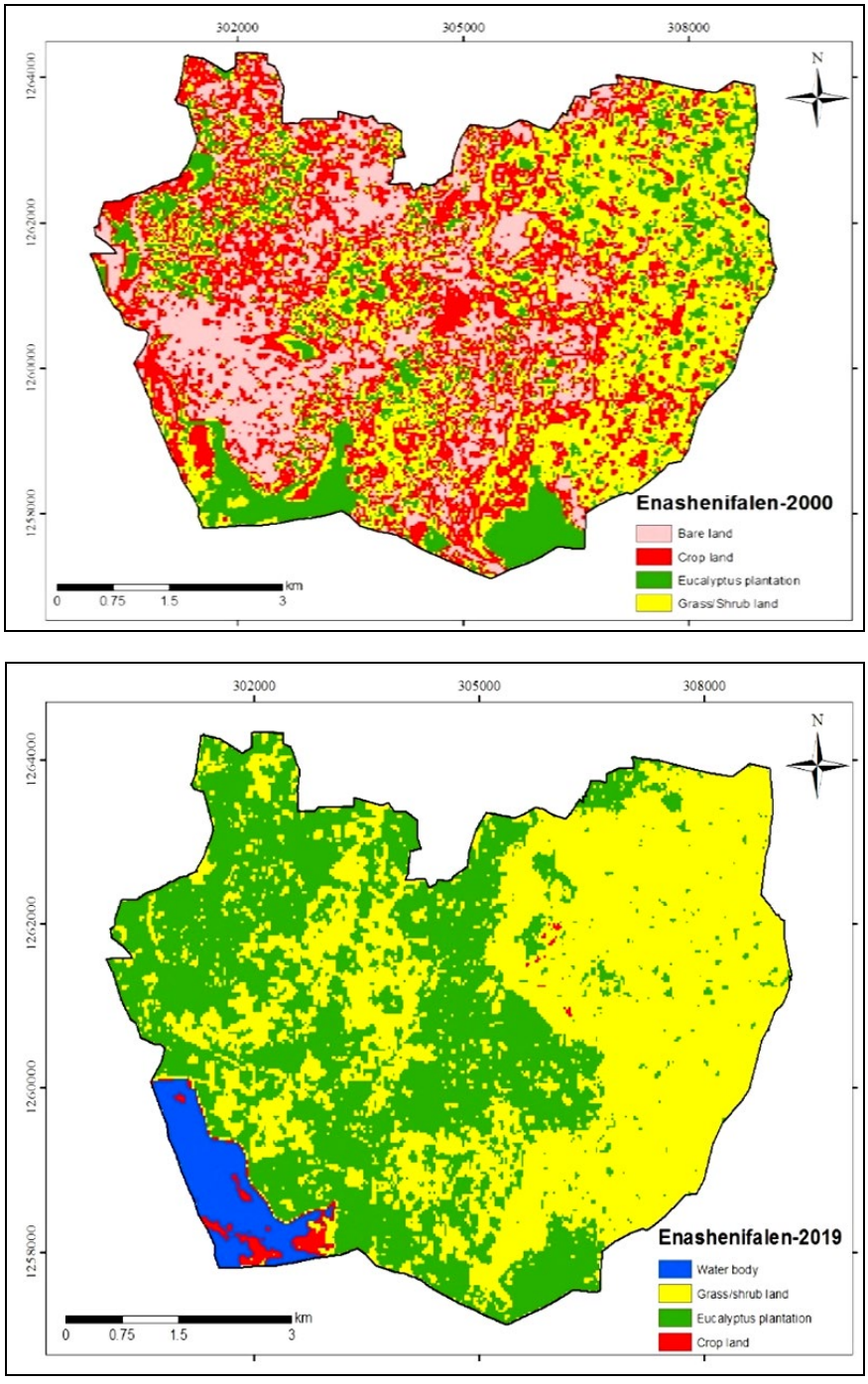


Fig 3: Eucalyptus and other land use/cover in Enashenifalen Kebele

Table 2: Distribution and confirmation by remote sensing analysis in Enashenifalen Kebele

Enashenifalen							
	2000		2019		2000-2019		
LC type	Area (ha)	%	Area (ha)	%	Change in ha (2000-2019)	Rate of annual change (2000-2019	Percentage change (2000-2019
Eucalyptus plantation	704.7	16	1988.55	44.1	1283.85	67.5711	28.1
Grass/shrub land	1391.67	31	2309.31	51	917.64	48.2968	20
Crop land	1404.54	31	42.39	0.9	-1362.2	-71.692	-30.1
water bod	0	0	178.65	4	178.65	9.402632	4
Bare land	1017.99	22	0	0	-1017.99	-53.5784	-22

In *Enashenifalen Kebele*, the land cover change of eucalyptus plantation was changed from 704 to 1988 ha, with a percentage cover change of 16 to 44% and an annual rate of eucalyptus plantation of 67.6%. The grass/shrub land cover changed from 1391.67 to 2309.31 ha, with a percentage cover change of 31 to 51% and an average rate of grass/shrub land change of 48.28. In *Enashenifalen Kebele*, the crop land scenario cover change was modified from 1404.54 to 42.39 ha, and the percentage cover change of crop land was changed from 31 to 0.9, with an annual rate of crop land decrease of-71.69. Water body cover change in the kebele has been increased from 0 to 178.65ha, and the percentage cover change of water bodies has been increased from 0 to 4%, with an annual average of 178.65. The bare land cover change in *Enashenifalen Kebele* has been reduced from 1017.99 to 0ha, and the percentage bare land cover change has been reduced from 22 to 0%, with an annual rate of bare land reduction of 53.58.

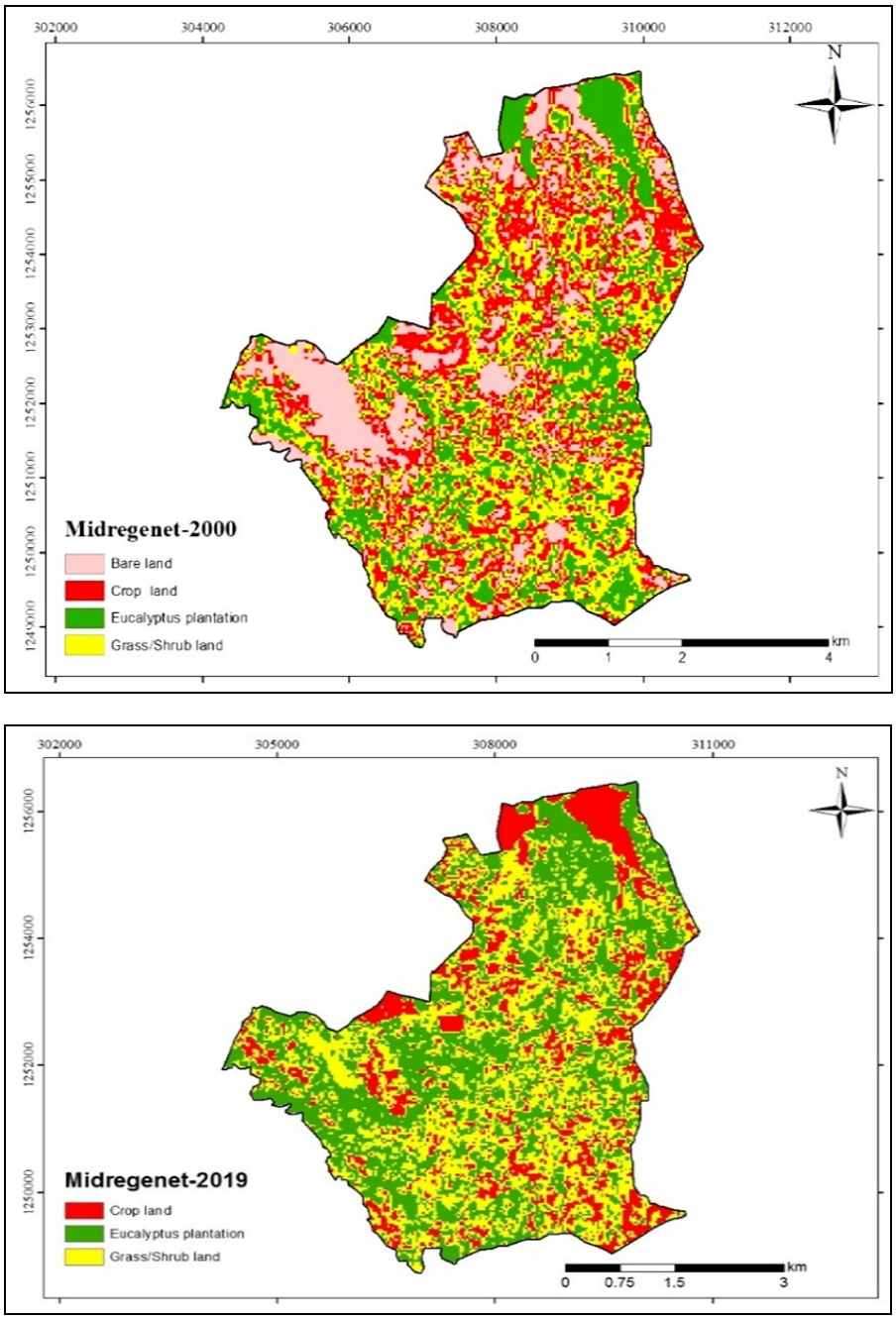


Fig 4: Eucalyptus and other land use/cover type in Midre-genet Kebele

Table 3: Distribution and confirmation by remote sensing analysis in Midre-genet Kebele

Midre-Genet							
	2000		2019		Change (2000-2019)		
LC type	Area (ha)	%	Area (ha)	%	Change in ha (2000-2019)	Rate of annual change (2000-2019	Percentage change (2000-2019)
Eucalyptus plantation	676.62	24	1048.23	39	371.61	19.5584	15
Grass/shrub land	740.52	27	1142.01	41	401.49	21.1311	14
Crop land	789.84	29	552.15	20	-237.7	-12.51	-9
water body	0	0	0	0	0	0	0
Bare land	535.41	20	0	0	-535.41	-28.1795	-20

The area under eucalyptus plantation in *Midre-Genet Kebele* has increased from 676.62 to 1048.23ha, and the percentage of eucalyptus plantation has increased from 24 to 39, with the annual rate of eucalyptus plantation increasing by 19.56. The annual rate of grass/shrub land has been increased by 21.13, and the percentage cover change of grass/shrub land has been adjusted from 27 to 41%. The crop land cover change scenario has been modified from 789.84 to 552.15 ha, with the percentage cover change of crop land changing from 29 to 20% and the annual rate of crop land rising by 12.51. The water body's cover change has been changed from 0 to 0ha, and the level of water body cover change has been changed from 0 to 0%, with the average rate of water body change remaining unchanged. While, the bare land cover change has been changed from 535.41 to 0ha and the percentage cover change of bare land has been changed 20 to 0% with annual rate of bare land has been decreased by 28.18

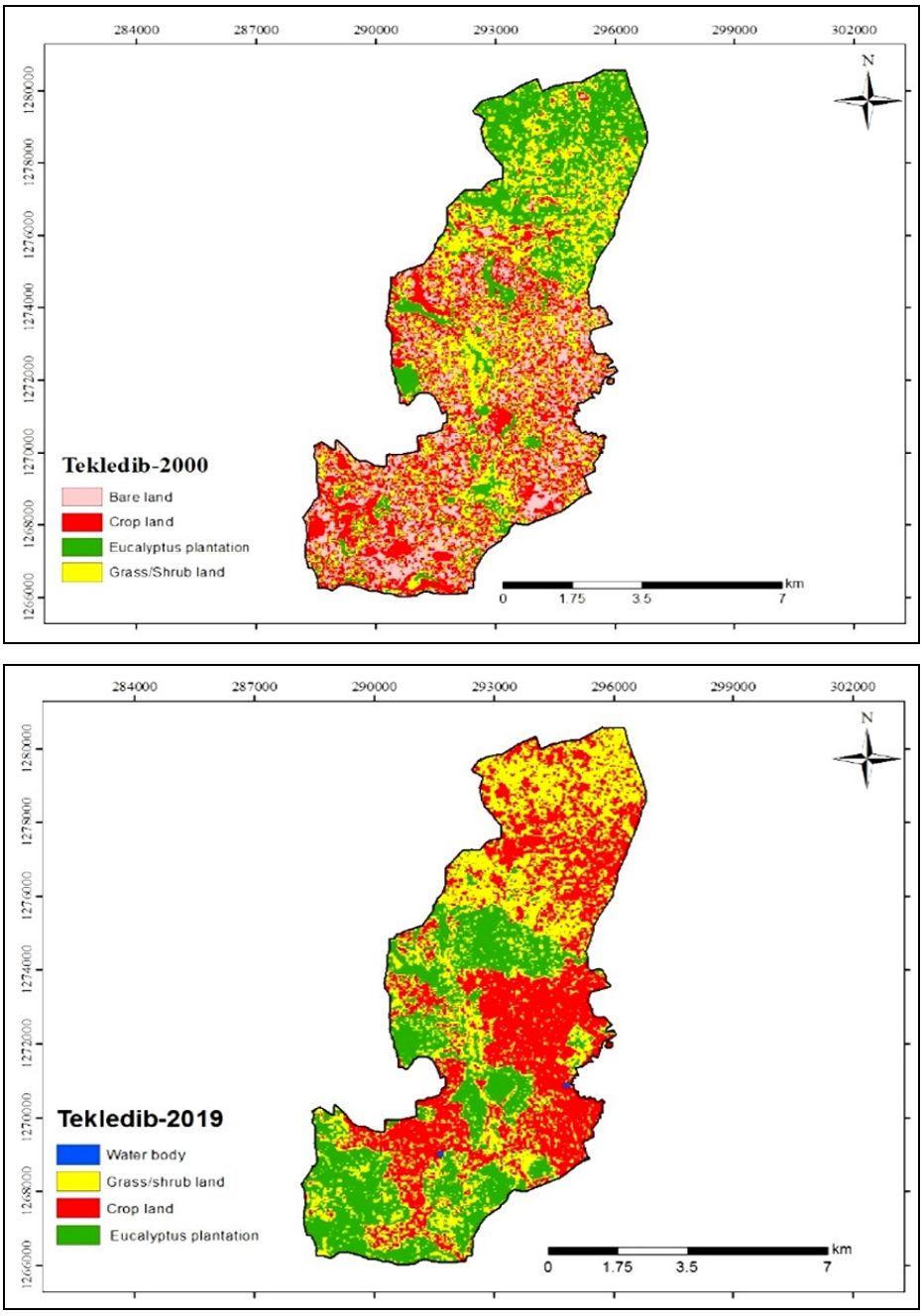


Fig 5: *Eucalyptus and other land use/cover in Tekledib Kebele*

Table 4: Distribution and confirmation by remote sensing analysis in Tekledib Kebele

Tekledib							
	2000		2019				
LC type	Area (ha)	%	Area (ha)	%	Change in ha (2000-2019)	Rate of annual change (2000-2019	Percentage change (2000-2019)
Eucalyptus plantation	1583.28	23	1939.32	30	356.04	18.7389	7
Grass/shrub land	1859.67	28	2195.01	33	335.34	17.6495	5
Crop land	1882.17	29	2476.08	36.91	593.91	31.2584	7.91
water bod	0	0	6.03	0.09	6.03	0.317368	0.09
Bare land	1291.32	20	0	0	-1291.32	-67.9642	-20

In *Tekledib Kebele*, the land cover shift of the eucalyptus plantation has been changed from 1583 to 1939ha. The annual rate of eucalyptus plantation has been raised by 18.74%, raising the percentage cover shift from 20% to 30%. The coverage of grass/shrub land has increased from 1859.67 to 2195.01ha, and the%age cover shift of grass/shrub land has increased from 28 to 33%, with the annual rate of grass/shrub land increasing by 17.65. Crop land area has increased from 1882.17 to 2476.08ha, and crop land coverage percentage has increased from 29 to 36.91%, with the annual rate of crop land increasing by 31.25%. The annual rate of water body has been increased by 0.32, and the land cover change of water body has been changed from 0 to 6ha and the percentage cover change of water body has been changed from 0 to 0.09%. The water body's land coverage has been reduced from 1291.32 to 0ha, and the amount of bare land coverage has been reduced from 20% to 0%, with the annual rate of bare land coverage reduced by 67.96.

Table 5: Aggregated land use types in the study area

Aggregated					
Land cover type	**Area (ha) (2000)**	**Area (ha) (2019)**	**Change (ha)**	**Annual rate**	**% Change**
Eucalyptus plantation	3864.24	6491.07	2626.83	138.2542	70.1
Grass/shrub land	5051.61	6552.09	1500.48	78.97263	33
Crop land	5027.94	3541.05	-1486.89	-78.2574	-46.19
water bod	0	709.65	709.65	37.35	19.09
Bare land	3350.07	0	-3350.07	-176.319	-76

In the study area the aggregated land use cover in the years 2000 to 2019 was shown (Table 5). The trends of eucalyptus plantation increased from 3864ha to 6491ha in the years 2000 to 2019, respectively; with annual rate accelerated by 138% from 2000 to 2019 years. This result implies that the eucalyptus plantation has lion share and extremely increased from time to time in the study area. The focus group discussants verified that the demand of farmers on planting eucalyptus is increasing for wood products for marketing; ease of cultivation, wider adaptability and high rate of biomass production of the woodlot and the decline in land productivity for agricultural uses. This result is similar to the study of Tola (2010) noted that the eucalyptus planting practice has been increasing over the past twenty to thirty years while natural vegetation has been deteriorating. According to Dereje *et al*. (2012) [4] confirmed that the increase of eucalyptus s in their surroundings. Eleni *et al.* (2013) [6] also shown that a significant decrease in natural woody vegetation of the *Koga* catchment since 1950 due to deforestation despite an increasing trend in Eucalyptus plantations after the 1980's. In line with this, Woldeamlak (2002) [12] revealed an increase in eucalyptus plantation cover at a rate of 11ha per annum in Chemoga watershed Northwest Ethiopia.

The average change in grass/shrub land cover in the study area increased from 5051.6ha to 6552ha in the years 2000 and 2019, with an annual trend accelerating from 2000 to 2019 by 78%. This finding means that the eucalyptus was transformed from grass shrub land in a small field. The grass/shrub property, however, nearly converted to eucalyptus in the case of Enamirt Kebele; due to its surroundings by *Merawi* town or its short distance to the main market.

In the scenario of crop land in the study area decreased from 5027.9ha to 3541ha in the years of 2000 and 2019; with annual rate declined 78% from 2000 to 2019 as a result of conversion to eucalyptus plantation. This implies that the crop land is decreasing from time to time due to highly converted to eucalyptus plantation. However, in the *Tekledib Kebele* crop land is increased by 593ha. The district and *Kebele* expert (key informant) revealed that *Tekledib kebele* most area of land is clustered to make applicable for irrigation. Focus group discussants and personal observation confirm that the farmers who have irrigated land has not been preferred to plant eucalyptus rather they prefer to cultivate field crop. Generally, eucalyptus plantation has been increasing in north *Mecha* district; while, crop land declining. The result consistent with the study of (Tilashwork *et al*., 2013) [10] in *Mecha* district found that fertile crop land has been converted to eucalyptus per each year.

The cover change of water bodies in the study area increased from 0ha to 709ha with an annual rate accelerated by 37% from the year 2000 to 2019. The result implies that no water body increased time to time rather due to *Koga* irrigation dam and reservoir and this water body is sourced from flood since eucalyptus sucks much water ground and surface water. For example, district expert (KII) confirms that a water body in *Midre-Genet* has almost zero hectares or decreased from time to time since it is out of *Koga* dam and reservoir. This is due to that, the *Kebele* has ground and surface water influenced by the eucalyptus plantation. The three *kebeles* (*Tekledib*, *Enamirt* and *Enashenifalen*) comprised by *Koga* dam and reservoir. The K*ebele* experts and elder people (KII) reveal that in the earlier time there was a stream, pond and Small River now becomes dried as eucalyptus plantation expanded so far. The result consistent with (Tilashwork, 2009) [11] experimentally found that eucalyptus dried springs.

The cover type of bare land in the study area was decreased from 3350ha to 0ha in the years 2000 and 2019, respectively and with annual rate declined by 176% from 2000 to 2019 years. The result implies that; bare land is tending to convert to eucalyptus plantations.

3.2. Driving Forces of Farmers' Decision towards Monoculture of Eucalyptus Tree Plantation

Farming households respond to policy and market signals rationally taking into account the socio-economic benefits and costs of their decisions. When farmers decide to plant eucalyptus, the same is true. Different factors, both internal and external, affect the advantages and costs that farming households consider when making a decision. Farmers' willingness to plant eucalyptus on their farms is a result of their attitudes toward the benefits of planting eucalyptus, their perceptions of formal and informal group influencers, and other socioeconomic factors, according to studies conducted in other parts of Ethiopia. Farmers as key informants who planted eucalyptus were asked to classify the most common socio-economic drivers for the expansion of eucalyptus plantation as higher prices of eucalyptus logs and thus better economic returns relative to annual crops were identified by the respondents as a result of expanding domestic and export

markets following the opening and growing importance of Ethio-Sudan border trade, Cutting timber trees from natural forests is prohibited by national forest law, rising prices of agricultural inputs, especially chemical fertilizers and improved seeds, and the ability to sell any time when cash is needed and get more cash income i.e. Farmers' responses are consistent with what has been published in the literature.

As a result, farming is motivated by a lack of resources to buy fertilizers and seeds, as well as the supply of native timber tree logs, especially Cordia africana, has significantly decreased lower, climatic and biotic risks in growing trees. Woodworkers and charcoal producers who previously depended on indigenous species are attempting to switch to eucalyptus logs. Since Maize is the main crop grown in the North Mecha district. Smallholders are finding it more difficult to produce cereals, especially maize, due to rising input costs and falling grain prices. This result is in line with finding of (Berihun T. and Habtemariam K., 2015) [2] the increasing cost of inputs and decreasing price of grains is making cereals production, particularly maize, less attractive for smallholders.

4. Conclusion and Policy Implications

The overall results showed that the driving forces of the decision of farmers from diversified farming to monoculture eucalyptus plantation were: a sharp increase in agricultural inputs, competition from eucalyptus grower neighbours, low labour demand, low susceptibility to disease and pests and eucalyptus can be changed to cash when needs arise than crops. During the years 2000 and 2019, the remote sensing data confirmed that eucalyptus increased from 3864ha to 6491ha. While the farmers in the irrigated area did not favour the planting of eucalyptus, but the cultivation of field crops. The farmers did not realize the impacts of eucalyptus plantation on ecological components regard to crop production and natural resources. From this, it is possible to conclude that farmers prefer to decide from diversified agriculture to monoculture of eucalyptus plantation by driving forces. The farmers have not been realized the long-term effects of eucalyptus plantation; so, the extension worker, ministry of environment, forest and climate change and other concerned stakeholder bodies should extend their services and aware of the advantage and disadvantages of diversified agriculture and monoculture eucalyptus plantation to the farmers and provide capacity building training for the farmers and provide the multipurpose tree which could be substituted eucalyptus. The policymaker needs to make a critical decision on the conflict of interest between short term benefit from eucalyptus plantation by farmers and long terms benefits from conserving the environment and biodiversity. Further researches need to be conducted on the comparative advantage of eucalyptus plantation with crop production to have more evidence and a generalization about eucalyptus plantation.

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