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STATUS AND TRENDS OF EUCALYPTUS EXPANSION AND ITS ENVIRONMENTAL IMPLICATION IN MEKET DISTRICT, NORTH WELLO ZONE, ETHIOPIA

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Abstract
Eucalyptus is one of the exotic and multipurpose tree grown in Ethiopia. This paper aims to assess the spatiotemporal expansion of eucalyptus trees in Meket district, north-central Ethiopia. Multistage sampling techniques reaching from farmer's perception to remote sensing data processing were employed. Household heads survey of 192 farmers, key informant interviews, and focus group discussions was used to collect primary data's. Sixteen years of Landsat images were processed to detect multi-temporal status of Eucalyptus plantation through a combination of NDVI and on-screen-digitizing. This has been done with the aid of walking on the transect lines established based on the abundance of eucalyptus tree. Finally, the data's were analysed through descriptive statistics. Both remote sensing and farmer's perception result verified the rapid increment of Eucalyptus plantation in the study area. Explicitly, 85.42% of the sampled farmers observed the increment of eucalyptus. The remote sensed information also verified that, coverage of eucalyptus plantation were expanded from 6022 to 7838 and 7930 hectare in the year 2003, 2010, and 2019, respectively. The effects of eucalyptus planting on ecological components and crop were understood by the farmers and there is a significant difference in the risk perception of the adopters and non-adopters farmers. However, 62% of the farmers head didn't consider the ecological effects of eucalyptus for its adoption. Provision of livelihood alternatives, execution of proper land use planning, and adoption of ecological friendly eucalyptus tree species are forward as a recommendation.

Key Words: *Eucalyptus expansion, Farmer's perception, NDVI, Meket district*

Introduction

Tree plantations provide the benefits and purposes that are gathered from the natural forests (Ashraf *et al*., 2014). In the tropics, over 10 million hactares of eucalyptus plantations were reported during 1990s (FAO, 1993). In east Africa, Ethiopia is one of the 10 pioneer countries in eucalyptus plantation which accounts more than 0.5 million hactare (Getahun, 2010).

Approximately 70 species of eucalyptus are available in Ethiopia (Zewdie, 2008) and 10 eucalyptus species are widely planted except the most arid areas of the country (Teshome, 2009).

Spatially, Eucalyptus plots/stands are common at the sloppy and degraded areas Ethiopian highlands (Haila, 2002). A survey conducted in highlands of Ethiopia indicated that eucalyptus trees were established on former cropland (40%) and along cropland borders (60%) and the majority on marginal lands (Chanie *et al.*, 2013). Milkiasa *et al*. (2014) stated that 72% of the farmers converted part of their farmland into Eucalyptus plantations in Arsi Negele Watershed, Ethiopia.

Regional State of Tigray in 1997 and Oromia Regional State has imposed a ban on the eucalyptus tree planting on farm land (Pender, 2000; ORLAUP No. 56/2002). Regardless of the prohibitions, planting eucalyptus tree were continued in those regions of Ethiopia (Teshome, 2009). In Amhara Regional State, nearly 67% of land covered with eucalyptus are farm forests developed by smallholder farmers (Lemenih, 2010). In Market district, eucalyptus trees have immense benefits as insurance, crop, guarantor of stable life and a means out of poverty (Lemenih, 2010).

The Amhara Regional State is currently well-known for a great expansion of eucalyptus and it is from state, community and farmers ownership. Currently, eucalyptus trees are considered as a cash crop in Meket district. Merely, the status, extent, and tendency of expansion was not measured and studied. Then, the lack of empirical data leads to poor land-use practice and mismanagement of the surroundings. The emphasis on the environmental aspects are not taken into consideration and left aside in farmer's decision making for planting of eucalyptus.

Objective

The main objective of this paper is integrating the data from farmers' perception and remote sensed technology to assess the status and trends of the Eucalyptus trees in Meket District.

Materials and Methods

Study Area Description

Meket District is located in North Wollo Zones in the Amhara Regional state of Ethiopia (figure 1). Its Agro-climate (agro-ecology) includes highland (Dega), mid-highland (Weina-Dega), and lowland (kola) with average annual rainfall range of 600 to 1000mm.

The topography of the districts includes rugged (65%), plain (28%), mountainous (4%) and the remaining 3% is gorge/valley. The district landmass is covered by cultivated land (43,584ha), grazing land (15,152ha), perennial woody vegetation's (54,000ha), settlement (39,528ha), degraded land (11,592ha), and the remaining 23,184ha is covered by other resources. Agriculture is the main economic activity and livelihood source of the people of the study area.

The projected population of the district for 2017 was 268,700 of which 135,011 are males and 133,689 are females. The urban and rural dwellers constitutes 20,479 and 248,221 of the district total population (CSA, 2013).

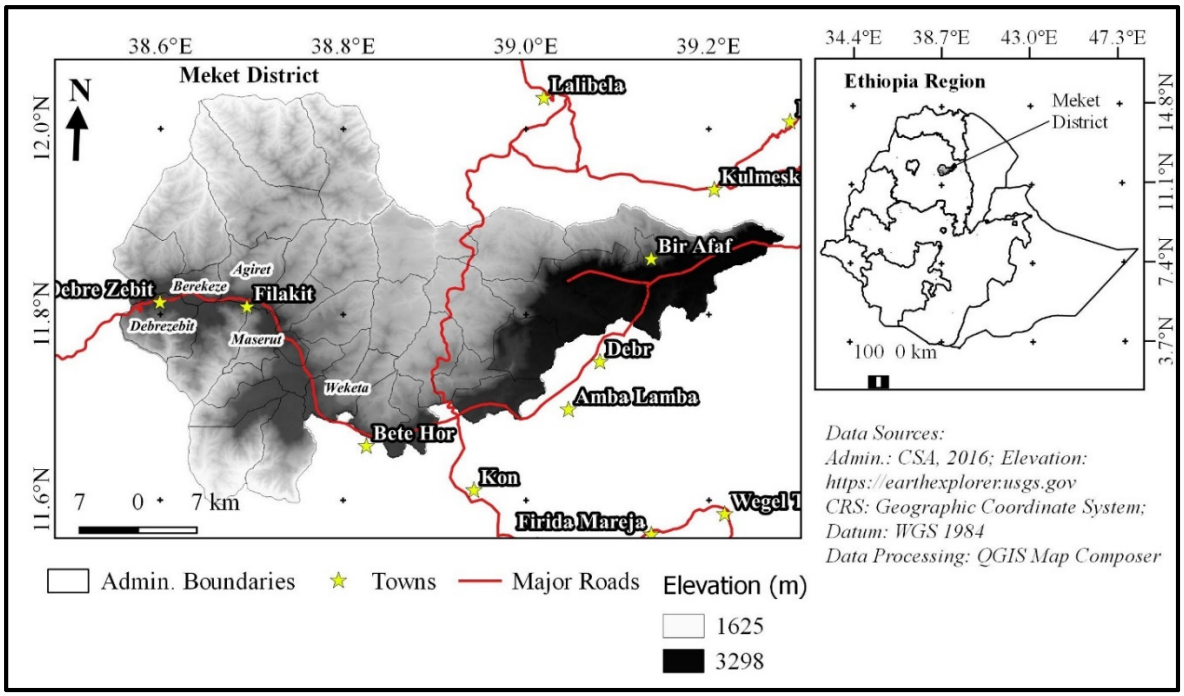

Fig. 4: Location map of the study area

Research Design, Sampling Procedure, Technique and Sample Size

This study used a cross-sectional survey employing both qualitative and quantitative approaches whereby the whole data collection processes complement each other. Because, Cross-sectional survey is effective in providing a snapshot of the current behavior, attitude and belief in a population and has an advantage of providing data relatively quickly and the data collected from the selected individual at a single point in time (Gay *et al.,* 2009; Creswell, 2012).

Indeed, multistage sampling procedure was instrumental. Prior to field survey, based on a knowledge about the study area and the support of Google Earth Image, the 2019 satellite image was interpreted visually and areas with higher Eucalyptus coverage were identified (table 1; figure 2). The interpreted image indicated that, most Eucalyptus plantations were found in the mid to higher altitudes. Therefore, based on abundance of eucalyptus, five kebeles namely Agiret, Berekeze, Debrezebit, Meserut, Weketa (figure 1) were selected with the help of the experts and the researchers' reconnaissance survey. Finally, a total of 192 household heads was selected through the procedure of systematic random sampling for household surveys.

Data Collection from Farmers

This research has attempted to integrate the use of qualitative and quantitative data collection approach. Key informant's interview (12 experts and 10 local elders) and focus group discussions ((FGD) with five groups one in each selected kebele) were employed to collect qualitative data's. The quantitative data was collected from household heads survey (HHS) and filed observation (individual farm level inventory for the 142 adopter's farmers).

Remote Sensed Data Collection

To examine the status of Eucalyptus expansion, three periods Landsat satellite

images (Thematic Mapper/TM, Enhanced Thematic Mapper/ETM+, & Operational Land Imagery/OLI) were accessed from United States Geological Survey (https://earthexplorer.usgs.gov) (table 1). The selection of satellite images primarily considered: (i) open source data availability, (ii) the dry season were chosen where Eucalyptus could be more separable than other features, and (iii) the image quality to reduce the effect of cloud cover on data reliability.

Table 1: Time series Landsat satellite images used for the study

Year		Path/Row	Acquisition date	Landsat sensor	Cloud cover %	Raw spatial resolution	Remark
2019		169/052	Jan.-08	OLI	0.41	30x30m	
2010	2010	169/052	Jan.-14	TM	0.00	30x30m	Mosaic
	2009	168/052	Nov.-04	TM	0.00	30x30m	
2003		169/052	Feb.-04	ETM+	0.00	30x30m	Mosaic
		168/052	Jan.-12	ETM+	0.00	30x30m	

Including kebeles selected for HHS, a transect lines were laid over three to seven kilometers radius along the road from Debre Zebit to Bir Afaf towns (figure 1). Following the transect line, with the help of local key informants, Ground Truthing Points (GTPs) were collected with the aim to (i) examines the trends of Eucalyptus plantation, and (ii) separate Eucalyptus plantation from other vegetation types. Google Earth/ Engine and local Key Informants' and the 2004 report of Woody Biomass Inventory Strategic Support Project (WBISSP) (only for 2003 image) was used as a support data's for GTPs collection. Indeed around 200 GTPs were collected for each year of under study. The overall field data collection was done during January 10-31, 2019.

Data Analysis

Farmer's Perception Analysis

Both qualitative (like narration) and quantitative methods of analysis were employed to examine the study information. At the end, the information generated from statistical analysis was collated and interpreted with the outputs of remote sensing image analysis.

Remote Sensed Data Analysis

In order to detect the extent of Eucalyptus plantation of the three periods, the successive combination of the Normalized Difference Vegetation Index (NDVI) and on-screen-digitizing approaches were employed. At the first stage (i) the raw Red and Near-Infrared bands were clipped to the extent of the study area, (ii) NDVI were calculated with the formula NDVI = (NIR-Red)/ (NIR+Red), and (iii) the GTPs were used to fix the NDVI ranges for Eucalyptus plantation and correction of errors (excluding other vegetation). Therefore, NDVI Value ranges 0.214-0.236627 (2019), 0.212-0.247592 (2010), and 0.113-0.137674 (2003) were fixed as areas of Eucalyptus plantations.

At the second stage, (i) the NDVI values were re-classed into Eucalyptus and non-Eucalyptus plantation areas, (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's for each period. In addition to those

ancillary data, editing of Eucalyptus NDVI's vector map has been operated by the aid of GTPs collected for each years; (iv) finally, the edited map showing the spatial distribution Eucalyptus plantation were generated for each year.

Results and Discussion

Demographic Characteristics of Sampled Farmers

Gender, Marital Status, Religion and Education Level of the farmers

Results from data analysis showed that 77.1% of surveyed farmers households were male-headed from which about 57.29% and 19.79% are eucalyptus tree adopters and non-adopters, respectively (table 2). This compares with 88% reported by Jenbere *et al.* (2012).

In the instance of marital status, 64.04% of farmers with eucalyptus trees and 21.35% of non-adopters of eucalyptus trees are married and the majority, (i.e. 72.40 % and 25.52% of adopters and non-adopters respectively) are Orthodox in the survey area. Of the entire sample, 66.1% of the farmers are illiterate and 33.9% of the farmers are literate. 47.40% and 26.56 % of adopter farmers are respectively illiterate and literate.

Table 2: Gender, marital status, religion and education level of the farmers

Variables		Farmers category				All sample	
		Eucalyptus tree growers		Non-growers			
		n	%	n	%	n	%
Gender	Male	110	57.29	38	19.79	148	77.1
	Female	32	16.67	12	6.25	44	22.9
Total		142	73.96	50	26.04	192	100
Marital status	Married	122	64.06	42	21.35	164	85.4
	Single	1	0.52	0	0	1	.5
	Divorced	14	7.29	3	1.56	17	8.9
	Widow	5	2.60	5	2.60	10	5.2
Total		142	74.47	50	25.51	192	100
Religion	Orthodox	139	72.40	49	25.52	188	97.9
	Muslim	3	1.58	1	0.52	4	2.1
Total		142	73.98	50	26.04	192	100
Education level	Illiterate	91	47.40	36	18.75	127	66.1
	Literate	51	26.56	14	7.26	65	33.9
Total		142	73.96	50	20.04	192	100

Status of Eucalyptus Tree

The eucalyptus is one of the dominant tree species in the study area. By taking the total size of the land of eucalyptus tree adopter farmers (138.06 ha of the land) 12.16% of the farmland (crop field) and 11.16% of the non-farm land cover with eucalyptus trees (table 3). The findings of this study compare with the report of Jenbere *et al*. (2012) in the south central part of Ethiopia that 11.1% part of crop field was converted to eucalyptus in 2015/2016 planting season. Another study by Yitaferu *et al.* (2013) indicate that, in Mecha district fertile croplands have been converted to eucalyptus wood lots per each year.

Generally, from 138.06 ha of the land, 23.32% of land was covered with the eucalyptus tree. This pattern shows that the eucalyptus tree area is expanding at the expense of cropland and jeopardizing the

crop productivity (table 3). Farming system of the study area can be characterized as a eucalyptus-crops-livestock farming system.

The FGD also supported that planting eucalyptus tree is along the rich land or crop land. One of the focus group discussant revealed that, the proper place to grow eucalyptus is mountainous land that has steep land (above 60% of slope), fragile land, eroded land and the place where water is not found. The district experts (KII) also agreed with above approximation of the FGD and extension worker also give an advice for the farmers where the eucalyptus tree ought to plant.

In addition to the above table (4), the survey result indicates 8,570 eucalyptus tree stands were grown in a hectare of land. Similarly, Kelemu and Tadesse (2010) reported that farmers plant 10,000 seedlings per hectare. But, the stocking rate in the study area was below the study of Jenbere *et al.* (2012) which constitutes between 15,000 and 40,000 stems/ha.

Table 3: Perceived average area cover with eucalyptus tree on both crop and non-farm land (in 2018/9)

	Sum	Mean	Std. Deviation	Percent
Total size of land of the eucalyptus adopters (ha)	138.06	0.97	0.51	
Crop or farm land cover with eucalyptus(ha)	16.79	0.11	0.13	12.16%
Non-farm land cover with eucalyptus(ha)	15.41	0.11	0.15	11.16%
Total land cover with eucalyptus, both on the farm and non-farm land(ha)	32.20	0.23	0.13	23.32%

Table 4. Number of stands of eucalyptus tree per adopter's farmers

	N	Minimum	Maximum	Mean	Std. Deviation
Number of stands of eucalyptus tree	142	100.00	7000.00	1944.50	1490.12

Trends of Eucalyptus Tree Expansion

In the study area, Eucalyptus is multipurpose (i.e. cash crop, emergent and accelerating activity) for the farmers. Accordingly, all most above half (85.42%) of the sampled farmers have a clear understanding about the increment of the eucalyptus tree cover or woodlots (figure 2). Similarly, the remote sensing image analysis confirmed that, eucalyptus plantation has increased from 6022 ha to 7838 ha and 7930 ha in the year 2003, 2010, and 2019, respectively (figure 2; 3). Therefore, it can be concluded as, plantation of eucalyptus tree were increasing rapidly in the past nearly two decades, especially on the highland parts of the study area (figure 3).

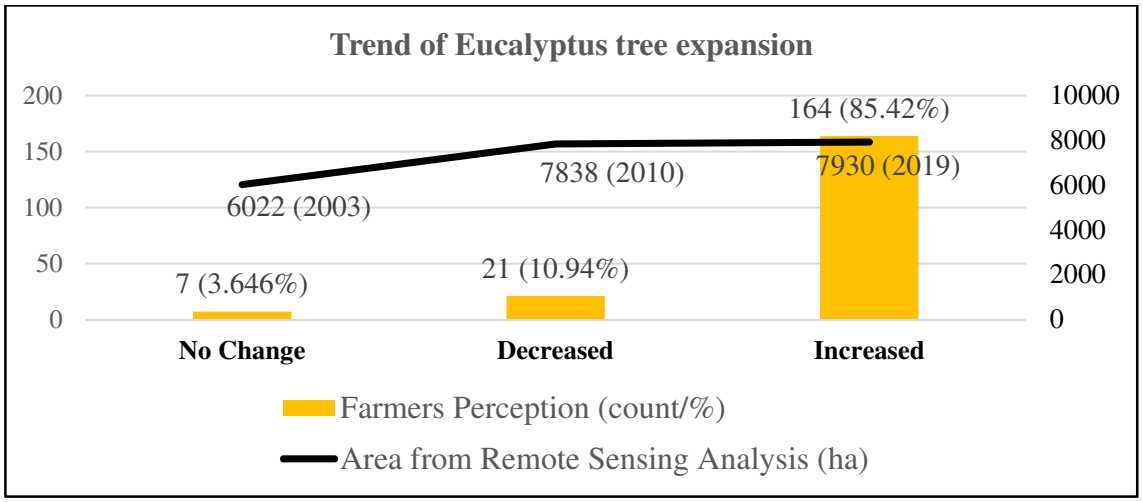

Fig. 2: Trends of Eucalyptus expansion (farmers' perception & remote sensing analysis)

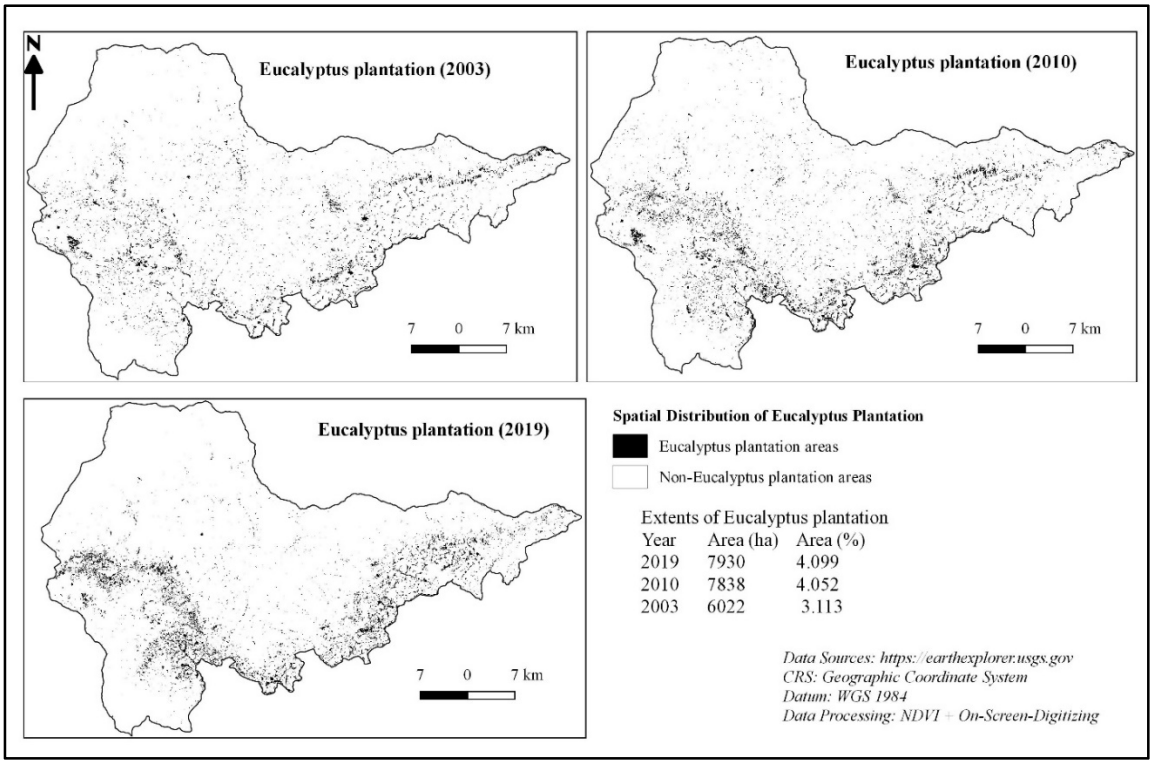

Fig. 3: Trends and spatial distribution of Eucalyptus plantation (2003-2019)

In Central Highlands of Ethiopia and Arsi Negelle District, most of the respondents confirmed the increasing of eucalyptus woodlots in their surroundings (Senbeta *et al.*, 2010; Jenbere *et al.,* 2012). In summing-up, Gemechu (2010) noted that, the eucalyptus planting practice has been increasing over the past twenty to thirty year's while natural vegetation has been deteriorating.

Primary Objective of Farmers' Decision in Planting Eucalyptus Trees

Table 5 shows that, 96.5% (in the case) of the farmers' primary objective of

planting eucalyptus was for the sake of income generation. A farmer in the FGD noted that "eucalyptus is everything for the district community and the person who teach his child and plant eucalyptus tree are in better-off than another and it is a guarantor for a stable life and it is an indicator of social superiority and status." Following Eucalyptus tree for erosion control and material production, 38.7% of (of the case) the farmers indicated the role of eucalyptus tree for climate change aversion and windbreak. In addition, 5.6% (in the case) of farmers also plant eucalyptus trees for other needs like farm equipment's, fencing of house and other land uses using the tree limbs and shoots (twigs).

Likewise, studies in Rwanda and Burkina Faso indicate that farmers were motivated to plant trees on farms for economic benefits (Ndayambaje *et al*., 2012; Etongo *et al*., 2015). Again Etongo *et al*. (2015) added, *E. camaldulensis* is the important specie for reforestation of degraded areas and soil fertility improvement due its rapid growth rate and success in degraded areas.

Table 5: Primary objective of farmer's decision in planting eucalyptus tree

Primary objective of farmers' decision in planting Eucalyptus tree	Responses		Percent of Cases
	N	Percent	
Income source	137	35.0	96.5
Wood production and construction	90	23.0	63.4
Erosion control	101	25.8	71.1
Climatic change aversion and wind break	55	14.1	38.7
Others	8	2.0	5.6
Total	391	100.0	275.4*

*Multiple response

Farmers' Preference and Source of Seedling

Eucalyptus tree accounts a high cover among the exotic tree species in the district. 93%, 87.3%, and 54.9% (of the cases) of the respondent's preferred Eucalyptus tree due to its ease of management and adaptability, less establishment cost and non-palatability by livestock, respectively (table 6). Likewise, 49.4% farmers have revealed similar reason in South Central Ethiopia (Jenbere *et al.*; 2012). The authors added, income generated from the sale of eucalyptus wood makes 43% of the respondents to prefer eucalyptus trees.

Table 6: Reason for preference on eucalyptus tree planting than other species

No	Reason for preference on eucalyptus tree planting than another	Responses		Percent of Cases
		N	Percent	
1	Easy of management	133	28.1	93.7
2	Not-edible by livestock	78	16.5	54.9
3	Easy establishment cost	124	26.2	87.3
4	Adaptability	133	28.1	93.7
5	Others	5	1.1	3.5
Total		473	100.0	333.1*

*Multiple response

Farmers Perceptions towards the Eucalyptus Tree on Crop Productivity and Environmental Aspects

Farmers Risk Perception of Eucalyptus Tree Effects

The impression of risk perception has got substantial attention from various areas due to its important consequence on the usage and acceptance of different technology. The perceived risk or uncertainty affects people's confidence in their decisions. Nearly 57.8% of the respondent farmers perceived that expansion of eucalyptus plantations will create problems in the future (Jenbere *et al.,* 2012).

The overall mean of the risk perception of the farmers who was involved in the eucalyptus tree planting was 0.708 (table 8). This indicates there was a significant difference in the risk perception toward to the effects of the eucalyptus tree planting between eucalyptus adopters and non-adopter farmers.

Table 7: Risk perceptions adopters and non-adopters towards the effects of planting eucalyptus

Indicators	Farmers category	n	Mean	Std. Deviation
Crop productivity & production	Adopters	142	0.74	0.020
	Non-adopters	50	0.81	0.029
Soil moisture	Adopters	142	0.77	0.020
	Non-adopters	50	0.85	0.030
Water condition	Adopters	142	0.82	0.021
	Non-adopters	50	0.90	0.027
Biodiversity	Adopters	142	0.50	0.019
	Non-adopters	50	0.51	0.030

Table 8: Risk Perception index of farmers

	Farmers category	Mean	Std. D	Test statistics
	Adopters (n=142)	0.708	0.148	

Perceived Impacts of Eucalyptus Planting on Environment and Crops

As indicated in table (9) below, 84.4% of the farmers perceived that eucalyptus tree sucking much more water than other native plant species. Approximately 53.6% of the surveyed farmers have observed dried streams, bound and bore holes and 46.4% of the respondents also didn't mention the dried water source. Yet again, 54.7% and 71.4% of the farmers responded that eucalyptus tree causes the shading effects on the crop seedling, and compete nutrient and causing non-vigorous crop, respectively. In contrary, 61.5% of the respondents replied that eucalyptus does not compete moisture with the crop. This is may be the unobservable effects. In further, around 82.8% and 51.0% of the farmers perceived that, eucalyptus reduces soil fertility through allelopathic effect and dry out soil moisture in their locality, respectively.

Table 9: Overall perception of the farmers on the impacts of eucalyptus planting on environmental and crop

Nº	Statements	Response				Total
		Yes		No		
		n	%	n	%	N
1.	Sucking much water than other native tree species	162	84.4	30	15.6	192
2.	Dried streams, spring and bore holes	103	53.6	89	46.4	192
3.	Causes shading effect	105	54.7	87	45.3	192
4.	Compete nutrient with the crop	94	49.0	98	51.0	192
5.	Moisture competition	74	38.5	118	61.5	192
6.	Thinning seedling of crops	137	71.4	55	28.6	192
7.	Causing un-fertility and Allelophatic effect	159	82.8	33	17.2	192
8.	Change in the soil colour	36	18.8	156	81.3	192
9.	Causing drying out of the soil moisture	98	51.0	94	49.0	192
10.	Increase insects in the area	177	92.2	15	7.8	192
11.	Rise of native plant species number	49	25.5	143	74.5	192
12.	Increasing bird species	173	90.1	19	9.9	192
13.	Increased wild animals species	168	87.5	24	12.5	192

On biodiversity perspective, 92.2%, 90.1% and 87.5% of the farmers agreed that insects, birds and wild animal were increased. Similarly, Zerga (2015) noted that, due to eucalyptus enlargement, the existence of birds and wild animals threatened croplands. The above idea also deals out in the FGD. But, out of 192 farmers, 143 of them perceived the decrement of native plant species in Meket district.

To reduce the adverse effects of eucalyptus, the FGDs listed different management system like applying the fertilizer for nutrient replacement in the croplands, creating a buffer zone between the cropland and the eucalyptus woodlots having the distance 4-7 meter to reduce the shading effects on the crop seedlings and developmen6t of forage for animals in that reserved land.

62% of surveyed farmers didn't consider the environmental impacts of eucalyptus tree for its adoption. However, 33% of adopters was reacted that the perceived impacts of the eucalyptus have taken into consideration while making the decision to embrace the tree (table 10).

Table 10: Farmers' reflection for decisions of planting Eucalyptus on environmental implications

		Sample Farmers				Total	
		Non-adopters		Adopters			
Do you consider its environmental effects while deciding to plant Eucalyptus?	Responsen		%	n	%	n	%
	No	42	21.88	77	40.10	119	62.00
	Yes	8	4.17	65	33.85	73	38.00
Total		50	26.05	142	73.95	192	100.00

Conclusion

The overall finding indicated that, 23.32% of the surveyed farmers land was covered by eucalyptus tree. In addition, 57.7% (of the case) of surveyed farmers plant eucalyptus tree on the cropland which indicates excessive competition of productive land uses. 85.42% of the farmers were agreed on the progressive increment of eucalyptus tree cover. The remote sensing analysis also confirmed that, plantation of eucalyptus was increased from 6022, 7838, and 7930ha during 2003, 2010, and 2019, respectively. Yet again, most of the farmers preferred planting eucalyptus tree prominently for income generation, construction material and ease of the management.

The study also shows that there is a significant deviation between the adopters and non-adopters of eucalyptus in the case of the perceived risk of eucalyptus on the ecological components and crop production. Specifically, dried out of water sources, shading effects, nutrient competition and uptake, casing non-vigorous crop seedling, allopathic effects, attraction of insects and wild animals are among the perceived consequences of eucalyptus tree. However, the majority of the farmers ignored these effects to plant eucalyptus.

Recommendations

Being the crucial sources of income and construction material, rapid expansion of eucalyptus tree were examined in Meket district. Thus, the extension worker, researcher and other stakeholder should work on livelihood alternatives. Despite the benefits of eucalyptus tree, land use competition with crop lands should be tackled though participatory land use planning approach.

Provision of technical and informative trainings related to eucalyptus tree benefits, demerits and land allocations for plantation should be carried out. Like Tigray and Oromiya regional state, the Amhara National Regional State should revise the rural land use and administration policy for sustainable utilization and management of land resources. In further, adoption of Eucalyptus species those are free from environmental strains are recommended.

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