

# Environmental Impacts of Eucalypt Plantations in the Western Gurage Watersheds, Central-South Ethiopia

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## Research

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# Abstract

## Background

Ethiopia has the largest area of eucalypt plantations in East Africa and is one of the ten pioneer countries that introduced the eucalyptus (hereafter eucalypt for singular and eucalypts for plural). In Ethiopia eucalypt plantations constitute 58% of the total plantation cover followed by *Cupressus* (29%), *Juniperus procera* (4%) and pines (2%). According to various studies establishing exotic forest plantations like eucalypts species has been under big debate over the last three decades regarding the advantages and disadvantages of growing eucalypts. The purpose of this study, therefore, is to assess the environmental impact of eucalypt plantations in Western Gurage Watersheds, which is located in Central-South Ethiopia. The specific objectives of this study were: to describe farmers' land use practices in eucalypt plantations; to assess farmers' perception on environmental impacts (negative and positive) of eucalypt plantations on environment; and to explore empirical literatures on the environmental cons and pos of eucalypt plantations and policy options.

## Methods

Samples from three Woredas (Districts) namely Cheha, Enemorna Ener, and Eza located in the Watersheds were used. Systematic purposive sampling method was employed by selecting households with eucalypt woodlots from the list of each Woreda's Kebeles (sub districts). Close- and open- ended questionnaires were distributed to every fifth households possessing eucalypt plantations. To supplement the information; critical observation, discussions with focus groups and interviews with key informant were employed. The survey data were analyzed using both qualitative and quantitative techniques. To describe data acquired from critical observations, focus group discussions and key informant interviews; critical and logical qualitative data analysis technique were used. Data acquired from questionnaires were analyzed using Statistical Package for Social Sciences (SPSS) version 20. Descriptive and dispersive statistics such as frequency, percentage, mean, variance, standard deviation, p- value and correlation were employed. Empirical critical review on discussion was employed to investigate the reality on environmental aspect of the species in the country and elsewhere.

## Results

The result showed that households in the study area have enough knowledge on environmental aspects of eucalypts such as competition with other land uses, soil erosion, soil fertility, stream volume, microclimate change, and wildlife conflict after having experienced in using the species for many decades. From multiple responses given with regard to expected eucalypts driven farmland constraints; all (100%) of the households believed that shortage of grazing land shall become more serious, there will be reduction of cattle number, productivity of enset and other crops will be decreased, and the strong traditional attachment Gurages have with enset shall get loose. About 89% of the households believed that farming transformation may take place from enset based farming system to other form.

## Conclusions

Households have given more emphasis on socioeconomic importance of the species and its environmental externalities gained less attention particularly in using multidimensional management options in its optimum planting practices such as site selections and tinning. Hence farmland and grazing land sizes were reduced as a result of their conversion to eucalypt plantations. Thus strict land use management and policy should be practiced to reduce environmental adverse impacts, to save these diminutive land uses from eucalypts plantation conversion and to sustain the livelihood and cultural settings of the Gurage Community.

## 1. Introduction

Ethiopia has the largest area of eucalypt plantations in East Africa and is one of the ten pioneer countries that introduced the *eucalyptus* (hereafter eucalypt for singular and eucalypts for plural) (Getahun 2002). In Ethiopia eucalypt plantations constitute 58% of the total plantation cover followed by *Cupressus* (29%), *Juniperus procera* (4%) and pines (2%) (Teketay, 2000). According to various studies (Lugo, 1992; Senbeta, 1998; Calder, 2002; Senbeta et al., 2002) establishing exotic forest plantations like eucalypts species has been under big debate over the last three decades regarding the advantages and disadvantages of growing eucalypts.

Some of the commonly mentioned advantages include quick provision of benefits associated with fast growth, short rotation plantations for production of fuel wood and timber. Under proper management they are good source of forage for bees (honey production), can produce fiber for pulp and paper industries under relatively short rotation, can grow adequately in a wide range of ecological conditions and sites among others (Jagger and Pender, 2000; Teketay, 2000; Brooker, 2002; Calder, 2002).

On the contrary, despite these benefits, eucalypts have been said to have their disadvantages (FAO, 1988; Jagger and Pender, 2000; Teketay, 2000). These alleged disadvantages include consumption of much ground water associated with its high growth rate. They may not provide good soil protection against erosion and may not provide good habitats and supports biodiversity. Its leaf litter has adverse effects on soil humus.

In Ethiopia, such critiques have led to develop an opinion differences among academic circles and policy makers. Eucalypts' impacts and responses at different sites are complex and may require substantial research and adequate information before conclusive arguments can be made. Given these scenarios, conclusive decisions on eucalypts will likely be a major debate in the years to come. The curse-blessing debate concerning eucalypts is not a new phenomenon. But, it is now more charged with a mixture of fact and fiction (Negash, 1990 and 1999; Teketay, 2000). Most criticisms are based on a range of technical, ecological and socioeconomic arguments (FAO, 1988). According to Davidson (1989), many of the criticisms are unfair, biased, nationalistic or emotional. He noted that the criticisms would apply equally to other exotic trees planted in many countries; they are not peculiar to the eucalypts. On the one

hand, the genus is highly popular with farmers as a cash crop but on the other hand the eucalypts are blamed for a great many evils, notably the drying up of water courses, suppression of other vegetation, a cause of erosion and adverse effects on nutrient cycling and soil properties (FAO, 1988; Teketay, 2000).

The suspected negative environmental impact of eucalypt is a global concern; FAO thus tried to provide unbiased views by commissioning several global, regional and country level studies (Davidson, 1985; FAO, 1988). In the issue, there seem to be three groups involved: growers, environmentalists and researchers. Eucalypts growers obviously support its planting, while environmentalists, backed by agriculturists, emphasize the negative impact. Researchers, the third category, argue for a cautious and fair evaluation of the pros and cons.

The main arguments against the eucalypt include: 1) it drains water resources 2) it enhances soil

erosion 3) it suppresses undergrowth 4) it depletes soil nutrients 5) it introduces allelopathic effects (Davidson, 1985; FAO, 1988; Teketay, 2000; Getahun, 2002). The arguments supporting the genus include: 1) it is a fast growing tree 2) it requires minimum care 3) it grows in wide ecological zones and poor environments 4) it coppices after harvest 5) it resists environmental stress and diseases 6) the seeds are easy to collect, store and no pre-sowing treatment is required (FAO, 1979; Hailu, 2002; Mekonnen, et al., 2007). The controversies surrounding eucalypts in Ethiopia have attracted several policy debates, scientific literature and workshops, both national and regional. Thus, two national workshops have been organized since 2000. These were: 1) *Eucalyptus* Dilemma, November 15 2000 and 2) *Eucalyptus* Species Management, History, Status and Trends, September 15–17, 2010.

Despite the growing concern against planting eucalypts, most of the reports available on

eucalypts in Ethiopia and elsewhere are in favor of planting it. The species is supported by researchers and growers better than ever starting from its introduction to Ethiopia and elsewhere in the world (Moges, 1998; Teketay, 2000; Senbeta and Teketay, 2001; Yirdaw 2002; Senbeta et al. 2002; Limenih, et al. 2004; Limenih and Teketay, 2005)).

The negative impacts can be minimized provided that the choice of species and site as well as the management of the stands are appropriate (Poore & Fries, 1985; FAO, 1988; Moges, 1998; Senbeta, 1998). The benefit derived can offset the losses that can occur from such plantations (Poore & Fries, 1985; FAO, 1988; Davidson, 1989; Pohjonen, 1989; Pohjonen & Pukkala, 1990; Mihretu, 1993; Turnbull, 1999).

Therefore, the debate on eucalypts under the pretext of concern for indigenous forests is 'a storm in a tea cup' and must not widen the urgent attention. At the face of such body of evidence, it is wrong to assume that only the side the opponents perceived exists and that the proponents have only imagined what they did not observe. Therefore, the attempt to establish direct link between eucalypts and ecological risk or biodiversity erosion is a misrepresentation of the reality. It only reveals that their subjective perception of eucalypt has not embraced and even lacked contact with the objective gains from the species. If the prejudice with the dissemination of such message persists, it can lead to skepticism in certain circles. It can even give the impression that the more eucalypt is planted, the increased shortfall in agricultural production and the greater the loss of natural forest. This can obscure and negatively affect the immense importance that policy makers can play to provide the suitable atmosphere for exotic species establishment. But, more than one hundred year since its introduction, agricultural production has been maintained and streams continue to flow (Senbeta, 1998; Limenih and Teketay, 2005; Moges, 2010)! This study therefore attempted to investigate the environmental impacts of eucalypt plantations in Western Watersheds of Gurage Zone. The specific objectives were: to describe farmers' land use practices in eucalypt plantations; to assess farmers' perception on environmental impacts (negative and positive) of eucalypt plantations on environment; and to explore empirical literatures on the environmental cons and pos of eucalypt plantations and policy options.

## 2. Research Methods

### 2.1. Study area

The Gurage Zone is located in South Central Ethiopia with the location between 7<sup>0</sup>40' to 8<sup>0</sup>30' North and 37<sup>0</sup>30' to 38<sup>0</sup>40' East and covers an area of 5,932 km<sup>2</sup> (Fig. 1). The Zone is bounded with Oromia Region in the west, north and east, Yem Special Wereda (District) in the southwest, and Hadiya Zone in the south. The Gurage Zone consists of thirteen weredas, such as Abeshge, Kebena, Eza, Welene-Gedebano-Kutazer, Sodo, Meskan, Mareko, Gumer, Cheha, Enemorna Ener, Mihurna Aklil and Endegagn. Topographically, the Zone lies within an elevation, ranging from 1,000 to 3,638 m. The highest point in the Zone is Mt. Zebidar. The climate of Gurage Zone is affected by the altitudinal gradients. The four traditional agro-ecological zones (AEZs), namely Afro-Alpine (Wurch), Temperate (Dega), Sub-tropical (Woina-Dega) and Tropical (Kolla) are found in the Zone. However, Woina Dega is the dominant one. The average temperature ranges from < 3<sup>0</sup>C in the Gurage mountain chains to 28<sup>0</sup>C in the Ghibe Gorge. The annual range of rainfall falls between 600 and 1,900mm. These ranges of agro-ecology have enabled the Zone to grow different types of crops, such as *enset* (*Ensete ventricosum* (Welw.) Cheeseman) (hereafter referred to as *Enset*), cereals, pulses, oil seeds, vegetables and fruits as well as support livestock, sheep, goat and pack animals. Different wild animals and birds inhabit the Zone, owing to this climatic diversity.

As noted by Woldetsadik (1994), soil colors in the *Enset* growing areas, like Gurage Zone, range from brown and black to red. Two of the soil groups, Pellic Vertisols and Euristic Nitisols, are most common and cover more than 60% of the region. Depending upon the population pressure and local farming systems, Vertisols are intensively cultivated and mostly devoted to grain production in the Dega (high plateaus). However, they are left largely for grazing in the low plateaus, the lower Woina-Dega and the upper Kolla sections of the region. Based on the 2007 census conducted by the Central Statistical Agency (CSA) of Ethiopia, this Zone has a total population of 1,279,646 of whom 622,078 are male and 657,568 are female. The Zone has a population density of greater than 450 person km<sup>-2</sup>. About 9.36% of them are urban inhabitants and the remaining are rural dwellers. Gurage Zone is one of the most densely populated areas in Ethiopia. High population pressure and a long history of settlement have resulted in an increasing quest for agricultural land, wood for farmhouse construction, fuel and other uses. This, in turn, has resulted in the degradation of the natural forests and shrubs along river valleys (Woldetsadik, 2003).

Gurage Zone is divided by four drainage basins, namely Awash, Rift Valley, Blate and Omo-Gibe (Sahle et al., 2018). With the exception of minor deviations at local level, the streams in the Zone have a dendrite drainage pattern. The direction of flow of the streams may vary depending upon orientation of local relief at micro level. However, all the major streams ultimately drain to west and south-west/east ward following the general inclination of the slope direction of the Zone. The Western Gurage Watersheds drain to Omo-Gibe Basin and covers large areas. In the western parts of Gurage, several rivers and streams are available, which drains from East to West to Gibe River. The major rivers are Wabe, Winike, Megecha, Rebu, Zizat, Gogare and Dire. These rivers have several numbers of streams, which emerge from the Gurage Mountains and join at different locations. The rivers Winike, Gogare and Derie are the main rivers next to Wabe River, and together cover an area of 173,476 ha (Fig. 1).

From these, the main watershed is Winike, which includes Megecha and Zizat rivers and covers an area of 117, 030 ha. The Gogare and Drie watersheds cover an area of 30,739 and 25,707 ha, respectively.

The five districts of Gurage Zone, i.e. Eza, Cheha, Gumer, Geta and Enemorna Ener, are found in these watersheds. These watersheds areas share almost all characteristics of Gurage Zone. These watersheds were selected due to their dense population and high coverage of eucalypts under expansion.

## 2.2. Secondary Data

To get clear understanding of the concept such as eucalypts' expansion, eucalypts' completion, income diversification, livelihood support and the like, secondary data from journals, theses, and reports were reviewed critically. In this part exclusion and inclusion approach, selecting and retrieving the appropriate and recent literatures were made. Thereafter the final report (findings) was analyzed and synthesized to show and fill the research gap.

## 2.3. Primary data

### 2.3.1. Sampling method, procedure and distribution

The study area, Gurage Zone has thirteen Woredas (Districts) with 1,279,646 populations (CSA, 2007). For the purpose of the study, samples from three Woredas located within Western Watersheds of Gurage Zone were collected. The selected Woredas were Cheha, Enemorna Ener, and Eza. These Woredas were purposefully selected due to large coverage of the watersheds, dramatic expansion of eucalypts farming and hereby high eucalypts pole production, incidences of serious competition of eucalypts with other uses, and the presences of road accessibility for data collection. Thus, these Woredas were representatives of eucalypt plantation activities since eucalypt growing and land holding system are more or less similar in the other parts of the Zone.

To get primary data about the study, systematic purposive sampling method was employed. Thus, after selecting households with eucalypt woodlots from the list of each Woreda's Kebeles (the lowest administrative unit), closed and open ended questionnaires were distributed to every 5th households possessing eucalypt plantations. The main reason for selecting this sampling method is to avoid the inclusion of non-eucalypt tree farmers and to keep the validity of the representative samples (to cover large villages within the Kebeles).

### 2.3.2. Sample size determination

From the total 71792 household population living in the three woredas (CSA, 2007), 383 household respondents were selected using the following formula by assuming confidence level at 95% and margin of error) at 5%. The sampling formula is shown as follow (Cothari, 2004).

$$n = Z^2 (p) (q) / d^2$$

Where, p = sample proportion of successes or 0.5;

q = Probability of failure (1 - p or 1 - 0.5 = 0.5);

d = margin of error and it is 5% (0.05)

n = number of trials (size of the sample);

z = standard variate for given confidence level (as per normal curve area table) and it is 1.96 for a 95%.

$$\text{Therefore: } n = 1.96^2(0.5)(0.5)/0.0025$$

$$n = 1.96^2 * 0.25 / 0.0025$$

$$n = 384$$

$$\text{Therefore: } S = N - n / N - 1(n) = 71792 - 384 / 71792 - 1 * 384$$

$$S = 383$$

Where, N = number of household in the woredas

S = sample size

Table 2.1  
Sample size and sampling distribution.

No.	Woredas	Agroclimatic zone Types	Sample kebeles based on agroclimate	Total Population	No. of Kebeles	No. of Households	No. of sample Households			%	
1	Cheha	Dega, Woina dega and Kolla	Moche, Wodro and Azerna Sise	115,918	38	27,527	143	D	W	K	37
							47	49	47		
2	Enemorna Enner	Dega, Woina dega and Kolla	Agata, Terede and Gonche Bete	167,745	65	25,315	140	45	47	48	37
3	Eza	Dega, Woina dega and Kolla	Worit, Shebraden and Zigba Boto	84,882	28	18,950	100	33	34	33	26
<b>Total</b>			<b>9</b>	<b>368,545</b>	<b>131</b>	<b>71,792</b>	<b>383</b>				<b>100</b>
D = Dega; W = Woina dega; K = Kolla											
Source: Compiled from CSA, 2007											

As stated in Table 2.1, from the selected four Kebeles, 383 households were surveyed as unit of analysis. These households were representatives of eucalypts plantation activities since eucalypts growing and tenure system are more or less the same in the Woredas. The numbers of households asked were 143, 140, and 100 in Cheha, Enemorna Ener, and Eza Woredas respectively. These sample sizes were selected based on the extent of expansion. The selected Kebeles in each district represented *Kola* (lowland), *Woinadega* (midland) and *Dega* (upland) traditional climatic zones. Thus 47, 49 and 47 households in Moche, Wodro and Azerna Sise Kebeles respectively were selected from Cheha Woreda; 45, 47 and 48 households in Agata, Terede and Gonche Bete Kebeles respectively were selected from Enemorna Ener Woredas; and 33, 34 and 33 households in Worit, Shebraden and Zigba Boto Kebeles respectively were selected from Eza Woreda. Tabular data analyses employed are based on the Woreda pooled results to reduce burdened numerical information of the nine Kebeles.

To supplement the information; critical observation, discussions with focus groups and key informant interviews were employed. Individual farm households whose were age were greater than 70 years old and knowledgeable persons to discuss on the eucalypts plantations, reasons for expansion, conversion of crop land to eucalypts woodlot and others were selected. Thereafter, three focus group discussions with farm households were conducted in the three districts. Each group included six up to eight members. The discussions were guided by facilitator during which group members were encouraged to talk freely on raised topics. Key informant interviews were conducted with well experienced individual farm households and experts in each district. Hence a total of nine key informants were selected from nine sample Kebeles of the three districts. Important professional key informant interviews were employed with six agricultural and natural resources experts from the three districts (two experts from each). Interviews with Agricultural Development Agents (DAs) and kebele chairpersons were employed. In each district individual interviews and informal communications with eucalypt pole traders and middle men were conducted. From all the focus group discussions and interviews valuable and detail information were gathered by principal researcher and assistants with the help of voice recording device and smart phone camera. After transcribing the audio documents in to written words, translation to English was performed. Thereafter, all the information investigated were included in the appropriate result and discussion parts of the research. The discussions were supported by various actual field photos.

### 2.3.3. Method of Data Analysis

The survey data were analyzed using both qualitative and quantitative techniques. To describe data acquired from critical observations, focus group discussions, key informants' interviews, critical and logical qualitative data analysis technique were used. Data acquired from questionnaires were analyzed using Statistical Package for Social Sciences (SPSS) version 20. Descriptive and dispersive statistics such as frequency, percentage, mean, variance, standard deviation, p-value and correlation were employed.

## 3. Results

### 3.1. Households' awareness on environmental impacts of eucalypts

Households in the study area have enough knowledge on environmental aspects of eucalypts after having many decades of experiences in using the species for various needs. They have given more emphasis to socioeconomic importance of the species and its environmental externalities gained less attention particularly in using multidimensional management options. As depicted in Table 3.1 below, about 87% of the households reported that they have heard messages about environmental impacts of eucalypt plantations. Only 13% of the rest did not hear any message towards such impacts. The three Woredas responses were proportional perceptions as to the pooled result. Those respondents who did not hear any message about the environmental impacts of the species were young farmers who were more attracted by its economic rewards and had short span experience in planting the species. Households practiced eucalypts tree planting as environmental conservation mechanisms in their private possessions. As described in Table 3.2 below, 84% of the households practiced environmental conservation using eucalypts planting particularly on the gully sides and erosion prone areas. The rest 16% of them did not practice eucalypts for this purpose. As clearly observed by researcher most gully sides and eroded lands of private possessions are becoming covered with eucalypts, whereas communal lands with similar problems are covered with *Grevillea robusta*, pines, *corpuses lusitanica*, and *juniperus procera* through government launched participatory watershed management.

Table 3.1  
Households' response on whether they heard any message about environmental impact of eucalypts or not.

Response	Cheha	%	En/Ener	%	Eza	%	Total	%
Yes	126	88	124	89	85	85	335	87
No	17	12	16	11	15	15	48	13

Source: Field Survey (2017).

Table 3.2  
Households' response on whether they have practiced in environmental conservation through eucalypts tree planting or not.

Response	Cheha	%	En/Ener	%	Eza	%	Total	%
Yes	121	85	122	87	78	78	321	84
No	22	15	18	13	22	22	62	16
Source: Field Survey (2017).								

As can be seen in Table 3.3 below, 78% of the households believed that population growth should not be controlled to alleviate environmental degradation. Their reason as reported in focus group and key informant discussion is that population growth is not aggravating such problem since farmers care for their lands. The other 22% of the respondents reported that population growth have impact on environmental degradation claiming that further crops and eucalypts planting shall leads to land exhaustion and degradation. The mean and standard deviation values are 127.67 and 125.34 respectively. The P-Value is 0.02082. The result is significant at  $p < 0.05$ . As clearly observed by researcher, population growth is not a major cause for land degradation in the study area, rather lack of appropriate land use management is a curtail problem. As reported by Woldetsadik (2003) more people more tree situation of Boserupian Theory is working in the Gurage area and thus land degradation and population growth have nothing to do with negative relationships. That is why eucalypts expansion in the study area is seen as environmental recovery since it covered extensive areas including gully sides and badlands. It has substituted forest degradation/deforestation. Hence eucalypt is seen as a blessing not a curse species in Gurage area, no matter how its competition with farm and grazing lands is threatening the area.

Table 3.3  
Households' response on whether population growth should/not be controlled to alleviate environmental degradation

Response	Cheha	%	En/Ener	%	Eza	%	Total	%
Yes	30	21	26	19	29	29	85	22
No	113	29	114	81	71	71	298	78
Do not know	0	0	0	0	0	0	0	0
<b>Mean</b>	<b>47.67</b>		<b>46.67</b>		<b>33.33</b>		<b>127.67</b>	
<b>Variance</b>	<b>2284.22</b>		<b>2379.56</b>		<b>849/56</b>		<b>15710.89</b>	
<b>Std.dev.</b>	<b>47.79</b>		<b>48.78</b>		<b>29.15</b>		<b>125.34</b>	
Source: Field Survey (2017).								

### 3.2. Households' expected farmland constraints

As depicted in Table 3.4 below, from multiple responses given with regards to expected eucalypts driven farmland constraints; all (100%) of the households believed that shortage of grazing land shall become more serious, there will be reduction of cattle number as a result of its conversion to eucalypt woodlots, productivity of *enset* and other crops will be decreased, and the strong traditional attachment Gurages have with *enset* shall get loose. About 89% of the households believed that farming transformation may take place from *enset* based farming system to other form. The other 23% of them believed that there will be serious surface run off. The mean and standard deviation values are 85.33 and 78.16 respectively. The P-Value is 0.00007. The result is significant at  $p < 0.05$ . All the perceptions understood by households are logical and only ideal land uses planning and management will balance all these constraints which are very serious as far as the Gurage cultural, livelihood and environmental settings are concerned.

Table 3.4  
Households' multiple response on expected farmland constraints in the near future due to eucalypts.

NO.	Responses	Cheha	%	En/Ener	%	Eza	%	Total	%
1	Shortage of grazing land shall become more serious	143	100	140	100	100	100	383	100
2	There will be reduction of cattle number	143	100	140	100	100	100	383	100
3	Productivity of <i>enset</i> and other crops will be decreased	143	100	140	100	100	100	383	100
4	The strong traditional attachment Gurages have with <i>enset</i> shall get loose	143	100	140	100	100	100	383	100
5	There will be serious surface run off	35	24	36	26	19	19	90	23
6	Farming transformation may take place from <i>enset</i> based farming system to other form	126	88	128	91	88	88	342	89
<b>Mean</b>		<b>122.17</b>		<b>120.67</b>		<b>84.5</b>		<b>327.33</b>	<b>85.33</b>
<b>Variance</b>		<b>1558.14</b>		<b>1452.89</b>		<b>877.25</b>		<b>11489.56</b>	<b>793.22</b>
<b>Std. dev.</b>		<b>39.47</b>		<b>38.12</b>		<b>29.62</b>		<b>107.19</b>	<b>78.16</b>

Source: Field Survey (2017).

### 3.3. Land use practice of eucalypts plantations

As depicted in Table 3.5, households who spent 2 to 5, 6 to 10, 11 to 20 and 21 to 30 minutes of average walking distance from eucalypt stands to the nearby grazing lands accounted 31%, 22%, 26%, and 21% respectively. Households who spent 2 to 5, 6 to 10, 11 to 20 and 21 to 30 minutes of average walking distance from eucalypt stands to the nearby farmland accounted 38%, 28%, 27%, and 7% respectively. Households who spent 2 to 5, 6 to 10, 11 to 20 and 21 to 30 minutes of average walking distance from eucalypt stands to the nearby stream accounted 42%, 46%, 7%, and 5% respectively. Households who spent 2 to 5, 6 to 10, 11 to 20 and 21 to 30 minutes of average walking distance from eucalypt stands to the horticulture accounted 8%, 6%, 40%, and 46% respectively.

Households who spent 2 to 5, 6 to 10, 11 to 20 and 21 to 30 minutes of average walking distance from eucalypt stands to homestead accounted 5%, 10%, 37%, and 48% respectively. Households who spent 2 to 5, 6 to 10, 11 to 20 and 21 to 30 minutes of average walking distance from eucalypt stands to road accounted 36%, 46%, 8%, and 10% respectively. The mean values of households who spent 2 to 5, 6 to 10, 11 to 20 and 21 to 30 minutes of average walking distance from eucalypt stands to all land uses accounted for 102.3, 101.3, 92 and 87.33 respectively. The standard values of households who spent 2 to 5, 6 to 10, 11 to 20 and 21 to 30 minutes of average walking distance from eucalypt stands to all land uses accounted for 61.34, 66.51, 54.35 and 74.5 respectively. The aggregate P-Value is 0.000036. The result is significant at  $p < 0.05$ . Hence eucalypt stands are in general relatively far away from homestead and horticulture and near to grazing land, farmland, stream and road. Since the average landholding size of the area is about 0.52 hectare, the species is competing to the latter land uses first and its final destination is to the former land uses. Unless urgent land use management is applied by the government and other bodies, the area in the near future will be transformed to eucalypt landscapes topography much higher than ever in the land use history of the area. The finally destiny will result in total food insecurity and alteration of environmental and cultural settings.

Table 3.5  
The average walking distance from eucalypt stands to different land uses in minutes

Distance to land uses	Distance in minutes							
	2-5	%	6-10	%	11-20	%	21-30	%
Distance to the nearby grazing land	120	31	85	22	100	26	78	21
Distance to the nearby farmland	145	38	107	28	102	27	29	7
Distance to the nearby stream	160	42	178	46	25	7	20	5
Distance to the horticulture	30	8	21	6	155	40	177	46
Distance to homestead	20	5	40	10	140	37	183	48
Distance to road	139	36	177	46	30	8	37	10
<b>Mean</b>	<b>102.3</b>		<b>101.3</b>		<b>92</b>		<b>87.33</b>	
<b>Variance</b>	<b>3763</b>		<b>4423</b>		<b>2954</b>		<b>5550</b>	
<b>Std. dev.</b>	<b>61.34</b>		<b>66.51</b>		<b>54.35</b>		<b>74.5</b>	

Source: Field Survey (2017).

### 3.4. The perceived Environmental changes

Households know all the multidimensional environmental changes perceived as a result of eucalypt plantation in their localities through experience and they are confidential to describe the indicators accordingly. As indicated in Table 3.6 below, all the households (100%) reported that eucalypts have

multidimensional effect. Thus from the given indicators, as depicted in Table 3.7 below, 39%, 20%, 5% 5% and 2% of the households reported that there is major decrease, minor decrease, no change, minor increase and major increase respectively towards soil erosion. Hence collectively about 74% of them are optimists and seen the species as a conservation safeguard. About 38%, 46% and 16%, of the households reported that there is major decrease, minor decrease and no change respectively towards soil fertility. None of them reported that there is minor increase and major increase observed in soil fertility. Here collectively 84% of them seen it as an agent of soil degradation.

About 62%, 29% and 9% of the households reported that there is major decrease, minor decrease and no change respectively towards stream flow volume. Here about 91% of the households have perceived a decreasing situation of stream flow. Hence eucalypt died up or reduced the volume of smaller tributaries and springs. None of them reported that there is minor increase and major increase observed in stream flow volume. About 34% and 66% of the households reported that there is minor increase and major increase respectively towards competition with croplands. Hence all of them perceived its serious competition with croplands. None of them reported that there is major decrease, minor decrease and no change observed in competition with croplands. About 66%, 8%, 12%, 5% and 9% of the households reported that there is major decrease, minor decrease, no change, minor increase and major increase respectively towards gully formation. Hence collectively 74% of them perceived a decreasing situation of gully formation. That is why most gully sides in private landholdings are covered with eucalypt plantations as a safeguarding strategy.

About 70%, 29% and 1% of the households reported that there is major decrease, minor decrease and no change respectively towards undergrowth. Hence almost all of them perceived a decreasing situation of undergrowth. None of them reported that there is minor increase and major increase observed in under growth. About 15% and 85% of the households reported that there is minor increase and major increase respectively towards presence of birds. Here all of them perceived that eucalypt is serving as a home to birds. None of them reported that there is major decrease, minor decrease and no change observed in presence of birds. About 79%, 16% and 5% of the households reported that there is major increase, minor increase and no change respectively towards presence of wild animals. Hence collectively 95% of them perceived that there is an increasing situation in presence of wild animals. Eucalypt is used as a hiding and transitional agent after wild animals cross over the forests or bushlands. None of them reported that there is major decrease and minor decrease observed in wild animals. That is why the area is known for wild animals' conflict and thereby domestic animals and crops are attacking by them much higher than ever as reported by focus groups and key informants.

There is a mean value of 104.6, 65, 20, 78.63 and 114.8 for major decrease, minor decrease, no change, minor increase and major increase respectively for all indicators. There is a standard deviation value of 110.9, 65, 20.96, 88.71 and 150.4 for major decrease, minor decrease, no change, minor increase and major increase respectively for all indicators. The aggregate P-Value is 0.037277. The result is significant at  $p < 0.05$ . Thus households were intrinsically following the perceived environmental changes, however, land diminution and short term valuable reward gained from its product overshadowed their opportunity to apply the optimum land use alternatives.

Table 3.6  
Households' response on whether eucalypts have multidimensional effect or not.

Response	Cheha	%	En/Ener	%	Eza	%	Total	%
Yes	143	100	140	100	100	100	383	100
No	0	0	0	0	0	0	0	0

Source: Field Survey (2017).

Table 3.7  
The indicators of perceived environmental changes.

Indicator	Changes									
	Major decrease		Minor decrease		No change		Minor increase		Major increase	
		%		%		%		%		%
Soil erosion	150	39	78	20	20	5	130	34	5	2
Soil fertility	145	38	175	46	63	16	0	0	0	0
Stream flow volume	240	62	110	29	33	9	0	0	0	0
Competition with cropland	0	0	0	0	0	0	130	34	253	66
Gully formation	253	66	30	8	20	5	35	9	45	12
Under growth	267	70	112	29	4	1	0	0	0	0
Presence of birds	0	0	0	0	0	0	56	15	327	85
Presence of wild animals	0	0	0	0	20	5	60	16	303	79
<b>Mean</b>	<b>104.6</b>		<b>65</b>		<b>20</b>		<b>78.63</b>		<b>114.8</b>	
<b>Variance</b>	<b>12300</b>		<b>4225</b>		<b>439.1</b>		<b>7870</b>		<b>22620</b>	
<b>Std. dev.</b>	<b>110.9</b>		<b>65</b>		<b>20.96</b>		<b>88.71</b>		<b>150.4</b>	

Source: Field Survey (2017).

As can be indicated in Table 3.8 below, 52% and the remaining 48% of the households reported that there are crops which resist and do not resist negative effect of eucalypts. The former stated crops such as wheat, maize, peas and bean, and most perennials resist the effects when planted in the nearby areas. The later reported that all crops are susceptible and its effect is not selective and clearly seen in the quantity and quality of production of annuals and perennials. As shown in Table 3.9 below, all households reported that there are dried streams, rivers, and springs due to eucalypt tree plantations in their localities. As observed by the researcher the volume of the known rivers in the study area are decreased dramatically particularly in dry seasons. Even in rainy seasons rivers which were known for their overflow out of their natural channels were decreased their volume due to the decrease in the volumes of tributaries and disappearance of smaller springs and through flow (seeping).

Table 3.8  
Households' response on whether there is difference among crop species in resisting negative effects of eucalypt or not.

Response	Cheha	%	En/Ener	%	Eza	%	Total	%
Yes	70	49	70	50	59	59	199	52
No	73	51	70	50	41	41	184	48
Source: Field Survey (2017).								

Table 3.9  
Households' response on whether there are dried streams, rivers and springs due to eucalypt trees plantation or not.

Response	Cheha	%	En/Ener	%	Eza	%	Total	%
Yes	143	100	140	100	100	100	383	100
No	0	0	0	0	0	0	0	0
Source: Field Survey (2017).								

As shown in Table 3.10 below, from multiple responses given towards changes observed in the forest cover after the expansion of eucalypts since the last 20 years, 100%, 95%, 20% and 6% of the households reported that eucalypt tree cover has increased, natural forest has increased, other plantation forests have increased and natural forest has decreased respectively. None of them reported that natural forest has disappeared. The mean and standard deviation values are 169.4 and 168.96 respectively. The P-Value is < 0.00001. The result is significant at  $p < 0.05$ . As clearly observed from the figures, eucalypts' cover increment and its substitution in fuel wood and construction resulted in the regeneration of forests and thereby there is increasing trend of the overall coverage. As clearly revealed in Table 3.11 below, 100%, 100%, 17%, 79% and 45% of the households perceived that stream flows are decreased or dried, farmlands are fragmented, runoffs are increased, yields are declined and gullies and rills are created respectively. The mean and standard deviation values are 260.8 and 124.49 respectively. The P-Value is < 0.00001. The result is significant at  $p < 0.05$ . The perception on incidence of runoffs as seen is minimal and about 83% of the households believed that eucalypt has nothing to do with it and in contrary they plant it to reduce runoff.

Table 3.10  
Households' multiple responses on changes perceived in the forest cover after the expansion of eucalypts since the last 20 years.

Responses	Cheha	%	En/Ener	%	Eza	%	Total	%
Natural forest has disappeared	0	0	0	0	0	0	0	0
Eucalypt tree cover has increased	143	100	140	100	100	100	383	100
Natural forest has increased	130	91	140	100	95	95	365	95
Natural forest has decreased	8	6	9	6	6	6	23	6
Other plantation forests have increased	28	20	32	23	16	16	76	20
<b>Mean</b>	<b>61.8</b>		<b>64.2</b>		<b>43.4</b>		<b>169.4</b>	
<b>Variance</b>	<b>3821.16</b>		<b>3939.36</b>		<b>1979.84</b>		<b>28547.44</b>	
<b>Std. dev.</b>	<b>61.81</b>		<b>62.76</b>		<b>44.49</b>		<b>168.96</b>	
Source: Field Survey (2017).								

eucalypts since the last 20 years.

Table 3.11  
Households' multiple response on negative changes perceived due to eucalypt.

Negative changes	Cheha	%	En/Ener	%	Eza	%	Total	%
Stream flow decreased or dried	143	100	140	100	100	100	383	100
Farmland fragmented	143	100	140	100	100	100	383	100
Runoff increased	25	17	23	16	18	18	66	17
Yield has declined	108	76	110	79	83	83	301	79
Gullies and rills created	45	31	78	56	48	48	171	45
<b>Mean</b>	<b>92.8</b>		<b>98.2</b>		<b>39.8</b>		<b>260.8</b>	
<b>Variance</b>	<b>2430.56</b>		<b>1939.36</b>		<b>1031.36</b>		<b>15498.56</b>	
<b>Std. dev.</b>	<b>49.30</b>		<b>44.04</b>		<b>32.11</b>		<b>124.49</b>	
Source: Field Survey (2017).								

As depicted in Table 3.12 below, households had enough experience towards microclimate change due to eucalypts over time. Thus 10%, 67% and 23% of the households perceived as bad, good and very good respectively towards the status of microclimate change in 2017. About 19%, 60% and 21% of the households perceived as bad, good and very good respectively towards the status of microclimate change in 5 years ago (2012). About 22%, 40% and 38% of the households perceived as bad, good and very good respectively towards the status of microclimate change in 2007 (10 years ago). About 25%, 34% and 41% of the households perceived as bad, good and very good respectively towards the status of microclimate change in 1997 (20 years ago). The mean and standard deviation values are 126.83 and 62.82 respectively. The P-Value is 0.000023. The result is significant at  $p < 0.05$ . Hence collectively most of the households perceived that eucalypts have good or very good trends in microclimate change over twenty years period. Those households who reported that they perceived bad trends in the aforementioned change might be due to lack of awareness on the concept of local climate change trends. Hence these households might have poor knowledge of climatic balance of the species in their locality.

Table 3.12  
Perceptions on the trend of micro climate change due to eucalypts over time.

Response	Now/2017		5 years ago/2012						10 years ago/2007						20 years ago/1997								
	1	%	2	%	3	%	1	%	2	%	3	%	1	%	2	%	3	%	1	%	2	%	3
Trend of microclimate change	38	10	256	67	89	23	70	19	230	60	73	21	86	22	152	40	145	38	95	25	131	34	15
<b>Mean</b>	<b>126.83</b>																						
<b>Variance</b>	<b>3945.81</b>																						
<b>Std. dev.</b>	<b>62.82</b>																						
1 = Bad, 2 = Good, 3 = Very good																							

Source: Field Survey (2017).

As described in Table 3.13 below, from the given multiple responses all the households preferred planting eucalypts in upslope, down slope, degraded and marginal areas. They do not preferred planting close to streams and farmlands, and over grazing areas. However, practically they are not practicing this assumption as a result of unsuitable nature of the former locations in harvesting and transportation. Thus they forced to plant in the later locations which is scientifically not advisable due to serious land use competition with crop, grazing and wet lands.

Table 3.13  
Households' multiple preference on location of eucalypts planting.

Location of planting	Cheha	%	En/Ener	%	Eza	%	Total	%
Upslope areas	143	100	140	100	100	100	383	100
Down slope areas	143	100	140	100	100	100	383	100
Degraded areas	143	100	140	100	100	100	383	100
Marginal areas	143	100	140	100	100	100	383	100
Close to streams	0	0	0	0	0	0	0	0
Close to farmlands	0	0	0	0	0	0	0	0
Over grazing areas	0	0	0	0	0	0	0	0
Source: Field Survey (2017).								

### 3.5. Impacts of Eucalypt plantations on the land use system

As depicted in Table 3.14 below, from multiple responses given about land use pattern, all (100%) households devoted their land under *enset*, vegetables, cereal crops, eucalypts, grazing and grasslands. Lands under orchards, *chat*, and coffee accounted 92%. Bushland and degraded areas constituted 40% and 25% respectively. The mean and standard deviation values are 321.8 and 107.55 respectively. The P-Value is < 0.00001. The result is significant at  $p < 0.05$ . The small possession of bushlands and grazing lands are due to the conversion of these lands to eucalypt woodlots.

Table 3.14  
Households' multiple responses on their land use pattern.

Land use pattern	Cheha	%	En/Ener	%	Eza	%	Total	%
Land under <i>enset</i>	143	100	140	100	100	100	383	100
Land under vegetables	143	100	140	100	100	100	383	100
Land under cereal crops	143	100	140	100	100	100	383	100
Land under orchards, <i>chat</i> , and coffee	123	86	134	96	95	95	352	92
Eucalypt woodland	143	100	140	100	100	100	383	100
Grazing land	143	100	140	100	100	100	383	100
Bushland	61	43	62	44	29	29	152	40
Degraded area	32	22	34	24	28	28	94	25
Grassland	143	100	140	100	100	100	383	100
<b>Mean</b>	<b>119.33</b>		<b>118.89</b>		<b>83.56</b>		<b>321.8</b>	
<b>Variance</b>	<b>1600.44</b>		<b>1482.76</b>		<b>868.47</b>		<b>11567.73</b>	
<b>Std. dev.</b>	<b>40.01</b>		<b>38.51</b>		<b>29.47</b>		<b>107.55</b>	
Source: Field Survey (2017).								

As can be shown in Table 3.15 below, households use their land holding size for different uses per hectare in different decades. From different uses eucalypts and *enset* ranked 1st and 2nd in the three decades of 1990s, 2000s and 2010s by accounting 13%, 36% and 45%; and 16%, 24% and 20% respectively. Grazing, grass and degraded lands taken the next share of land holding size. The aggregate mean and standard deviation values are 1.91 and 6.18 respectively. The aggregate P-Value is < 0.00001. The result is significant at  $p < 0.05$ . All others are possessed very small holdings. Hence their former sizes were reduced as a result of their conversion to eucalypt plantations. The average landholding size is about 0.52 hectare. Thus strict land use management and policy should be practiced to save this diminutive land use from eucalypts plantation conversion. As described in Table 3.16 below, 68%, 86%, 100%, 73%, 88%, 58%, 75% and 86% of the households reported that they plant eucalypts on the farm land with crops, farm boundary, degraded lands (gully sides), previously cultivated land, around the course of streams, close to settlement, along roadside, and on grazing lands respectively. The mean and standard deviation values are 301.13 and 45.93 respectively. The P-Value is 0.037375. The result is significant at  $p < 0.05$ . This shows that most of the sites are not considered as ideal sites except on degraded lands (gully sides) and along road sides mixed with indigenous plants. Their opportunity to use ideal sites is already overshadowed by its multidimensional and short term benefit.

Table 3.15  
Households' land holding size for different uses per hectare in different decades.

Land use type	Land use in hectare (1990s)	%	Land use in hectare (2000s)	%	Land use in hectare (2010s)	%
Eucalypt woodlots cover	0.066	13	0.182	36	0.226	45
Area under cereal crops	0.041	8	0.034	7	0.029	6
Area under pulses	0.035	7	0.023	5	0.013	3
Area under <i>enset</i>	0.082	16	0.122	24	0.099	20
Orchard	0.015	3	0.034	7	0.012	2
Coffee	0.009	2	0.023	0.5	0.005	1
<i>Chat</i>	0.003	0.6	0.074	15	0.009	2
Shrubland	0.008	2	0.014	3	0.002	0.4
Grazing area	0.089	18	0.008	2	0.062	12
Degraded area	0.086	18	0.006	1	0.064	12
Grassland	0.073	15	0.069	14	0.006	1
Total	0.507		0.520		0.526	
<b>Mean</b>	<b>0.046</b>		<b>0.34</b>		<b>5.37</b>	
<b>Variance</b>	<b>0.0011</b>		<b>0.0028</b>		<b>312.48</b>	
<b>Std. dev.</b>	<b>0.33</b>		<b>0.53</b>		<b>17.68</b>	
Source: Field Survey (2017).						

Table 3.15  
Households' multiple response on location of eucalypts plantation.

Location of eucalypts	Cheha	%	En/Ener	%	Eza	%	Total	%
On the farm land with crops	96	67	102	73	64	64	262	68
On farm boundary	122	85	123	88	85	85	330	86
On degraded lands (gully sides)	143	100	140	100	100	100	383	100
On previously cultivated land	104	72	101	72	73	73	278	73
Around the course of streams	115	80	116	83	85	85	316	83
Close to settlement	81	57	82	59	60	60	223	58
Along roadside	103	72	97	69	88	88	288	75
On grazing lands	123	86	121	86	85	85	329	86
<b>Mean</b>	<b>110.88</b>		<b>110.25</b>		<b>80</b>		<b>301.13</b>	
<b>Variance</b>	<b>317.86</b>		<b>290.44</b>		<b>155.5</b>		<b>2109.61</b>	
<b>Std. dev.</b>	<b>17.83</b>		<b>17.04</b>		<b>12.47</b>		<b>45.93</b>	
Source: Field Survey (2017).								

As shown in Table 3.17 below, 7% and 93% of the households removed and did not remove respectively for eucalypt woodlots for agricultural use. The lesser number of households who removed the species for agricultural use is attributable for the non-affordability of the households to use tractors for this purpose. As reported by focus groups, those households who afforded using tractors are relatively wealthy ones either by themselves or by remittance support.

Table 3.17  
Households' response on whether they removed eucalypt woodlots for agricultural use or not.

Response	Cheha	%	En/Ener	%	Eza	%	Total	%
Yes	11	8	8	6	8	8	27	7
No	132	92	132	94	92	92	356	93
Source: Field Survey (2017).								

Households perceived yield risk level of farming types. As shown in Table 3.18 below, 39%, 26%, 27% and 8% of households reported that *enset* crop is highly risky, risky, moderately risky and not risky respectively in yield. About 36%, 39%, 25% and 0% of households reported that annual foods crop are highly risky, risky, moderately risky and not risky respectively in yield. Similar risk levels are followed by vegetables, cash crops and mixed cropping. About 94% and 6% of households reported that eucalypt woodlots are not risky and moderately risky respectively in yield. None of them reported that it is highly risky and risky. Similar case is followed by fruit trees. The aggregate mean and standard deviation values are 95.75, 75.34 respectively. The P-Value is 0.000069. The result is significant at  $p < 0.05$ . Hence the yield risk level is less perceived in eucalypt woodlots and fruit trees. This might be attributable for the perennial nature of these two products and less requirement of farm management. Eucalypt woodlots insusceptibility for most risks is already scientifically justified. Its completion with the former farming types aggravated risk level in yield. One of farmers' attractions of planting more eucalypts is also attributable for its less riskiness.

Table 3.18  
Households' response on yield risk level of farming types.

Farming type	Risk level								Aggregate	
	Highly risky	%	Risky	%	Moderately risky	%	Not risky	%		
Enset crop	150	39	100	26	102	27	31	8	100	
Annual food crops	137	36	149	39	97	25	0	0	100	
Fruit trees	20	5	38	10	175	46	150	39	100	
Vegetables	170	44	142	37	71	19	0	0	100	
Cash crops ( <i>chat</i> and coffee)	96	25	120	31	104	28	63	16	100	
Mixed cropping	87	23	72	19	124	32	100	26	100	
Eucalypt woodlots	0	0	0	0	23	6	360	94	100	
<b>Mean</b>	<b>94.29</b>		<b>88.71</b>		<b>99.43</b>		<b>100.6</b>		<b>95.75</b>	
<b>Variance</b>	<b>4188</b>		<b>3050</b>		<b>2166</b>		<b>16040</b>		<b>5677</b>	
<b>Std. dev.</b>	<b>64.71</b>		<b>55.23</b>		<b>46.54</b>		<b>126.6</b>		<b>75.34</b>	
Source: Field Survey (2017).										

Figure 3.10. Yield risk level of farming types

As depicted in Table 19 below, from the given multidimensional impact of eucalypt plantations, households' replied their attitudes by responding agree or disagree. Households have enough awareness on the various aspects of eucalypt plantation and it is clearly seen in their perception of each listed attitudes. For instance 81%, 94%, 98%, 95%, 97%, 96% and 93% of the households agreed on statements: eucalypt tree expansion can change a fertile land to wasteland; planting eucalypt on farmland can increase land degradation problem; fast growing trees like eucalypt are water sacking plants; avoiding litters fallen from eucalypt can reduce soil degradation and improve the regeneration of undergrowth; it is important to use animal dung and crop residue as soil fertilizers rather than using it for fuel wood; eucalypt tree cover can balance local climate with similar cases to other plants; and it is possible to reduce the adverse impact of eucalypt by thinning and planting it in rugged lands respectively. The aggregate mean and standard deviation values are 191.5 and 154 respectively. The aggregate P-Value is 0.001025. The result is significant at  $p < 0.05$ . The value of R is -1. This is a strong negative correlation, which means that high X variable scores go with low Y variable scores (and vice versa). Surprisingly farmers are real farm managers in their indigenous knowledge. Farmers know what agronomists did not know. Farmers need what they have not.

Table 3.19  
Households' attitudes/statements on eucalypt plantations.

No.	Attitudes/Statements	Agree	%	Disagree	%	Total	%
1	Eucalypt tree expansion can change a fertile land to wasteland.	309	81	74	19	383	100
2	Eucalypt Tree farming is good for proper land use.	29	18	354	92	383	100
3	Planting eucalypt on farmland can increase land degradation problem.	360	94	23	6	383	100
4	Fast growing trees like eucalypt are water sacking plants.	375	98	8	2	383	100
5	It is necessary to plant eucalypt to combat soil erosion problems.	243	63	140	37	383	100
6	Avoiding litters fallen from eucalypt can reduce soil degradation and improve the regeneration of undergrowth.	364	95	19	5	383	100
7	It is important to use animal dung and crop residue as soil fertilizers rather than using it for fuel wood.	373	97	10	3	383	100
8	Eucalypt planting is important in sloppy areas because it reduces the rate of soil erosion.	260	68	123	32	383	100
9	It is preferable to keep the land under eucalypt cover to ensure land tenure	208	54	175	46	383	100
10	Eucalypt tree cover can balance local climate with similar cases to other plants.	367	96	16	4	383	100
11	It is possible to reduce the adverse impact of eucalypt by thinning and planting it in rugged lands.	357	93	26	7	383	100
12	The blame raised on eucalypt tree farming should be on the management of the species rather than the species itself.	368	96	15	4	383	100
13	Eucalypt tree planting decreases water holding capacity of the nearby environment.	370	97	13	3	383	100
14	Eucalypt planting helps us to reduce run-off and rate of erosion.	265	69	118	31	383	100
15	Eucalypt reduces pressure on natural forests and hereby allows forests to regenerate and expand.	370	97	13	3	383	100
16	A farmer with eucalypt woodlots can lead his family livelihood sustainably much better than he spent his time and energy on management of crops like chat, fruits, vegetables and coffee.	326	85	57	15	383	100
17	Farmers with many eucalypt woodlots have better prestige in the community than those with many cattle.	348	91	35	9	383	100
18	Eucalypt is a living bank account than food and cash crops.	350	91	33	9	383	100
19	Eucalypt has adverse impact on germination and regeneration of undergrowth.	346	90	37	10	383	100
20	Eucalypt is a curable plant in flue and other related diseases.	380	99	3	1	383	100
21	Swampy areas can be drained by eucalypt plantation and then can be converted to agricultural and other land uses.	375	98	8	2	383	100
22	The fast coppicing and growing ability of eucalypt tree is much better than other plants used by households.	379	99	4	1	383	100
23	Replacing eucalyptus with other plants in the near future is impossible.	355	93	28	7	383	100
24	The potential of eucalypt for biogas and industrial oil is promising	253	66	130	34	383	100
<b>Mean</b>		<b>308.3</b>		<b>74.7</b>		<b>191.5</b>	
<b>Variance</b>		<b>10010</b>		<b>10010</b>		<b>23720</b>	
<b>Std. dev.</b>		<b>100</b>		<b>100</b>		<b>154</b>	
Source: Field Survey (2017).							

As shown in Table 3.20 below, 48% and 39% of the households reported that agricultural experts visit their farm once in a year and twice in a year respectively. The remaining 17% of the households reported that they are visiting them once or twice below a quarter years. The mean and standard deviation values are 47.13 and 70.68 respectively. The P-Value is < 0.00001. The result is significant at  $p < 0.05$ . This shows that the support from experts is too small. Hence their gap is only lack of mechanization which are geared from government or other bodies and disseminated from top to down approach without the awareness and involvement of farmers. Hence the attitudes perceived by households are logically acceptable and this is critically reviewed and scientifically proved in later discussion section.

Table 3.20  
Households' response on how often the Woreda agricultural experts do visit their farm.

Status of delivery	Cheha	%	En/Ener	%	Eza	%	Total	%
Once in a year	63	44	61	44	60	60	184	48
Twice in a year	62	43	65	46	24	24	151	39
Once in quarter of a year	14	10	12	9	7	7	32	8
Once in two months	0	0	0	0	0	0	0	0
Once in a month	3	2	2	1	1	1	6	2
Twice in a month	2	1	1	0.7	1	1	4	1
Once in a week	0	0	0	0	0	0	0	2
No visit	0	0	0	0	0	0	0	0
<b>Mean</b>	<b>18</b>		<b>17.63</b>		<b>11.63</b>		<b>47.13</b>	
<b>Variance</b>	<b>678.75</b>		<b>701.23</b>		<b>393.23</b>		<b>4995.86</b>	
<b>Std. dev.</b>	<b>26.05</b>		<b>26.48</b>		<b>19.83</b>		<b>70.68</b>	
Source: Field Survey (2017).								

## 4. Discussion

Eucalypts have been blamed for many evils, including the drying-up of water courses, adverse effects on nutrient cycling and soil properties, the suppression of other vegetation and erosion. These are serious accusation made by authors from many countries and they have even overshadowed the benefits of the eucalypts (Okia, 2009).

No single fact should be taken as sufficient evidence to promote or to discourage the planting of the eucalypts, though the results from a large number of studies taken together may yield valid generalizations (Jagger and Pender, 2000; FAO, 1988; Davidson, 1985). There is no question that trees in general and the eucalypts in particular utilize large amounts of water and nutrients, but the returns that can be realized in terms of biomass production per unit of input must also be considered.

Similarly, Davidson (1989) argues that the criticisms would equally apply to other exotic trees planted in many countries, not just the eucalypts. Therefore, any balanced argument should compare the nutrient depletion to the outputs produced for each unit of water and nutrient consumed than the absolute amount consumed in isolation. In the controversy over eucalypts there has been a tendency for the negative and positive aspects of the genus to be highlighted. Some of these are briefly discussed in the following subsections.

### 4.1. Water use by Eucalypts

Eucalypt has taken the vast area of the world and raising fears over water resources and eco

hydrological effects (Shi et al., 2012). Bewket and Sterk (2005) and Zerga (2015) indicated that among other types of land use changes, eucalypts and land degradation in the highlands of Ethiopia lead to the decrease stream flow more clearly in the drier season. Similarly, Chanie (2013) reported farmers' response as eucalypts dries up springs in the highlands. Eucalypt is known by its high transpiration rate ranged from 0.5 to 6.0 mm per day and also believed that eucalypt plantations may extract water from shallow ground water (Shi et al., 2012). Soils dry up in the eucalypts up to 3m than other vegetation cover and it has indicated that vegetation changes affect evapotranspiration, water yield flooded area, water balance and other hydrologic variable (Nosetto et al., 2012). On the contrary, eucalypt is water efficient tree species than other crops though eucalypt is perceived as high water consumer by some environmentalist (Davidson, 1989; Teshome, 2007; FAO, 1988). Most eucalypt species averagely use 785 liter of water to produce 1kg of biomass (Davidson, 1989).

To the extreme, it has been thought that eucalypt species consume a lot of water more than any

other tree species and agricultural crops. However, this is far from reality. They have greater water use efficiency (i.e. they consume less water per unit of biomass produced) than most agricultural crops, conifers, acacias and broad-leaved tree species (Table 3.21). To produce one unit of woody matter young trees require between 300 and 500 units of water, but as they get older their efficiency decreases and more water per unit of wood is needed (Teketay, 2000). In fact, use of water is proportional to the amount of biomass produced (wood, branches, twigs, leaves, flowers, fruits, etc.), and the relatively high water consumption is consistent with their high growth rate and biomass production.

In arid regions, water is limited and plants with deep spreading roots take most water while

plants with shallow roots may be stunted or unable to survive. In low rainfall areas, eucalypt species may suppress other plants by competing for water, but this is unlikely to occur in areas of high rainfall (Davidson, 1989). If the planting is not well planned, it may reduce the groundwater level and thereby affect water supplies of the local people.

Davidson (1989) also reported that at Nekemte (Western Ethiopia) with annual rainfall of 2158 mm, *E. saligna* and *E. grandis* could produce 46.6 m<sup>3</sup>/ha/yr without drawing on water reserves (rainfall only) compared to 16.4, 16, 12.4 m<sup>3</sup>/ha/yr biomass production for the coniferous, acacia, and broadleaf species, respectively. These figures reveal that for the same amount of water consumed, eucalypt produces higher amount of biomass, which is economically profitable and acceptable.

In swampy areas, the groundwater level is near or at the surface, and some species of eucalypts have been used to drain the water away by drawing it up through the roots. *E. globulus* is useful for this purpose. Mosquito breeding swampy areas can sometimes be controlled in this way. Drainage removes swamps which provide a habitat for mosquito larvae, thereby reducing the risk of malaria. This method has been used in various parts of Ethiopia (Teketay, 2000).

Many studies reported that water use in eucalypt is comparable to other tree species. There are some cases where afforestation with eucalypts (or other tree species) has led to reduced water run-off and supply of streams or changes in water table levels, especially in regions with limited rainfall. However, in many well documented cases eucalypt plantations do not have any significant negative impacts on hydrology. A key finding of many experiments revealed that eucalypt is highly effective in regulating its water consumption relative to available supplies and regulates its growth accordingly. Based on numerous comparisons that have been made between the potential hydrological impacts of eucalypt and other tree species, it is not expected that the eucalypt trials planted under these permits would be any more impactful on local hydrology than planting other fast growing trees species.

Study conducted in the Ethiopian highlands, Pohjonen and Pukkala (1990) reported that *E. globulus* converted energy and available water into biomass more efficiently when compared with exotic coniferous tree species. Therefore, although some species of eucalypts may consume more water than the indigenous forest or other plantations, which may lead to reduced water yield and leaves less available water for other crops growing in association with the tree, it is more efficient in terms of converting water into biomass.

Table 3.21  
Water use efficiency or consumption of water per unit of biomass produced.

Plant	Liters of water/kg of biomass produced
Sorghum	250
Maize	250
Caw pea	500
Soybean	500
<i>Eucalyptus</i> (tree)	510
<i>Albizia lebbek</i> (tree)	580
Potato	600
Sunflower	600
Field pea	600
Horse bean	600
Pddy rice	600
<i>Syzygium cuminii</i> (tree)	610
Cotto/coffee/banana	800
<i>Acacia auriculiformis</i> (tree)	860
<i>Dalbergia sisso</i> (tree)	890
Conifers	1,000
<i>Pongamia pinnata</i> (tree)	1,300
Source: (FAO, 1988; Davidson, 1989)	

## 4.2. Effects on soil fertility

The effects of the eucalypts on soils have been studied in several countries over many years (Kindu et al., 2006, Poore & Fries, 1985). Most of the concerns related to effects on soil quality deal with the depletion of nutrients. Moreover, a number of studies indicated that changes in some soil properties are influenced by tree species (Poore & Fries, 1985).

Studies by Dessie and Erkossa (2011), Kidanu (2004), Chanie (2013) argued that eucalypts decreases soil nutrients within 20m distance from the trees. The comparison study of eucalypts with mixed plantation has revealed that eucalypt has three times more fine root biomass in surface soil which indicated that planting crops in association and adjacent to eucalypts should be avoided (Gindaba, 2003). However, eucalypt species exceptionally can extend the nutrient cycling deep to ground soil where other trees and crop could not access that much depth (Hailu et al., 2003).

The wetland conversion study has indicated that there is significant difference between wetlands and converted land to dominantly eucalypts by reducing major nutrients from the converted land which is eucalypts (Mekonnen and Aticho, 2011). Similarly, Soil nutrient and carbon pool under eucalypts is lower than the mixed plantation (Gindaba, 2003). In addition to the above, as reported by Chanie (2013), the soil under eucalypts becomes water repellent and the perceptions of the local farmers agreed with the experimental findings by reducing the crop productivity of the land. On contrast to the above, Tadele and Teketay (2014) has found that the maize dry matter production and grain yield planted on cleared felled eucalypts stand are significantly higher than adjacent field. According to Hailu et al. (2003) eucalypt does not over exploit the soil than the traditional fuel usage such as litter and cow dung collection. Similarly, the study has indicated that due to non browsed characteristics of eucalypts than other fodder tree, it is well fitted for soil protection purposes if it is incorporated with avoidance of litter and bark collection in overgrazing practiced places. Generally, there is lack of clear scientific evidence that shows eucalypts' impact on soil nutrient that lead to soil degradation.

Although it is blamed to extracts substantial amount of nutrients and compete with crops, at the same time eucalypts impoverish the soil. It could be legitimate to raise such concern under poor management where there is lack of species-site match (Davidson, 1989; FAO, 1988; Nigatu and Michelsen, 1993 and 1994).

Eucalypt copes with such variability through a root system that has intimate contact with the large volume of soil. With the extension of its root deep into the soil, given its high degree of adaptability, it extracts nutrients outside the realm of crops feeding zone. That is why its nutrient requirement is significantly lower than that of many agricultural crops (Moges, 1998, 2010). As a result, the species flourishes with sustainable high yield without fertilizer on red ash and degraded land. Further, eucalypt is not a natural forest that has little disturbance. If it were a closed system, nutrients would have been recycled from decomposing litter back to the tree and increase the nutrient bank (Teshome, 2009). But, eucalypt is an open system and nutrients are removed from the site when the stem, leaves and bark are harvested for various uses (Nigatu and Michelsen, 1993 and 1994). This means that the nutrient capital of the soil could be diminished. Therefore, the secret lies in nutrient mining. This is equally true for crops under poor management. Under viable environment, soil nutrient levels can be improved through sound management without the carrying capacity of land being overstretched.

Very few comparative studies have been made in Ethiopia on soil nutrients among plantations of different species including eucalypt species and the adjacent natural forests (Michelsen et al., 1993; Nigatu and Michelsen, 1994; Michelsen et al., 1996; Alemu, 1998). These studies have shown that plantation stands of fast growing exotics such as *E. globulus*, *E. grandis*, *E. saligna*, *Cupressus lusitanica* and *P. patula* had lower nutrient contents than soils of the adjacent natural forest. This seems logical as they are fast growing, thereby drain, and consume more nutrients from the soil. Eucalypt species have high demand for nutrients, but this incomparable with other tree species and much lower than agricultural crops. Teshome (2009) pointed out that the nutrient consumption of fast growing species like eucalypt species need to be well studied before wrong conclusion and recommendation is being made.

### 4.3. Issues on soil erosion

Soil erosion is among the most important surface processes that result in land degradation in the tropics. Trees can influence soil erosion mainly through intercepting rainfall which dissipates its kinetic energy. The rain drops that are intercepted eventually fall to the soil surface with reduced erosive energy, depending on the size and orientation of the leaves. Large leaves produce larger size droplets which have greater impact on the soil. Accordingly, erosive energy of rain under the crowns would be least for *Casuarina* spp. with *Acacia* spp. (e.g. *A. auriculiformis*) and narrow-leaved eucalypts (e.g. *E. camaldulensis*) occupying the mid-range and the broad-leaved eucalypts (e.g. *E. globulus*) at the top of the range for the eucalypts (Jagger and Pender, 2000).

Consequently Jagger and Pender (2000) reported that there is no evidence to single out the eucalypts for special criticism with regard to soil erosion. It has been hypothesized; however, that long term exposure to allelo-chemicals may result in increased risk of soil erosion, which may have implications for sustainable land use over time (Jagger and Pender, 2003).

Eucalypt has been found to have impacts on topsoil retention and soil erosion (Dessie and Erkossa, 2011; Sunder, 1993; Poore and Fries, 1985). Some studies have concluded that eucalypt can worsen soil erosion as an indirect result of frequent disturbance from repeated harvesting (Poore and Fries, 1985). Others argue that eucalypt plantations can help control soil erosion on sloped or degraded sites, but their efficacy depends on environmental factors such as intensity of rainfall, soil condition, slope and the presence of ground vegetation and litter cover. Though few Ethiopia-specific case studies exist, the limited evidence available suggests that eucalypt may be an ineffective choice for erosion control (Sunder, 1993). Rather, eucalypt trees are generally expected to lead to an increase in soil loss due to the reduced understory cover in densely planted eucalypt areas (Poore and Fries, 1985).

The litter which accumulates under most eucalypt plantations can help to form a protective

barrier against erosion, but in many places the litter is collected as fuel or removed to reduce fire hazard. For instance, the depth of the accumulated litter under eucalypt stands in Shashemene Munessa Forest Project area was found to be on average 20–30 cm (Teshome, 2009). However, under eucalypt stands around Addis Ababa and very big towns, the accumulation of litter is very low as a result of human and livestock disturbances. People take away most of the litter and cattle and foot traffic compact the soil. If the litter is left on the site uncollected, it would have been incorporated into the soil system to slow down runoff and improve infiltration, and substantial amount of nutrients may pass to the soil system, thereby improving soil fertility (Teshome, 2009). However, as a result of litter collection, the ground under the trees is left bare and the soil is exposed to erosion. Therefore, litter should be allowed to accumulate on the sites, particularly on sites that are easily eroded.

A realistic assessment of each area to be planted is needed to decide whether erosion will be a serious problem, and if so, whether it can be controlled. Some places may not be suitable for

plantation establishment. Eucalypt plantations on steep slopes can provide effective erosion control if careful techniques such as contour planting are used (Teketay, 2000). The root systems of selected species for catchment protection influence the soil binding capacity and as a result reduce erosion. *E. globulus*, for instance, has a strong tap root and good lateral root system that makes it very reputable species for catchment protection (Teketay, 2000; Teshome, 2009).

In regard to soil erosion by water under trees, there is no evidence to single out eucalypts for special criticism. Erosive resistance (physical characteristics) of soils is more important than crop management and crop management is more important than the type of tree crop. Since, in nearly every example where the litter is removed, erosion increases substantially, it is important to focus more on ground cover and ground level activities (cultivation, compaction by foot traffic, livestock grazing, trampling, and harvesting/logging damage rather than on the species of trees planted. On erosion-prone slopes it is better to use a periodic, partial harvesting system based on cutting of trees on lines around the contour or on removal of small patches in a mosaic pattern (Teketay, 2000; Jagger and Pender, 2003).

## 4.4. Allelopathic effect

Allelopathy is the release of chemicals from leaves or litter that inhibit the germination or growth of other plant species (FAO, 1985), and consequently reduce the output of crops. Allelopathic effect of eucalypt is among the issues dominating the agroforestry literature. Allelopathic exudates from eucalypt tree components have shown an inhibiting effect on undergrowth vegetation regeneration and growth (Poore & Fries, 1985).

Most of the studies put forward as "evidence" for eucalypts being strongly allelopathic involve laboratory studies of extracts on germination of seeds or early growth of potted plants which may not accurately represent field conditions. Soil bioassay studies have been carried out with three agricultural crops: chickpea (*Cicer arietinum*), tef (*Eragrostis tef*) and durum wheat (*Triticum turgidum*) under laboratory and field conditions in the Ethiopian highlands. According to the findings, bioactive compounds from the decomposing litter of *E. globulus* did not affect the test crop seed germination nor root growth. However, a litter extract with 5% dry matter concentration significantly hindered germination and root growth of the tested agricultural crops. On a farm field experiment, declining barley yield was observed near a *E. globulus* plantation (Jagger and Pender, 2005).

Results evidently vary across a wide spectrum of conditions from humid, fertile sites to dry, infertile ones. The magnitude of the negative effects may be influenced by rainfall. Although it is likely that allelo-chemicals do accumulate in the soil, they are highly soluble and rainfall is likely to leach them out and the effects of Allelopathy are thus likely negatively correlated with rainfall. It has been noted that allelopathic effects are more severe in low rainfall regions prone to soil erosion than in drier regions. However, the hampering effect on growth of understory or adjacent intercropped crops may more often be the result of strong competition for water and nutrients than Allelopathy. Farmers in the highlands of Ethiopia linked this effect to competition for water and nutrients (Jagger and Pender, 2005).

The potential allelopathic effect of *E. camaldulensis*, *Cupressus lusitanica*, *E. globulus*, and *E. saligna* on seed germination and seedling growth was investigated with four crops: chickpea, maize, pea and teff (*Eragrostis tef* Zucc.) (Limenh and Michelsen, 1993). The results revealed that aqueous leaf extracts of all the tree species significantly reduced both germination and radical growth of the majority of the crops. It has been shown that the shoot and root dry weight increase of the crops was significantly reduced after ten weeks treatment with leaf extracts.

Allelo-chemicals can effect germination and growth of plants through interference in cell division, energy metabolism, nutrient uptake etc. (Nigatu and Michelsen, 1993; Fetene and Habtemariam, 1995; Teshome, 2009; Yirdaw and Luukkanen, 2003). In this regard, eucalypt has toxic allelo-chemicals that consist of phenolic acids, tannins, and flavonoids (Yirdaw and Luukkanen, 2003). When realized into the soil, these inhibit other plants and play a role in shaping plant communities. For instance, leaf decomposition product from eucalypt is shown to suppressed germination and growth of chickpea, field pea, maize, and tef (Nigatu and Michelsen, 1993) while it exerted an antibiotic effect on soil microorganisms (Limenh and Bongers, 2010).

However, concentration matters. For instance, allelo-chemicals from decomposed eucalypts' litter in high rainfall areas did not accumulate in sufficient concentration to affect seed germination and root growth of crops. Different strength of water extract from leaves of eucalypts did not delay the onset of germination and seedling growth of *Olea* (Yirdaw and Luukkanen, 2003; Limenh and Bongers, 2010; Limenh and Teketay, 2004). In fact, positive results have also been reported concerning the interaction of eucalypts with other plants (Kidanu et al., 2005). The lack of susceptibility of certain crops and the regeneration of other species suggest that eucalypts provide some benefit rather harm. Again, it is not only eucalypts but other exotic tree species such as *Grevillea robusta* which is a common feature in Ethiopia has allelopathic effects on most agricultural crops (Teshome, 2009).

However, in Ethiopia, little attention has been given to Allelopathy as determinant of crop production and productivity (Kidanu et al., 2004 and 2005; Chanie, 2009) and plant community structure (Senbeta, 1998; Moges, 1998; Yirdaw, 2002; Limenh, 2004). Therefore, empirical information is needed to resolve such negative effect. Until then, Allelopathy can be minimized with sound management through compatible crops based on proper eucalypt species' site selection.

## 4.5. Competition with nearby vegetation

One of the criticisms associated with eucalyptus is that it prohibits the establishment of understory plant species. Eucalypt is usually taller than other plants of equal age. This has determined the amount of gap that would be available for sunlight to penetrate through its canopy. When planted at high density, the shade created has adverse influences on the understory environment (Zerga, 2015). The consequence could be vegetation free surface. The dense stands not only affect the growth of colonizing woody species, but also nearby crops given the added competition for water and nutrients. Then, yields from crops close to eucalypts may not be as good as those farther from the edge. Then, it is not eucalypts rather the lack of sound management that is to blame (Teketay, 2000). On the other hand, not all eucalypt species cast heavy shadow to discourage understory plants. Some even cast less shade than broad-leaved trees because they have often narrow, patchy crowns and leaves positioned downwards on the twigs (Yirdaw and Luukkanen, 2003).

As a case in point, several eucalypt plantations in different agro-ecological zones showed richness of herbaceous plant species than under adjacent natural forest. Further, the less dense plantations harbored more regenerated indigenous woody tree species than high dense eucalypts stands (Yirdaw, 2001; Senbeta

and Teketay, 2001; Michelsen et al., 1996; Limenih and Teketay, 2004). This indicates that an inverse relationship exists between eucalypts density and diversity of the regenerated species. In relation to economic crop, wheat production was not affected by eucalypts on heavy clay soil (Kidanu, et al., 2005). When used as shade tree for coffee, its cup quality was acceptable as that within the indigenous forest (Shiferaw and Tadesse, 2010).

Because of shading and competition for water, the yields from agricultural crops close to eucalypt plantations are sometimes not as good as they are further away from the edge (Teketay, 2000). However, some eucalypt species cast less shade than other broadleaved trees because their leaves are held vertically downwards on the twigs and their crowns are often narrow. It is widely accepted that shelterbelts increase crop yields. On the other hand, the study made by Onyewotu et al. (1994) on the competitive effects between a *E.camaldulensis* shelterbelt and an adjacent millet (*Pennisetum typhoides*) crop indicated that the yield of the crop grown very close to the belt was reduced because of competition with the trees for light, soil moisture and nutrients, and shading. On the other hand, the results indicated that the yield of millet grown adjacent to the shelterbelt increased substantially. It is worthwhile to note that in eucalypt species the shade is characteristically patchy because the leaves usually hang downwards, indicating that shading is not a major problem.

However, not all eucalypts' cast shade which is heavy enough to discourage ground vegetation or understory shrubs, and shading can be adjusted by varying the density of the trees. There are complex interactions between light and water requirements of different trees that make generalizations difficult. Certainly there are several species of trees with larger leaves than the eucalypts, thus they cast more shade.

## 4.6. Scarcity of wild animals

Ethiopia has diverse wildlife of world importance. Yet, there has been the erosion of these resources due to the destruction of their habitat from introduction of agriculture, recurrent drought, war and conflict. Among others, the unpalatability of eucalypt leaves is supposed to reduce the number of wildlife and livestock in an area. Due to its competitive nature, eucalypt is considered not to provide adequate fodder to wildlife (FAO, 1988; Negash, 1999). There is thus the debate should be on whether wildlife would remain in their newly established eucalypts habitat or not.

In the first place, eucalypt is never established in natural forests that harbor wildlife. If there were some in the landscape, the destruction of the habitat might have forced them to migrate; obviously prior to eucalypts. Then, it is difficult to imagine that degraded area, barren and treeless landscape could have provided the suitable habitat to wildlife.

Instead, they would migrate due to deforestation of the original forest. The subjective perception of the species is in the absence of objective studies which demonstrate that eucalypt plantations host lower wildlife population compared to a barren landscape that is now rehabilitated with indigenous species under a similar setting. The objective reality, however, is that with the establishment of eucalypts, the canopy has provided shade for the emergence of undergrowth vegetation and the regeneration of indigenous trees. Now that they have a suitable habitat, some of the wildlife has returned. As a case in point the scenic evergreen eucalypts plantation on Entoto Mountain that surrounds Addis Ababa hosts diverse wildlife even with large human population around and has become a prime destination to tourists (Senbeta and Teketay, 2001; Senbeta et al., 2002).

Further, the flower of eucalypts that produces abundant pollen and nectar has been essential in the life cycles of many insects and birds. These are important in the pollination of crops and bees provide additional benefit through production of honey. This has become a lucrative business to many rural communities. Under sound management similar plantations could exploit such potential without adverse effect on the ecology or crops. Palatable leguminous trees, shrubs, forages, pastures, and grasses can also be established under appropriate sound management. Then, such rehabilitated areas can be made favorable to wildlife instead of the categorical blame of eucalypts as restriction to their proliferation (Davidson, 1989 and 1995; FAO, 1988; Pohjonen and Pukkala, 1988 and 1990).

The unpalatability of most species to browsing and grazing animals (FAO, 1988; Davidson, 1989; Pohjonen, 1989; Turnbull, 1999) and incapability of providing adequate food and habitat for wildlife (FAO 1988; Negash, 1999; Teketay, 2000) can thus reduce wildlife in an area. However, this problem can be alleviated by establishing mosaics of plantations, natural forests, pastures, grasslands and croplands. It is important to note that the biodiversity of a natural forest and that of eucalypt plantations are not comparable. The natural ecosystems are very diverse, whilst the biodiversity of eucalypt plantations is limited. Mammals and birds that used to live in natural forests can be encouraged to return to a forest replanted with a mixture of exotic species by leaving open spaces occasionally, and allowing undergrowth to remain here and there.

## 4.7. Climate change effect

One of the criticisms against eucalypt plantations is that they may cause a change in the local

climate. This is because of their very high evapotranspiration rate, which may lead to a lower water table. This high rate of soil water loss is claimed adversely to affect local rainfall levels, resulting in possible desertification of a given area. But others argue that the contribution of the land mass to the hydrologic cycle is small compared with that of the oceans (Lee, 1980). On the other hand, the mere presence of a forest in a certain area does not necessarily affect the occurrence of rainfall in that area.

Some studies have shown that the microclimate within eucalypt plantations may be different from those of other species and from native forests, but the data are not conclusive. In terms of their effects on regional rainfall or on other regional climatic parameters, however, there is nothing to distinguish eucalypts from plantations of any other tree or from different types of native forests of similar structure and albedo (Poore and Fries, 1985).

Generally, the greater the leaf area and the more horizontal the leaves are, the greater the shading effect and the higher the evapotranspiration rate. Eucalypts cast less shade, on average, than other broadleaved trees, but there are big differences in the amount of shade cast by different species because they have different leaf sizes and orientations. The influences which are the result of shading can be manipulated based on need, by increasing or reducing the density of planting. Therefore, there is no reason to distinguish eucalypts from other genera with similar crown architecture regarding micro-climate at local level.

Eucalypt trees do an excellent job of sequestering CO<sub>2</sub> because they efficiently store carbon in all their live biomass. Especially in the tropics, where sun and rain are abundant, extremely high conversion of CO<sub>2</sub> occurs in the biomass. With such high efficiency, it is only natural that eucalypt trees grow quickly and with high productivity. Eucalypt is an efficient biomass producer; it can produce more biomass than many other tree species. It is known that carbon sequestration is proportional to biomass production. Therefore, Eucalypt plantations can play an important role in generating additional revenues from carbon trade.

## 4.8. Effects on plant species diversity

One of the major criticisms that have been debated over years among the scholars concerning eucalypt is its impact on flora of the area. On contrary to the above, eucalypt has potential in encouraging the recruitment, establishment and successions of native species, which promote biodiversity improvement (Senbeta et al, 2002). Regeneration of *Junipersprocera* on previously eucalypts plantation was also possible at Entoto, Ethiopia, which has shown wrong believes that planting other trees after harvesting eucalypts is not possible (Woldu, 1998; Senbeta and Teketay, 2001; Senbeta et al., 2002).

Mostly, eucalypt is feared for ecological hazardous and ecosystem destructor, but eucalypt is an important tree in fostering ecosystem serving as conservation tree at beginning of restoration process of degraded sites. Eucalypt plantations in southern Ethiopia were used as a buffer for degrading natural forest and have reduced impact on the forest (Senbeta et al., 2002, Zerga and Woldetsdik, 2016). Thus, eucalypt plantation has reduced natural forest deforestation in one way and reduced human impact on the other hand that provide time for natural forest regeneration and allow improvement of biodiversity richness.

Additionally, eucalypt plantations can be used to foster natural forest re-colonization and succession process (Senbeta et al., 2002; Lemenih et al., 2004). Similarly, it can also facilitate the regeneration of native woody species in the plantation through reducing soil erosion and facilitating attractive conditions for seed germination (Lemenih et al., 2004). In addition, eucalypt plantation can also foster the regeneration of other native woody species in degraded area by providing protection (Teketay, 2000; Hailu et al., 2003; Senbeta and Teketay, 2001).

Plantation stands of eucalypts and other tree species have been shown to foster or catalyze the regeneration of native woody species under their canopy provided that they are established close to seed sources and protected from human and livestock disturbances, thereby enhancing biodiversity (Senbeta, 1998; Moges, 1998; Teketay, 2000).

The studies made by Mihretu (1992) and Kidane (1998) indicated that there is a good natural regeneration of *J. procera* under *E. globulus* plantations at Entoto hills in Addis Ababa. The juniper has grown effectively on the eroded areas competing well with the eucalypt trees. Similarly, the studies made by Senbeta (1998) and Moges (1998) at Shashemene Munessa Forest Project Area clearly showed that plantation stands of *E. globulus*, *E. saligna*, *C. lusitanica* and *P. patula* have been found to foster the natural regeneration of several native woody species like *P. falcatius*, *Prunus africana*, *Syzygium guineense* and *Crotonmacrostachyus*. The source of seeds for the naturally regenerated native woody species is the adjacent to natural forest.

Many of the allegations on species of eucalypts and other exotics, e.g. the allegation of hampering native biodiversity, are unscientific and disproved by many recent research findings (Moges, 1998; Senbeta and Teketay, 2001; Yirdaw 2002; Senbeta et al. 2002; Limenih, et al. 2004; Limenih and Teketay, 2005). Thus, there is now increasing knowledge of the ecological pros and cons of eucalypts better than before and most importantly the biodiversity impacts are clearly disproved. Rather eucalypts are considered as a foster species that nurse the rapid re-colonization of native species when planted on barren and degraded lands.

## 4.9. Policy Options

As Janz and Persoon (2002) expressed, there are serious shortcomings in the supply and use of information needed for policy-making in the forestry sectors, particularly those of developing countries. It should be underlined that, for a successful forest policy process, it is often necessary to know, among several other things, more about plantations and their role for rural communities. There is a general prejudice against forestry, particularly against fast-growing trees plantation, as compared to agriculture (Cossalter and Pye-Smith, 2003).

The current policy issue regarding eucalyptus planting in Ethiopia seems not in the favor of the species. There is no encouraging concern in the country to raise eucalyptus seedlings from government nurseries and distribute them for smallholder farmers. The views of policy makers are largely less favorable to eucalyptus. Owing to its importance, the policy practice of discouraging and in some cases banning planting of eucalyptus by farmers need rethinking from the side of the policy makers. Taking into account the dwindling natural forests in Ethiopia, it would be necessary to pass legislation to require that almost all charcoal, poles and firewood be derived from plantations of fast-growing species such as eucalyptus, to prevent further loss of natural forests (Turnbull, 1999).

There is a need for care when comparing policy and actual practice, because stated intentions in policy documents sometimes bear no relation with how policies are interpreted and applied (Sithole, 2002). In another concern, interventions to support market prices for the products of tree growing and to ensure producers' access to markets may be as effective as or more effective than subsidies. Agricultural policies should be complementary to tree growing. Subsidies for credit, price supports and incentives, including measures affecting land and tree tenure, should be seen in parallel to both agricultural crops and tree growing like eucalypts by farmers in order to avoid policy measures that likely to distort decisions against one at the expense of the other (FAO, 1981).

Actually, the poor management should be blamed rather than eucalypts. All things are always changing; and our way of thinking should change with the rapidly changing conditions of our world. At the face of heightened climate risks, the harmonization of forestry and agriculture policy unquestionably helps combat food insecurity and poverty. In reference to eucalypts, as elaborated, the evidence so far reveals that the species will continue to figure prominently in

the life of both rural and urban people (Moges, 2010). Hence, its justifiable place in the development policy of the country means that individuals and communities can be encouraged to accelerate the establishment of commercial exotic plantation and indigenous forest that will not contravene the ecology.

## 5. Conclusion And Recommendations

Eucalypt has become the most preferred species for planting by farmers due to its economic benefit and huge demand of fuel wood and construction materials. In Ethiopia Eucalypt plantations constitute 58% of the total plantation followed by Cupressus (29%), Juniperus procera (4%) and pines (2%). Apparently, in recent years, planting of eucalypts has been faced controversies and critiques based on ecological and socio-economic arguments in Ethiopia and elsewhere. Hence eucalypts have been blamed for many evils, including the drying-up of water courses, adverse effects on nutrient cycling and soil properties, the suppression of other vegetation, allelopathic effect and erosion. Whether these criticisms are based on fact or arise from deliberate bias or even lack of accurate information may be questioned. Most of the reports available on eucalypts are in favor of planting it. The paradox mostly results from the poor management rather than its biological characteristics. Therefore, the debate on eucalypts under the pretext of concern for indigenous forests is 'a storm in a tea cup' and must not widen the urgent attention. In this regard, farmers are not blind to its claimed negative ecological and agricultural impact. They have utilized the knowledge and experience through time to ensure sound eucalypts production. Then, their primary focus must be the acquisition of the knowledge on what motivates farmers to embrace eucalypts. With the insight and wisdom gained, the effort should be to win them not against their will but against their background.

In the study area, households use their land holding size for different uses per hectare in different decades. From different uses eucalypts and *enset* ranked first and second in the three decades of 1990s, 2000s and 2010s by accounting 13%, 36% and 45%; and 16%, 24% and 20% respectively. Grazing, grass and degraded lands taken the next share of land holding size. All others are possessed very small holdings. Hence their former sizes were reduced as a result of their conversion to eucalypt plantations. The average landholding size is about 0.52 hectare. Thus strict land use management and policy should be practiced to save this diminutive land use from eucalypts plantation conversion. About 68%, 86%, 100%, 73%, 88%, 58%, 75% and 86% of the households reported that they plant eucalypts on the farm land with crops, farm boundary, degraded lands (gully sides), previously cultivated land, around the course of streams, close to settlement, along roadside, and on grazing lands respectively. This shows that most of the sites are not considered as ideal sites except on degraded lands (gully sides) and along road sides. Their opportunity to use ideal sites is already overshadowed by its multidimensional and short term benefit.

Households have enough awareness on the various aspects of eucalypt plantation and it is clearly seen in their perceptions. Thus about 81%, 94%, 98%, 95%, 97%, 96% and 93% of the households agreed on statements such as: eucalypt tree expansion can change a fertile land to wasteland; planting eucalypt on farmland can increase land degradation problem; fast growing trees like eucalypt are water sacking plants; avoiding litters fallen from eucalypt can reduce soil degradation and improve the regeneration of undergrowth; it is important to use animal dung and crop residue as soil fertilizers rather than using it for fuel wood; eucalypt tree cover can balance local climate with similar cases to other plants; and it is possible to reduce the adverse impact of eucalypt by thinning and planting it in rugged lands respectively. The aggregate P-Value is  $< .00001$ . The result is significant at  $p < .05$ . The value of R is -1. This is a strong negative correlation, which means that high X variable scores go with low Y variable scores (and vice versa). Surprisingly farmers are real farm managers in their indigenous knowledge. Farmers know what agronomists did not know. Farmers need what they have not.

Collectively most of the households perceived that eucalypts have good trends in microclimate change over twenty years period. Eucalypts' cover increment and its substitution in fuel wood and construction resulted in the regeneration of forests and thereby increasing trend of the overall coverage. Thus about 100%, 100%, 17%, 79% and 45% of the households perceived that stream flows are decreased or dried, farmlands are fragmented, runoffs are increased, yields are declined and gullies and rills are created respectively. The perception on incidence of runoffs is minimal and about 83% of the households believed that eucalypt has nothing to do with it unless the litters are cleared for fuel wood purpose and in contrary they plant it to reduce runoff.

About 70%, 29% and 1% of the households reported that there is major decrease, minor decrease and no change respectively towards stream flow volume. About 34% and 66% of the households reported that there is minor increase and major increase respectively towards competition with croplands. About 9%, 12%, 5%, 66% and 8% of the households reported that there is major decrease, minor decrease, no change, minor increase and major increase respectively towards under growth. About 39%, 20%, 5% 5% and 2% of the households reported that there is major decrease, minor decrease, no change, minor increase and major increase respectively towards soil erosion. About 38%, 46% and 16%, of the households reported that there is major decrease, minor decrease and no change respectively towards soil fertility. About 15% and 85% of the households reported that there is minor increase and major increase respectively towards presence of birds. About 5%, 16% and 79% of the households reported that there is no change, minor increase and major increase respectively towards presence of wild animals.

Thus households were intrinsically following the perceived environmental changes, however, land diminution and short term valuable reward gained from its product overshadowed their opportunity to apply the optimum land use alternatives.

About 7% and 93% of the households removed and did not remove respectively for eucalypt woodlots for agricultural use. The lesser number of households who removed the species for agricultural use is attributable for the non-affordability of the households to use tractors for this purpose. As reported by focus groups and key informants, those households who afforded using tractors are relatively wealthy ones either by themselves or by remittance support. Thus, based on the findings of the study, the following recommendations were forwarded.

- instead of blaming eucalypt species itself, there should be an intrinsic criticism to management of the species by all stake holders in order to involve in the ideal management of land use allocation;
- farmlands, grasslands, grazing lands and wetlands should be kept from eucalypt plantations to save these land uses from its adverse externalities;

- there should be substitutions for income generations of eucalypt poles by improved horticultural crops in order to curb its environmental and cultural drawbacks;
- farmers, government, NGOs and other stakeholders have to involve in implementation of appropriate species and site selection, tinning, and blending of the species in order to minimize its adverse impacts;
- district and zonal agricultural and natural resources experts have to give continuous training to farmers on the appropriate land use practices;
- there should be a community service on best pilot land use practitioner farmers at the beginning and these best practices should be scaled up to all farmers through time;
- participatory in depth research should be conducted on environmental aspect of eucalypts to reach at final decision and act accordingly towards the optimum plantation; and
- there should be a specific policy ratification and enacting towards eucalypt plantations in order to use it at optimum land use practices in private and communal lands.

## Abbreviations

AEZs Agro-ecological Zones

CO<sub>2</sub> Carbon dioxide

CSA Central Statistical Authority

DAs Development Agents

FAO Food and Agricultural Organization of the United Nations

SPSS Statistical Package for Social Sciences

## Declarations

### Ethics approval and consent to participate

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### List of Abbreviation

Not applicable

### Consent for publication

The authors agreed up on the publication of the manuscript.

### Competing interest

The authors declared there is no competing interest.

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### Authors' contributions

The first author prepared the first draft. All other authors read, review and approve the manuscript.

### Availability of data and material

The data and materials used in this research are available and included in the methods

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## Figures

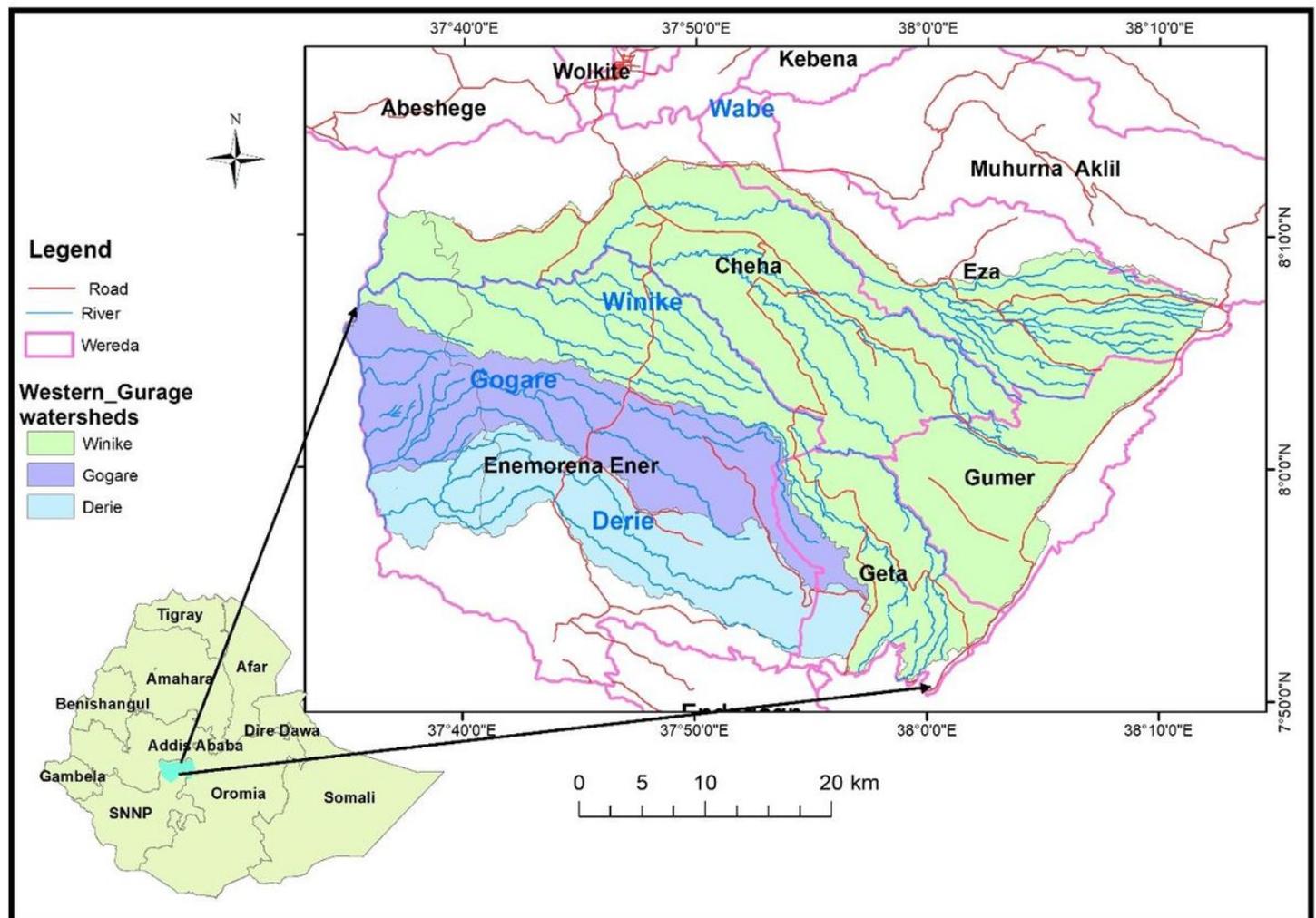


Figure 1

Location map of the Western Watersheds of Gurage Zone. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

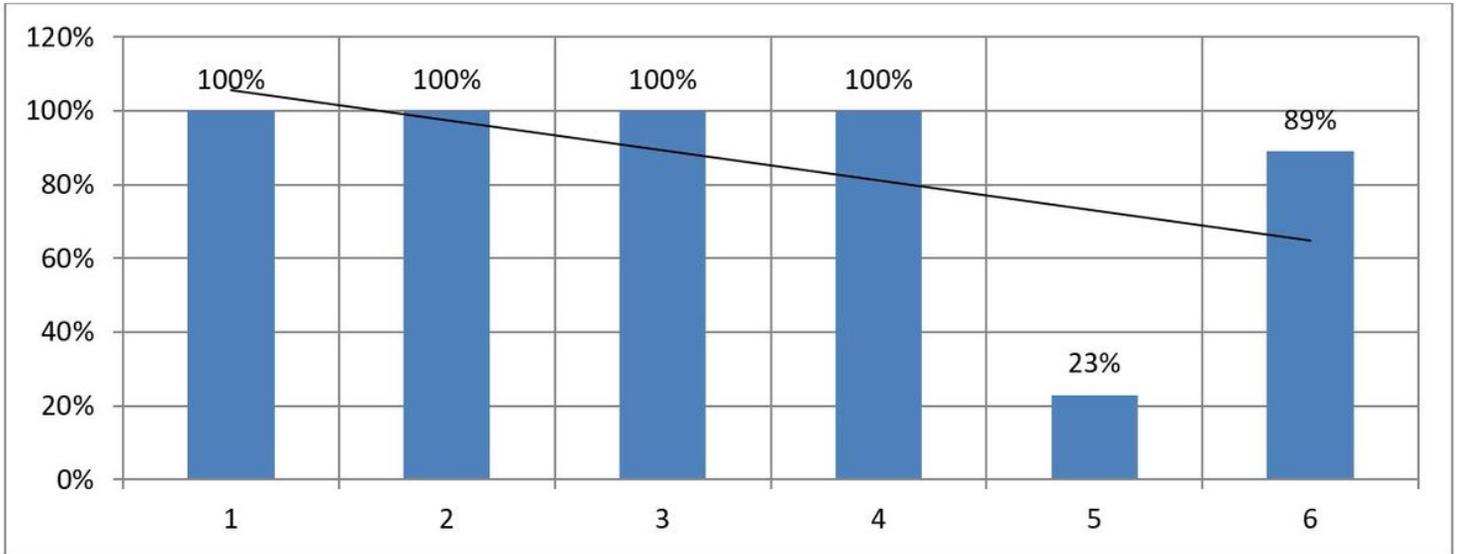


Figure 2

expected farmland constraints in the near future due to eucalypts.

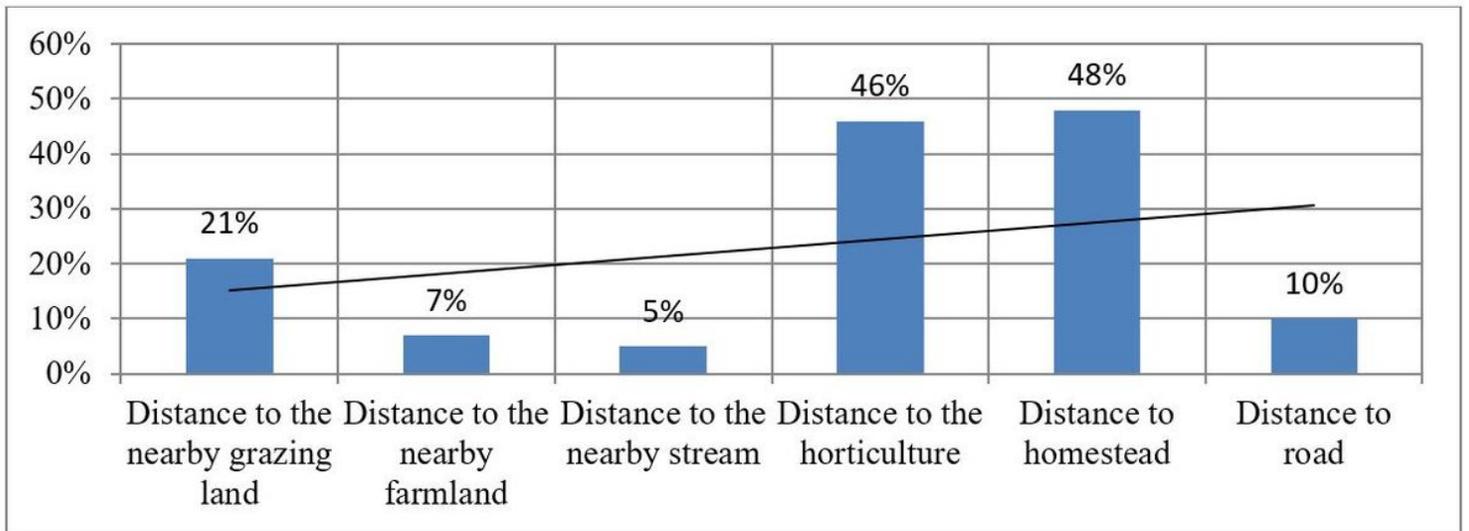


Figure 3

The average walking distance from eucalypt stands to different land uses in minutes.

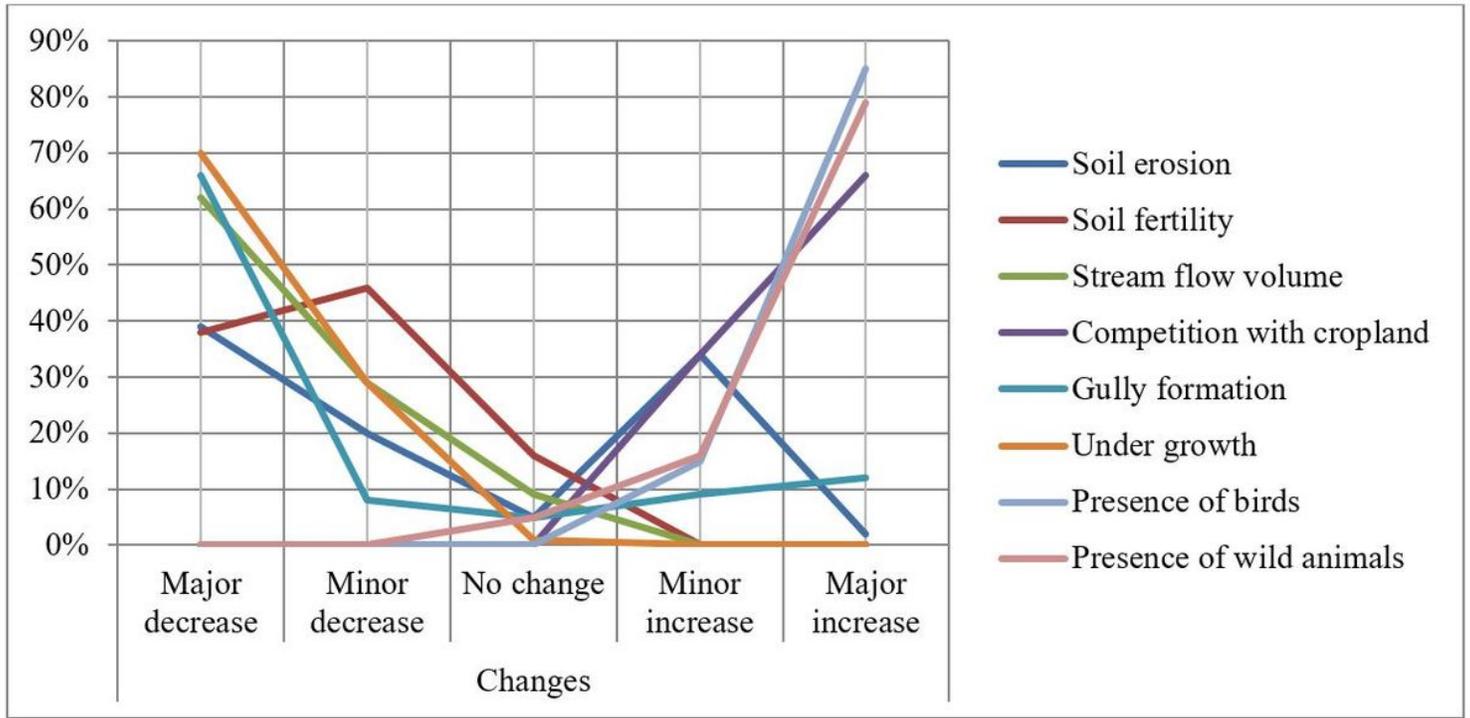


Figure 4

The indicators of perceived environmental changes.

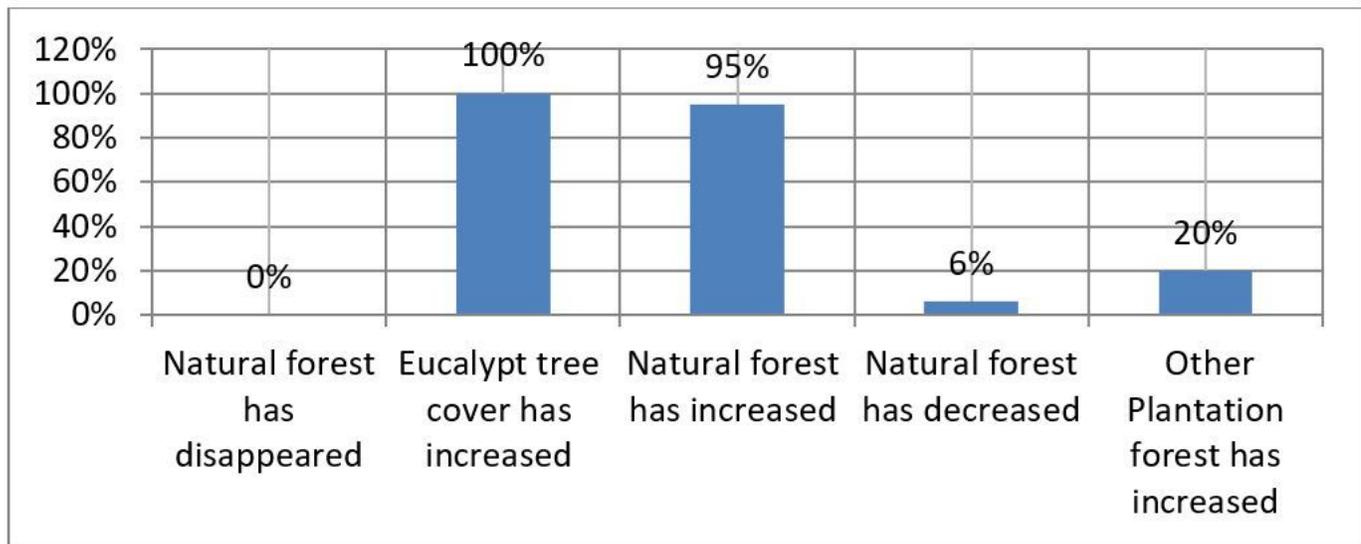
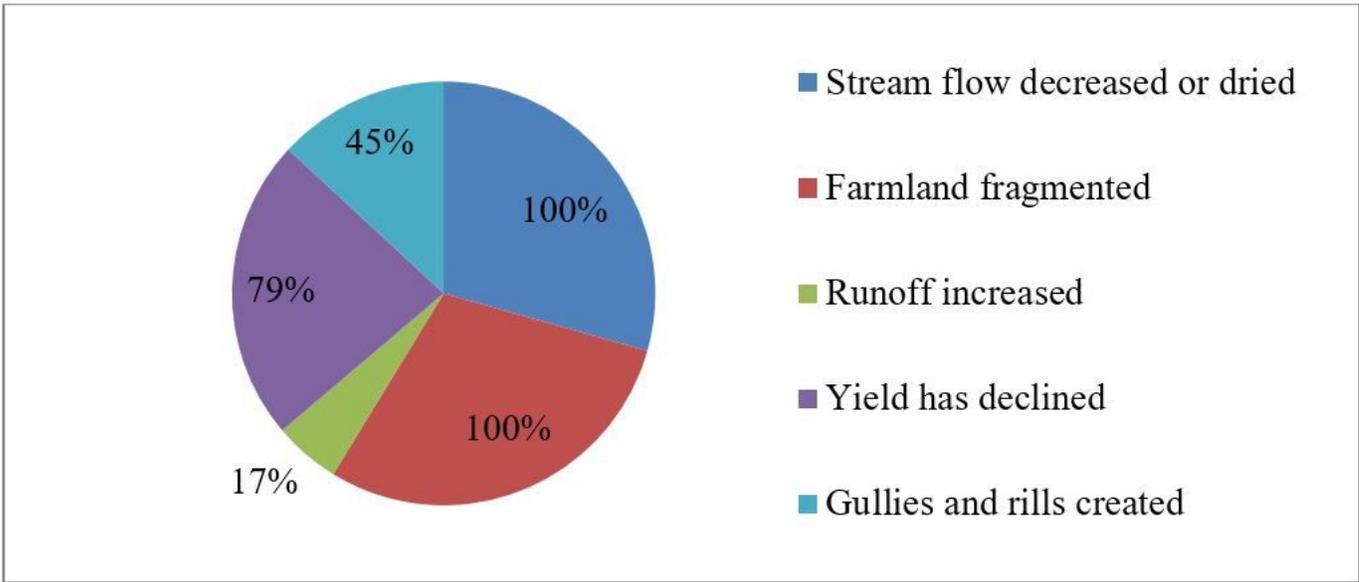
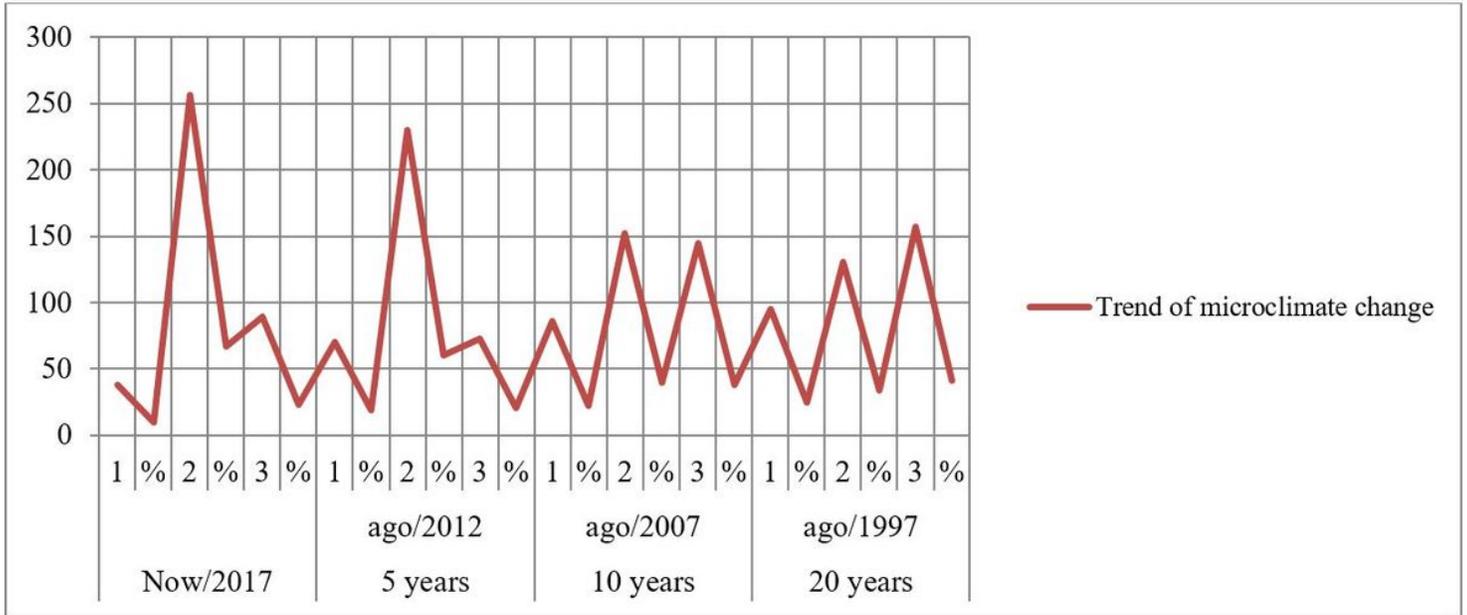


Figure 5

Changes observed in the forest cover after the expansion of eucalypts since the last 20 years.



**Figure 6**  
Negative changes perceived due to eucalypts.



**Figure 7**  
Perceived trend of trend of micro climate change due to eucalypts over time.

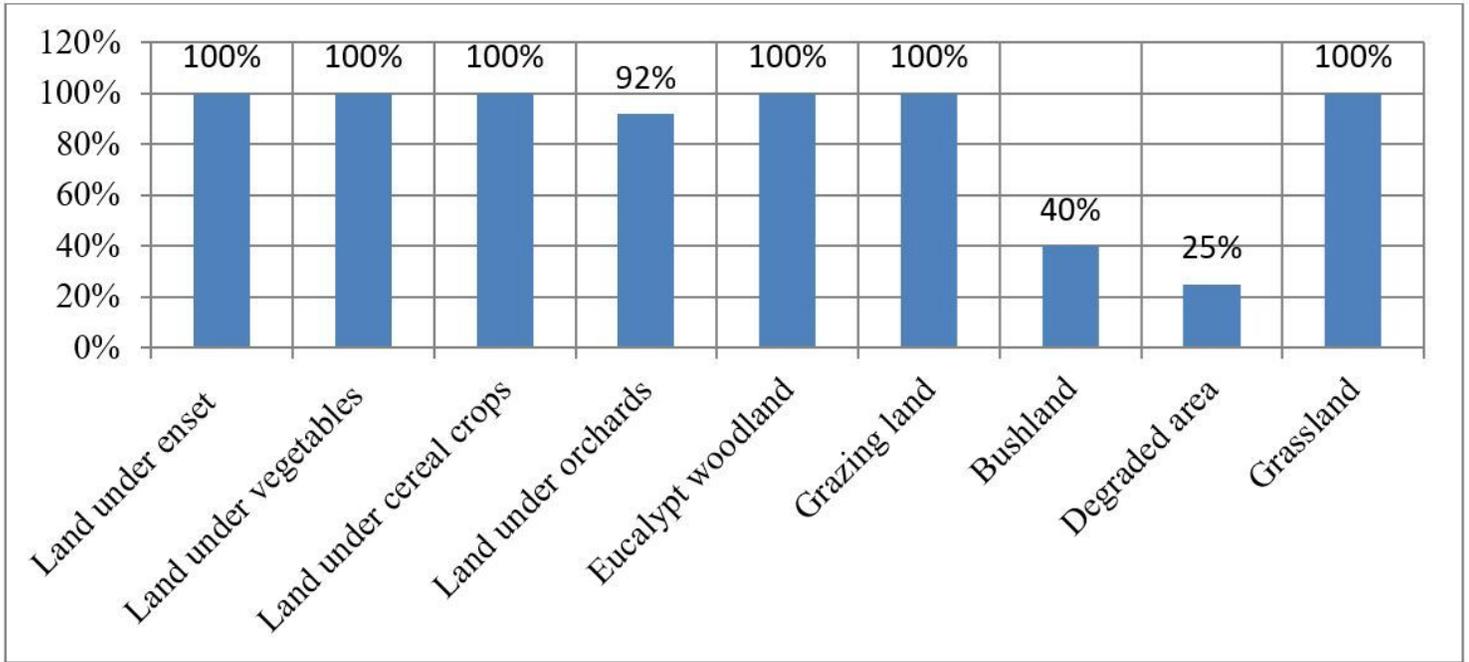


Figure 8

Land use pattern used by households.

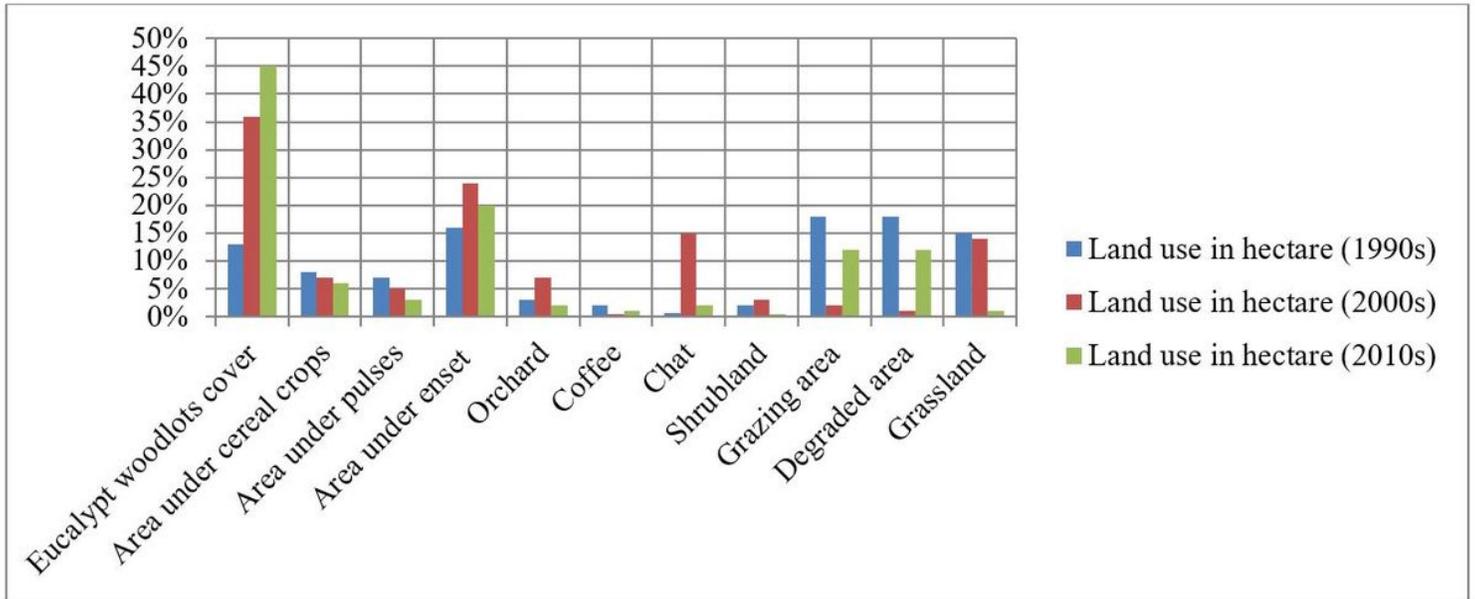


Figure 9

Land holding size for different uses per hectare in different decades

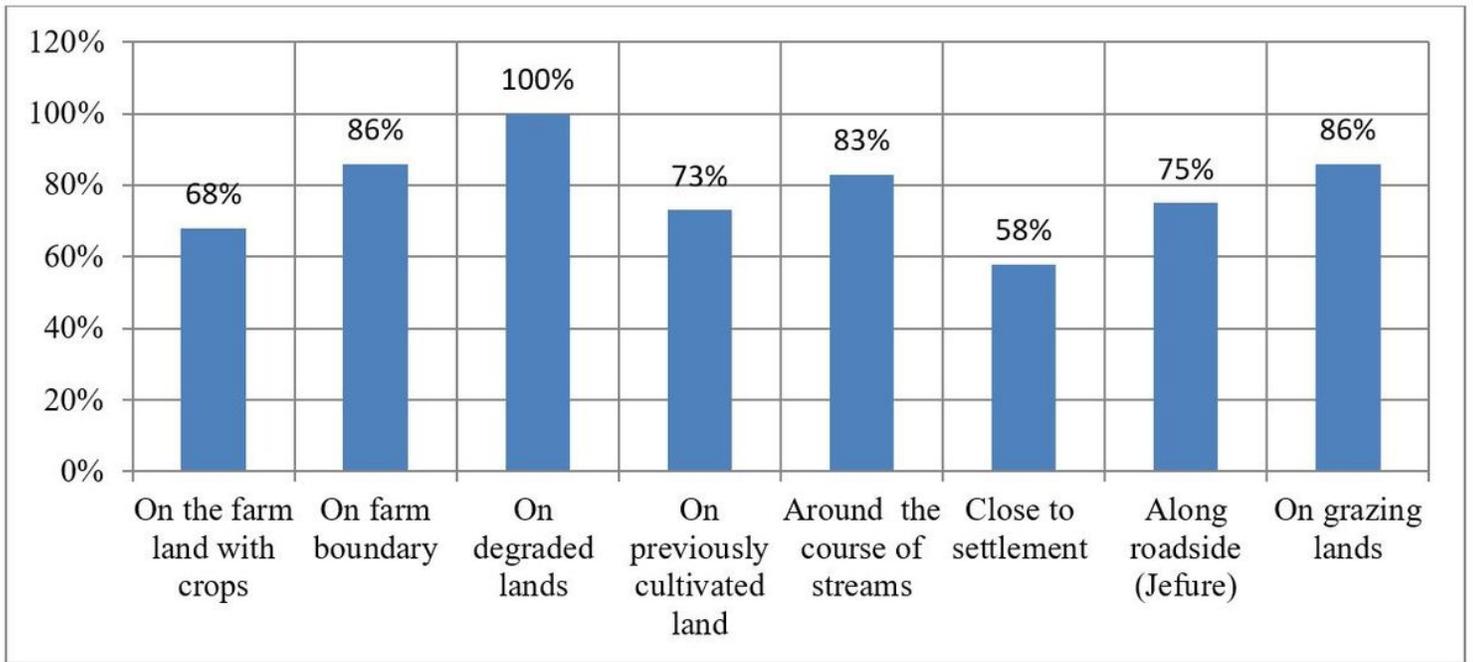


Figure 10

Location of eucalypts plantation.

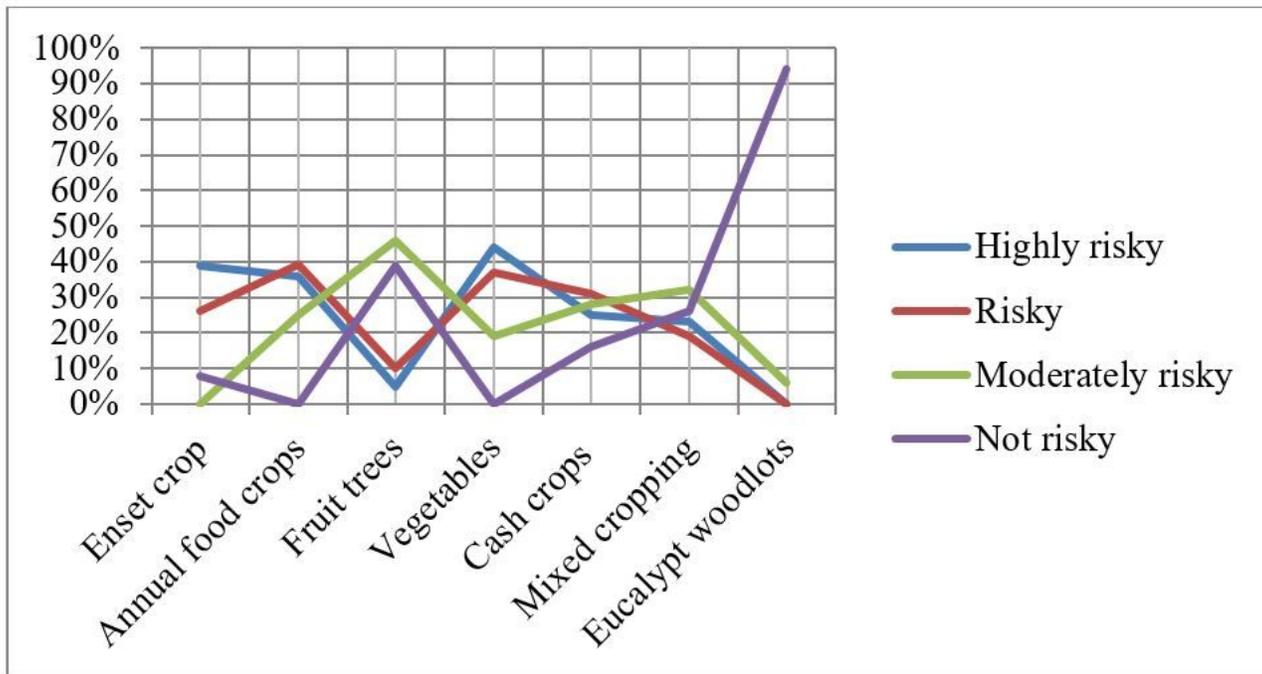


Figure 11

Yield risk level of farming types

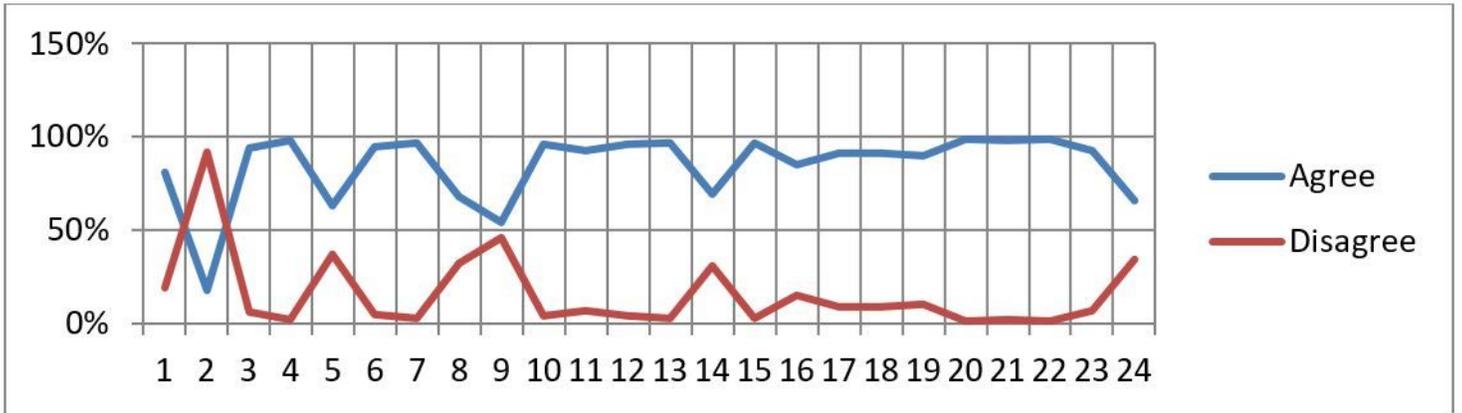


Figure 12

Households' attitudes/statements on eucalypt plantations.

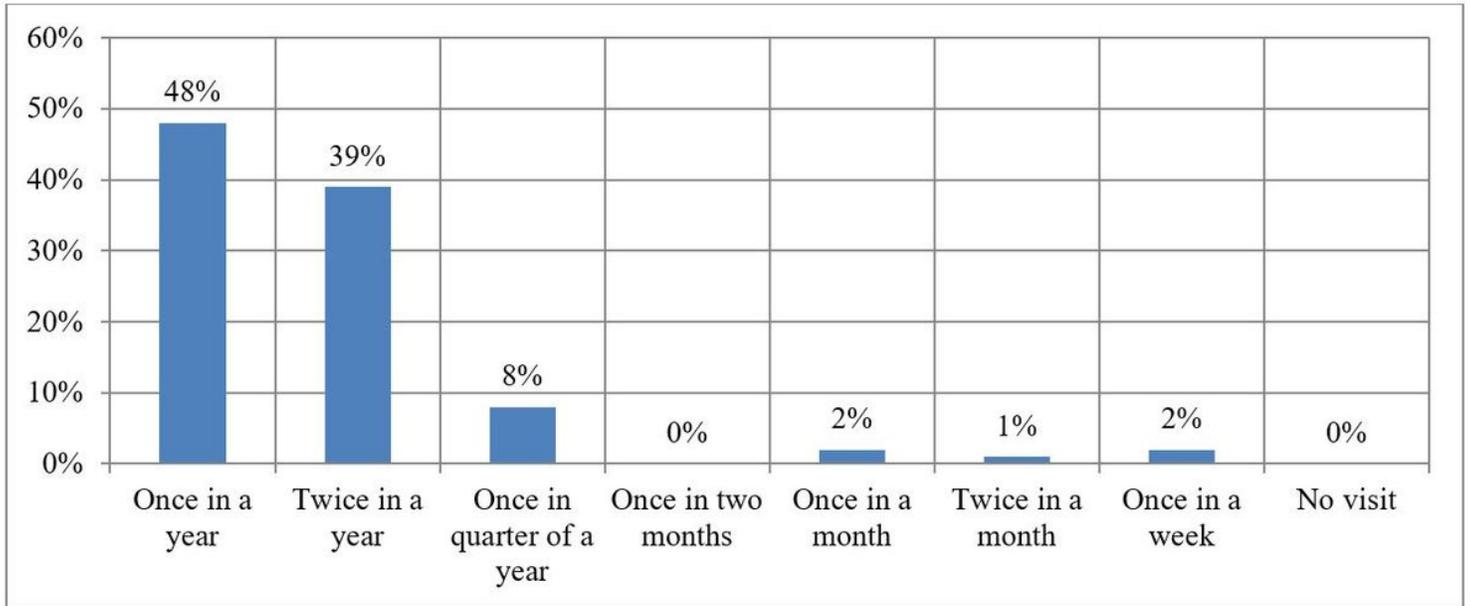


Figure 13

Status of Woreda agricultural experts' visit to households' farm.