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Research Article

Assessment of agroforestry practices in Buno Bedele and Ilu Abba Bora zones of Oromia region, Ethiopia

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Article Info

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Abstract

Agroforestry practices are considered as one of the major sources of food and income to meet the needs and the wellbeing of the rural communities. This study was conducted in Buno Bedele and Ilu Abba Bora zones, with the objective to identify and assess agroforestry practices, importance, constraints and farmers' perception on the existing agroforestry practices in study area. Accordingly, 3 districts from each zone and a total of 12 Kebeles (2 Kebeles each from 6 districts) were selected purposely. A total of 299 household were selected for the survey. Semi-structured questionnaire data was generated by conducting household survey, key informant interviews, and direct field observations were applied. Based on the respondent's response across both zones, the results of this study have shown that there were existing agroforestry practices covering Homegardens (96 %), Coffee based agroforestry practice (91.3), Fruit trees based agroforestry practice (86.6%), woodlots (65.6%), windbreak/shelterbelts (62.5%), Trees on rangeland (57.2%), Life fencing (53.8%), Parkland agroforestry (43.1%), Taungya (26.4%) and Alley cropping (16.7%) in the study area. The major Importance of agroforestry practices were income generation, regulation of climate effects, soil improvements, used for shade, food human and livestock feed, proper land use, wood for construction, fuel wood and timber. Impacts on wild animals, insect pest and diseases, competition of trees with crop (i.e. shading effect), shortage of land for tree planting, lack of capital, lack of knowledge, taking long time for profit, lack of seed accessibility and shortage of labor were the major constraints recorded in the study areas. Majority of respondents have strongly agreed with the benefits of the existing agroforestry practices such as increased farm income, improved soil fertility and conserved soil and water, saved time on collecting fodder and fuel wood from the forest and improved the environmental conditions. The respondents in study area have shown positive attitude towards the existing agroforestry practices such as planting of trees like Albizia gummifera (78.2 %), Cordia africana (67.9%) and Croton macrostachyus (63.2%) were the most common trees that dominated the study areas. Albizia gummifera (67.2%) and Cordia africana (61.9%) also were most preferred trees by farmers in field. Avocado (91.3%), Banana (79.6%) and Mango (61.9%) were the most dominant fruit trees/shrubs, while Maize (95%), Coffee (91.3%), Teff (76.6%), Chat (65.9%) and Sorghum (52.8%) were the most dominant crops. Cows, Oxen, Calves, Chicken were the most dominant livestock categories. The study recommends further studies have to be made on positive trees/shrubs selection, management and introducing new agroforestry practices and manage the exist agroforestry practice in the study areas.

Keywords: Onno Biosphere, Diameter Distribution, Parameter estimation

1 Introduction

Agroforestry is a form of sustainable land use systems that integrates trees with crops or animal husbandry to initiate an agro ecological succession (FAO, 2013). Agroforestry provides various ecosystem services through providing diversified household needs including cultural services such as agro-tourism, beautiful fascinations, demonstration, and education. Principally, agroforestry affords amendable services such as soil conservation, watershed management, pest control and sinks for carbon. In so doing, it contributes to the mitigation of global climate change (Jose and Bardhan, 2012).

In Africa, rapid population growth, decline of per capita food production and environmental degradation are the main problems. Consequently, the need for intensification of agricultural production coupled with population growth forces poor farmers to expand their cultivation to hilly and marginal areas. This process aggravates the degradation of natural resources. In relation to this, agroforestry practice can be one of the superior options to reduce pressure on remaining natural forests and sustain biodiversity (Kang, Akinnifesib, 2000; Gustavo, et al., 2004).

In Ethiopia, the integration of trees and shrubs into agriculture emerged many years ago (Edmond et al., 2000). The historical development of farming practices in the country followed by the human settlement in the past impacted the agricultural production in northern part than the other parts of Ethiopia. The current agricultural land coverage in Ethiopia is estimated to be about 46% by supporting 83% livelihoods of the population, 80% of export earnings and 73% of the raw materials in agro-based industries (Brown et al., 2012; Bishaw et al., 2013). Various agroforestry systems are practiced in different parts of the country. One of the oldest indigenous parkland agroforestry systems characterized by retention of scattered tree such as Faidherbia albida on crop land of rift valley and highlands of eastern Ethiopia (Abebe, 2005; Asfaw and Ågren, 2007). The deliberate retaining of naturally occurring trees on farmlands is a common land use practice carried out by smallholders for monetary, construction and fuel wood materials, environmental, and cultural uses (Jamala et al., 2013; Iiyama et al., 2017). However, parkland agroforestry practices are declining from agricultural landscapes due to increased demands for fuel wood and degradation of nearby forests (Onyekwelu et al., 2015). Agricultural intensification, the increasing popularity of exotic tree species which generate larger economic benefits for farmers (Teshome, 2009), and the fact that land proclamations do not specify clear instructions for farmers on how to manage and conserve indigenous trees. Several Agroforestry practice can be relevant for different agro-ecological zones, and many systems with a range of different composition can fulfill essentially the same function for livelihoods and landscapes.

In Ilu Abba Bora and Buno Bedele zones, there are many agroforestry practices in farmlands for value of indigenous conservation measures. However, the existing agroforestry practices and systems are not assessed, identifying by research to documented and characterize the existing farmland agroforestry practices and to share best practices of agroforestry existing at study area.

Therefore, study was initiated with the objective to identify and assess the existing Agroforestry practices, analyse constraints, opportunities and farmers' perception of these practices in study area.

2 Research Methodology

2.1 Description of study areas

The study was conducted in the six districts of Ilu Abba Bora and Buno Bedele zones of the Oromia Regional State, Southwestern Ethiopia. Three districts from each zone, namely, Bacho, Alle and Darinu and Gechi, Chora and Bedele districts, respectively were purposely selected (Figure 1).

Ilu Abba Bora is in the Southwestern part of the regional state of Oromia, Ethiopia. The capital town of the zone is Mattu, which is located at distances 600km, southwestern of Addis Ababa. It lies between 34°52'30"E - 36°53'0'E longitudes and 7°27'30"N - 8°49'30"N latitudes. The zone is surrounded by two Regional States and three zones of Oromia National Region. The zones and regions bordering the Zone are in the West by Gambela Region, in East and Southeast by SNNPS, in the North and West Wollega, in the North-East by East Buno Bedele zone and in the South by SNNPS. The areal coverage of the Ilubabor zone is estimated to be 10,920 KM² or (1,092,000 hectares). The zones consist of highland (17%), midland (62%) and lowland (21%) agro-ecologies; and temperature ranges from16c° to 26c° (Zone Physical and Socio-Economic Profile, 2021-2022). The farming systems of the zones are characterized by mixed farming system comprising both cropping and livestock production.

Buno Bedele Zone is one of the Zones of Oromia National Regional State in Ethiopia and bordered in the south by Southern Nations, Nationalities, and Peoples Region, in the west by the Ilu Aba Bora Zone, in the north by the East WollegaZone and West WollegaZone and in the east by the Jimma Zone. The capital town of the zone is Bedele, which is located at the distance 480km, southwestern of Addis Ababa, the capital city of the country.

2.2 Sample size and sampling technique

Firstly, meetings were made with two Agricultural offices of the zones (Buno Bedele and Ilu Abba Bora) in order to identify the most potential districts where agroforestry practices are carried out. Then three districts were selected purposively from each zone. Totally six districts, three from Buno Bedele zone (Bedele, Gechi and Chora districts) and three from Ilu Abba Bora zone (Bacho, Alle and Darimu districts) were selected. Two kebeles also were selected purposively from each district. A total of 12 kebeles six from Buno Bedele zone (Obolo Bechara and Sidisa Kebeles from Bedele district, Gito and Chara kebeles from Gechi district and Hawa Yember

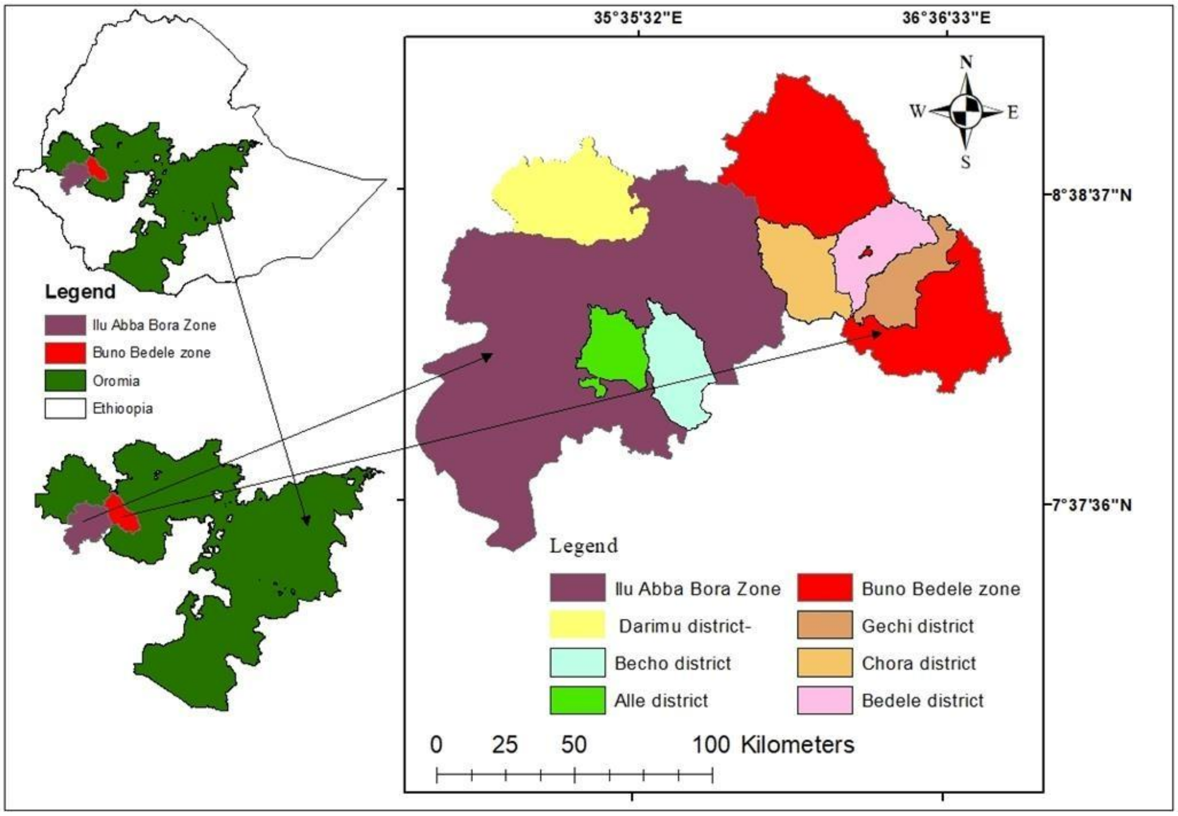

Figure 1: Map of study area

and Hawa Geba kebeles from Chora district) and six from Ilu Abba Bora zone (Kundi and Chatu Kebeles from Alle district, FogoSardo and Bake kebeles from Bacho district and Boto and Gobora kebeles from Darimu district) were selected.

Accordingly, 150 household were selected purposively from Buno Bedele zone (50 households from each district and from each Kebele 25 households were selected) and 151 household were selected from Ilu Abba Bora zone. 53 households from Alle district 25 household from Kundi kebele and 28 households from Chatu, 46 Households from Bacho district 25 Household from Fogo Sardo and 21 Household from Bake kebele and 52 Household from Darimu district 25 Household from Boto kebele and 27 household from Gobora kebele were selected. Totally 301 household were participated.

2.3 Methods of data collection and analysis

The data were collected in each zone at kebele level through questions using questionnaire, key informant interviews and direct field observations. The key informant interviews were conducted in the study areas with purposively selected community representatives such as elderly individuals who had ample knowledge about agroforestry practices in the study areas and Development Agents, natural resource experts to check the data collected from normal resources survey were correct and relevant. Accordingly, seven key formants have participated from each kebele. Direct field observations were carried out to identify component arrangements of agroforestry practices in the study areas.

The types of agroforestry practices existed in the study areas were identified based on farmer's indigenous knowledge through normal survey. The data collected from samples household responses were analyzed by using statistical package for social science (SPSS version 20). Descriptive analysis was employed using tools such as percentage and frequency distribution.

3 Results and Discussion

3.1 Characteristics of respondents

The general characteristics related with agroforestry practices as identified by household respondents are presented by sex, age, marital status, family size education status and experience of farming system stated (Table 1).

The majority of the respondents about 91.6% out of 301 households were male whereas 8.4% were female. This implies that majority of the household head in agroforestry practices in zones were male and low number of females were observed in the study sites.

The majority of the household heads were between 31-40 years age group (31.4%), followed by age group 20-30 years age group (23.7%) and 42-52, 53-63 and above 63 years which in percent

21.1%, 15.4% and 8.4%, respectively. From the above results, it can be deduced that the households surveyed on agroforestry practices were dominated by medium age group. The smallest portion of age group was above 63 years old.

The marital status of the household head showed that the married respondents share the majority percentage (96%), followed by a single and divorced constitute 2% and 2%, respectively.

About 55.9% household respondents had family members between 5-8 while 30.1 % respondents had range of 1-4 family members and remaining respondents (14%) had above 8 family members per household, respectively.

Concerning to education status, about 77 of % respondents were literate while 23.1% of the respondents were illiterate. From educated respondents 56.6% of respondents educated levels were above grade four. The majority of the respondents (57.9%) had above 24 years of experience in farming system (Table 1).

3.2 Agroforestry practices in study area

Based on the results of the study, 10 agroforestry practices were identified and documented in study areas. Smallholder agroforestry practices vary depending on the socioeconomic and biophysical conditions (Jamala et al., 2013; Abrham et al., 2016; Iiyama et al., 2017). The results of the study revealed that among the identified agroforestry practices, home garden is the most dominant (96%) of agroforestry practice followed by coffee based agroforestry practice (91.3%), fruit trees based agroforestry practice (86.6%), woodlots (65.6%), windbreak/shelterbelts (62.5%), trees on rangelands (57.2%), life fencing (53.8%), parkland agroforestry (43.1%), taungya (26.4%), and alley cropping (16.7%), respectively (Table 2). The identified agroforestry practice in both zones (Buno Bedele and Ilu Abba Bora) were almost of similar status.

The respondents have reasoned out why the home garden agroforestry practice was widely practiced in study area is because of its simplicity for management, especially for protecting home garden from attack of wild animals and it consists of multipurpose trees, fruit trees and livestock in and around of households and get diversified outputs from this practice.

The second dominant agroforestry practice was coffee responded by 91.3 % because the area is suitable for coffee production and the households obtain most income from this practice.

From existing agroforestry practices in the study areas, alley cropping was the least practiced component responded by 16.7% of respondents in both zones. In contrast, the study made by Musa et al., 2022, in East Hararghe parkland agroforestry has been mentioned 58% of the respondents, followed by alley cropping as hedge row intercropping 33%, home garden 22%, multipurpose trees on farmland 19%, live fence/boundary tree planting 18%, and wind breaks 4% were identified. In this report, alley cropping was the second dominant agroforestry practice. Similarly, the findings of the study made in Arba Minch Zuriya district of Gamo Gofa Zone indicated that homegardens, intercropping and livestock production were the major agroforestry practices of the area, respectively, the dominant being the homegardens practice (Alemu, 2016).

The homegarden is one of dominantly identified agroforestry practices in the study areas. Homegardens are practiced around home and composed of a high diversity of plants and an important source of diversified products used by the households. Products like avocado, banana, mango, orange, guava, apple and enset, maize, khat, coffee, cardamom, were cultivated in study areas. Albizia gummifera, Cordia africana, Varnonia amygdalina and Ricinus communis were the most available species in homegardens of study areas.

Coffee based agroforestry practice was the second major agroforestry practice identified at study areas. The farmers of study areas cultivate coffee under diverse shade trees like Albizia gummifera, Acacia spp, Cordia africana, Croton macrostachyus and Sesbania sesban in study areas.

Fruit trees-based agroforestry practice is widely used by farmers at study areas, and it has a role in providing multiple benefits to the households in the study areas. Fruit trees contribute towards income generation, food security and also used as a shade for coffee-based agroforestry practices. Avocado, Banana, Mango, Orange, Guava and Custard apple were the most dominant fruit trees dispersed through crop land, pasture and near home in study areas.

Woodlots are planted by farmers in study areas on a small-scale as one land use practices, for income generation, fuelwood and construction material production. Eucalyptus spp, Grevillea robusta and Pinus patula trees species were the most preferred tree species for woodlot agroforestry practice in study areas.

Windbreaks/Shetterbelts are lines of trees or shrubs which are used for the purpose of reduction of wind speed in the study areas. The tree species used for the windbreak in the study areas included Eucalyptus spp, Grevillea robusta, Juniperus procera and fruits like Avocado and Mango.

Trees on rang land are scattered trees in rangelands and beneficial in providing shade for livestock. Grevillea robusta and Pinus patula trees species were planted dispersed on range land of study areas.

Life fencing is widespread agroforestry practice trees/shrubs area established to border plots of home gardens and farmlands. It is used for protection of wild animals and cattle from crops. Erythrina brucei and Capparis tomentosa tree species are used as a live fence in study areas. Erythrina brucei is used for firewood, medicine, fodder, bee forage, mulch, nitrogen fixation, soil conservation and life fence, also Capparis tomentosa is also used for firewood, medicine, life fence and fencing material (Azene B.T, 2007).

Parkland agroforestry practice involves the growing of individual trees and shrubs scattered in the farmland, while field crops are grown under shade of the trees. Some of the naturally grown tree species include Cordia africana, Acacia spp, Ficus vasta and Croton macrostachyus Syzygium guineense Albezia gumufera and Primus africana and are mostly dispersed in the crop fields of maize and teff in the study areas.

Table 1: Characteristics of the sample household at study area

Category	Variables	Buno Bedele Zone N (%)	Ilu Abba Bora Zone N (%)	Overall N (%)
Sex	Male	141(94)	133(89.3)	274(91.6)
	Female	9(6)	16(10.7)	25(8.4)
Age class	20-30	35(23.3)	36(24.2)	71(23.7)
	31-40	46(30.7)	48(32.2)	94(31.4)
	42-52	36(24)	27(18.1)	63(21.1)
	53-63	25(16.7)	21(14.1)	46(15.4)
	¿63	8(5.3)	17(11.4)	25(8.4)
Marital status	Single	4(2.7)	2(1.3)	6(2)
	Married	144(96)	143(96)	287(96)
	Divorced	2(1.3)	4(2.7)	6(2)
Family size	1-4	48(32)	42(28.2)	90(30.1)
	5-8	83(55.3)	84(56.4)	167(55.9)
	¿8	19(12.7)	23(15.4)	42(14)
Educational	Illiterate	36(24)	33(22.1)	69(23.1)
	Grade 1-4	34(22.7)	27(18.1)	61(20.4)
	Grade 5-8	51(34)	61(40.9)	112(37.5)
	Grade 9-12	28(18.7)	26(17.4)	54(18.1)
	Diploma	10(7)	2(1.3)	3(1)
Experience of farming	1-5 years	3(2)	7(4.7)	10(3.3)
	6-14 years	22(14.7)	29(19.5)	51(17.1)
	15-24 years	39(26)	26(17.4)	65(21.7)
	¿24 years	86(57.3)	87(58.4)	173(57.9)

Taungya practice is trees planting; growing agricultural crops for 1-3 years until the shade of trees become denser or increase canopy cover. The farmers exercised this practice by using Cardamom crop under Grevillea robusta and pinus patula plantation and it's used to generate income. The majority of trees used in taungya practice tree are planted using spacing of 1m*1m between trees.

Alley cropping is one of an important agroforestry practice in which legume trees species are planted in row and crops planted between of hedgerow trees. High organic biomass is produced from the pruning of hedgerows and accumulates soil organic matter and nutrients. From identified agroforestry practices in the study areas, this practice was the least used in both zones. Banana, mango and avocado are used around homestead as alley cropping plants with maize crop in the study areas.

Major common trees at study area Albizia gummifera, Cordia africana, Croton macrostachyus, Eucalyptus spp, Grevillea robusta, Acacia spp, Sapium ellipticum and Varnonia amygdalina, Juniperus procera, Ficus vasta, Syzygium guineense, Podocarpus facaltus and Prunus africana were the common trees found in the study areas (Table 3). According to the reply of respondents, Cordia africana is the best trees for timber production in the study areas.

3.3 Tree species most preferred in field by Farmers

Albizia gummifera, Cordia africana, Grevillea robusta, Acacia spp, Eucalyptus spp, Croton macrostachyus, and Varnonia amygdalina were most preferred trees by farmers in study areas (Figure 2). Eucalyptus tree species was planted on uncultivated land as woodland used to obtain cash income for the household economy. This result is line with (Endale, 2017) who found that Eucalyptus camaldulensis and Cupressus lustianica tree species were the most preferred for woodlot purpose around Jimma town.

3.4 Major fruit trees/shrubs, crops and livestock at study area

The farmers in the study area use different agroforestry practices such as production of fruit trees, crops and livestock. The results of the study indicated that among the fruit trees, avocado (91.3%), banana (79.6%) and mango (61.9%) were the most dominant, while maize (95%), coffee (91.3%), teff (76.6%), khat (65.9%) and sorghum (52.8%) were the commonly used crops. Cows, oxen, calves, chicken, sheep, goat, donkey, and horse were the most dominant livestock found in the study areas (Table 4). Coffee and khat were the major cash crops in the study areas. FAO (2013) mentioned that agroforestry is a form of sustainable land use systems that integrates trees with crops or animal husbandry to initiate an agro ecological succession.

3.5 Farmer's perceptions on agroforestry practices

The results of the investigation showed that farmers in study areas widely participated in agroforestry practices on their farmlands and around homesteads. The majorities of respondents have benefited from the existing agroforestry practices in various forms such as increased farm income, improved soil fertility and conserved soil and

Table 2: Types of existing agroforestry practice in study area

Agroforestry practice	Buno Bedele zone n=150			Ilu Abba Bora zone n=151			Overall n=301
	Bedele district n=50	Gechi district n=50	Chora district n=50	Alle district n=53	Bacho district n=46	Darimu district n=52	
	Obolo Bechara kebele n=25	Sidisa kebele n=25	Gito Kebele n=25	Chara Kebele n=25	Hawa Yember kebele n=28	Kundi Gaba kebele n=21	
Homegardens	100	100	100	96	96	96	96
Coffee based	84	100	84	60	100	96	91.3
Fruit trees based	84	76	72	76	64	88	86.6
Woodlot	60	68	80	52	64	72	65.6
Windbreak/Shelterbelts	96	72	72	84	64	72	62.5
Trees on Rang land	64	68	44	72	48	68	57.2
Life Fencing	52	36	52	24	40	24	53.8
Parkland agroforestry	44	44	52	40	28	32	43.1
Taungya	12	20	20	44	28	44	26.4
Alley cropping	8	8	4	36	12	12	16.7

Table 3: Major common trees at the study area

Tree species	Local name	Uses of trees for:	Buno Bedele N (%)	Ilu Abba Bora N (%)	Total N (%)
Croton macrostachyus	Bakkannisa	Soil fertility/shade/construction/medicinal	64.7	71.1	67.9
Eucalyptus spp	Bargamoo	construction/income	54.7	71.8	63.2
Ficus vasta	Qiltuu	Soil fertility/shade	6	22.1	14
Grevillea robusta	Giravilaa	Soil fertility/shade/construction/timber	44.7	39.6	42.1
Juniperus procera	Gaattiraa	Timber	16.7	12.1	14.4
Podocarpus facaltus	Birbinsa	Soil fertility/shade/construction/timber	14	0.7	7.4
Prunus africana	Hoomii	Soil fertility/shade/medicinal/timber	8.7	6	7.4
Sapium ellipticum	Bosoga	Soil fertility/shade/construction/timber	3.3	26.2	14.7
Syzygium guineense	Baddeessa	Soil fertility/shade/construction/timber	12.7	4.7	8.7
Varnonia amygdalina	Eebicha	Soil fertility/shade/medicinal	12.7	16.8	14.7
Acacia spp	Laaftoo/Sondi	Soil fertility/shade/construction	41.3	24.2	32.8
Albizia gummifera	Ambabbeessa	Soil fertility/shade/construction/medicinal	70.7	85.9	78.2

water, saved time on collecting fodder and fuel wood from the forest and improved the natural condition (Table 5). Based on respondent's reply most households had good perceptions and faithfulness for agroforestry practices in the study areas. The results of this study are similar to the finding of Alemayehu et al. (2021), the farmers had positive perception on agroforestry practices, and they knew very well its utilities for income diversification, improvement of soil quality, fuel, construction materials, food, and feed, provision of shade, accessibility and ecological values that could be understood from the given inquiry parameters.

3.6 Major constraints and importance to agroforestry practices at study area

The finding revealed that, among the identified importance of agroforestry at study area increasing income of household, regulate climate of the area, shading importance, add soil fertility, purpose for food and fodder, properly using the land, for construction, fuel wood and timber were the major opportunities of agroforestry respectively (Table 6). In similarly agroforestry practices are considered as one of the major source of food and income to meet the needs and the wellbeing of the rural community (Galhena et al., 2013).

On other side, impacts of wild animals, Insect pest and disease, competition trees with crop (i.e. shading effect), shortage of land for tree planting, lack of capital, lack of knowledge, taking long time for profit and lack of seed accessibility and shortage of labor are the main constraints in agroforestry practices respectively at study area (Table 7).

3.7 Trends of each value over last ten years

The results of the study showed that fruit trees planting, and agroforestry practices have increased in study areas over last ten years. The reasons of increasing of these practices in the study areas were awareness creation on management and management of the natural resources. Generally, honey, crop production and animal husbandry have been through time (Figure 3). The crop production was decrease because shortage of agricultural land, lack of oxen for ploughing the farmlands and increasing agricultural input costs.

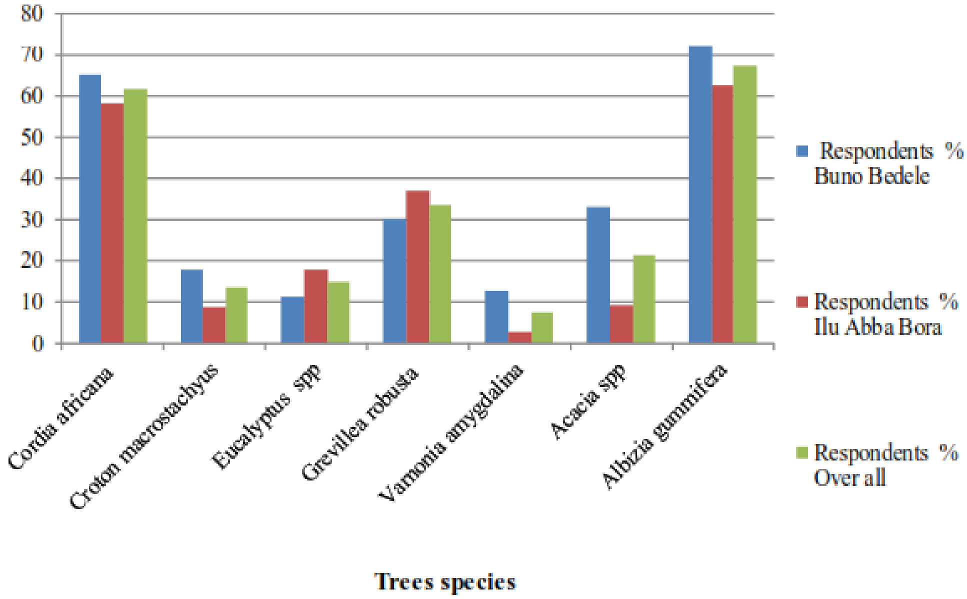

Figure 2: Tree species most preferred in field by Farmers

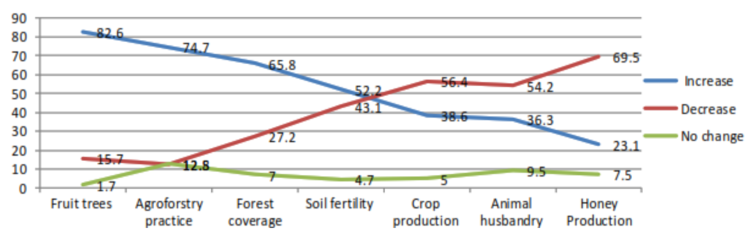

Figure 3: Response of respondents in percentage on trends of each value over ten years

Therefore, the farmers practically participated in planting coffee, fruit and Eucalyptus trees instead of crop production.

4 Conclusion

The study of the existing agroforestry practices revealed that home garden, coffee-based agroforestry,fruit trees based agroforestry, woodlot, windbreak/shelterbelts, trees on rangelands, life fencing, parkland agroforestry, taungya, and alley cropping were the most common types of agroforestry practices identified in the study areas. These practices had components of common trees like Albizia gummifera, Cordia africana, Croton macrostachyus, Eucalyptus spp, Grevillea robusta, Acacia spp, Sapium ellipticum and Varnonia amygdalina, Juniperus procera, Ficus vasta, Syzygium guineense, Podocarpus facaltus and Prunus africana. The major fruit trees species in the study areas were avocado, banana and mango mixed major crops like maize, coffee, teff, khat and sorghum. The agroforestry practices in study areas have played important role in increasing income of households, regulate climate of the areas, shading effect, increase soil fertility, proper use of available land, produce food and fodder, construction materials, fuel wood and timber. Major constraints of the existing agroforestry practices mentioned by the respondents included problems associated to negative impacts on wild animals, occurrence of insect pest and disease, competition trees with crop (i.e. shading effect), shortage of land for tree planting, lack of capital, lack of knowledge and improved seed accessibility. Generally, the study results indicated that home garden are the dominant and alley cropping the least agroforestry practice used. Impacts of wild animal were also found to be the one of the constraints of the existing agroforestry practices in study areas.

Further studies for the improvement of agroforestry practices in the study areas should be done on positive interaction trees/shrubs and management of different components of the existing agroforestry practices to improve the livelihoods of farmer to reduce the existing constraints.

Acknowledgements

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Table 4: Major fruit trees/shrubs, crops and livestock at study area

Category	Buno Bedele N (%)	Ilu Abba Bora N (%)	Overall N (%)
Fruit trees/shrubs			
Mango	57.3	66	61.9
Banana	67.3	92	79.6
Orange	18	34	26.1
Lemon	8	15.3	11.7
Avocado	90.7	92	91.3
Papaya	20	16.7	18.4
Apple	13.3	9.3	11
Pineapple	5.3	10	7.4
Guava	21.3	17.3	19.1
Custard Apple	20.7	16	18.1
Citron	3.3	4.7	4
Cashmere	10	6	8
Crops			
Maize	90.7	99.3	95
Haricot bean	4.7	30.1	17.4
Teff	82	71.1	76.6
Fingermilet	19.3	22.8	21.1
Sorghum	31.3	74.8	52.8
Coffee	87.3	95.3	91.3
Chat	77.3	54.4	65.9
Hot pepper	2	14.1	8
Barely	24	6.7	15.4
Wheat	20.7	15.4	18.1
Fabien	9.3	10.7	10
Field pea	4.7	4	4.3
Livestock			
Oxen	83.3	79.9	81.6
Cow	86.7	83.2	84.9
Chicken	64.7	89.9	70.2
Sheep	38	51	44.5
Goat	34.7	12.8	23.7
Calve	75.3	65.8	70.6
Donkey	17.3	12.8	15.1
Horse	6.7	20.8	13.7

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Competing Interest

No competing of interests associated with this publication.

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Table 5: Farmer's perception about agroforestry practice at study area

Statements	1	2	3	4	5
Increased farm income	59.9	37.1	2.3	0.7	0
Increased soil fertility & conserved soil & water	69.2	30.8	0	0	0
Reduced chances of complete crop failure	43.1	48.2	7.4	1.3	0
Saved time on collecting fodder and fuel wood from the forest	64.2	33.1	2.3	0.3	0
Took a long time to get income	45.5	45.8	7.1	1.7	0
Sustain/improve the natural condition	65.6	33.1	0.7	0.7	0
Preferred trees in farmland increase crop productivity	49.8	45.2	5	0	0
Trees in farmland used as windbreak, &increase soil fertility & crop production.	64.4	34.6	1	0	0

Table 6: Major importance to agroforestry practice at study area

Importance	Buno Bedele N (%)	Ilu Abba Bora N (%)
Properly using the land	29.5	24.5
Add income	51.4	55.2
Shading importance	37.7	28.7
Regulated climates	48.6	52.4
Timber	9.6	14.7
Construction	28.1	16.8
Fuel wood	15.8	18.2
Add soil fertility	52.1	23.8
Food and livestock feed	24.7	37.1
Save time	3.4	nil

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Table 7: Major constraints to agroforestry practice at study area

Constraints	Buno Bedele N (%)	Ilu Abba Bora N (%)
Shortage of land for tree planting	4.4	9.9
Take long time for profit	9.7	nil
Lack of capital	6.2	4.4
Insect pest and disease	25.7	19.8
Impacts of arboreal animals	45.1	54.9
Lack of seed accessibility	9.7	Nil
Lack of knowledge	8.8	1.1
Shortage of labor	1.8	7.7
Competition trees with crop (i.e. shading effect)	19.5	11.0

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Research Article

Floristic Composition and Diameter Distribution Models for The Management of Omo Biosphere Reserve, Ogun State, Nigeria

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Abstract

Stem diameter distributions is highly needed in most forest management decisions. This study developed some models for describing the diameter distribution of Omo Biosphere Reserve in lowland rainforest ecosystem, Nigeria. Systematic sampling design was used to lay three straight line transects, four temporary plots of 0.25ha (50 m x 50 m) were laid in alternating position along each transect at 100 m interval to make up a total of 12 plots for the study and Diameter at breast height (DBH) was measured for all trees with Dbh $\geq$ 10cm in every plot.A total of fifty-seven species were encountered and exploratory analysis of the collected data showed that the observation was right skewed consequently resulting in the choice of six probability diameter distributions functions using Maximum likelihood estimator. The selected distribution models are Weibull, Lognormal Distribution (LN), Gamma, Logit-logistic (LL) and Burr distribution. The Kurtosis and Skewness are 6.43 and 1.34 respectively with a mean Dbh of 36.40cm. Burr had the least values of Kolmogorov Smirnov (Dn) (0.046), Anderson Darling (AD) (1.102) and Cramer-von Mises (CvM) (0.178). This is followed by log logistics with 0.05, 2.769 are 0.258 for Dn, AD and CvM respectively. High and positive skewness and kurtosis values reflect abundance of trees in the lower Dbh class. These are sufficient to replace the trees in the upper dbh class through regeneration. Hence, the Burr and Log-logistic distributions were adjudged the most flexible to describe the diameter structure of Omo Biosphere Reserve.

Keywords: Omo Biosphere, Diameter Distribution, Parameter estimationn

1 Introduction

The tropical rain forest is the most diverse of all terrestrial ecosystems, containing more plants and animals' species than any other biome (Turner, 2001). Tropical forests are among the richest and most complex terrestrial ecosystems supporting a variety of life forms of not less than half of all the species on earth (Phillips, 1994; Ojo, 2004; Oladoye, 2014). It possesses a tremendous intrinsic ability for self-regeneration if properly maintained. The great number of species that form them is the reason for their fascination to people, their value to the biosphere, and the complexity of their proper management.

In recent times, effort has been focused at conservation of this important ecosystem, because of its richness in biodiversity. Development of growth models for Omo Biosphere reserve will enable sustainable promotion of productive and protective aspects of the diverse species present (Gorgoso, et al., 2007). Stem diameter distributions is highly needed in majority of forest management decisions, and this has made diameter distribution modelling procedure to be one of the widely applied practices in forest management techniques (Ajayi, 2005). DeLiocourt (1898) reported the idea of diameter distribution that plotting the number of trees against diameter classes as a frequency histogram results in an inverse J-shaped curve.

Tree size distributions remain the most effective tool to describe the status and structures of any forest estate. Thus, value forests, planning to harvest activities, predicting forest growth, enhancing forest productivity, information on past disturbance events, forest successional status, and aboveground biomass stocks are some of the reasons for tree diameter distributions modelling (Bailey and Dell, 1973; Coomes and Allen, 2007; Burkhart and Tome, 2012; Ezenwenyi, et al, 2018).

Diameter class models allow planning of various uses and provide data about stand structure. These models are used to estimate stand variables and their structure with a density or distribution function, which is fitted to diameter distributions at breast height (DBH) or individual tree volume (Ige et al., 2014). Several authors have established the validity of some probability distributions that provided information about forest stand structure. Some of them are Beta distribution (e.g., Gorgoso–Varela et al., 2008; Ige et al., 2014), gamma distribution (e.g., Mirzaei et al., 2015; Adedoyin et al., 2021), Burr distribution (e.g., Tsogt et al., 2013), Johnson's SB distribution (Tsogt et al., 2013; Mayrinck et al. 2018; Ogana and Ekpa 2020)) and Weibull distribution (Gorgoso et al., 2012; Ezenwenyi et al., 2018; Sun et al. 2019; Egomnwan and Ogana 2020; Ige and Adedapo, 2021), however, No single type of stand model can be sufficiently enough to provide all the needed information for effective decision making (Adesoye, 2002; Ige et al., 2014).

Hence, it is important to test a wide variety of models of varying degree of complexity for the management of Omo Biosphere reserve, Nigeria. Most studies on diameter distribution models in Omo biosphere reserves had been on plantations (Ogana et al., 2017; Ezewenyi, et al., 2018; Ogundipe et al., 2018;) hence, the importance of this study can be well justified from this point of view. Therefore, the main objective of this study was to develop diameter distributions models for Omo biosphere reserve Nigeria.

2 Methodology

2.1 The study area

This study was conducted in Omo Biosphere Reserve, within Omo Forest Reserve, Ogun State, Nigeria. It is an internationally recognized unique habitat. Omo Forest Reserve, Area J4, is located in Ijebu East Local Government Area of Ogun State, Nigeria, on latitude 6º 50' N and longitude 4º 22' E (Figure 1). It became a United Nations Educational, Scientific and Cultural Organization (UNESCO) Biosphere Reserve in 1949 (Were, 2001). IUCN, 1991). The reserve is divided into core (460 ha) and buffer zones (8,165 ha). The reserve falls within the tropical wet- and-dry climates characterized by two rainfall peaks separated by a relatively less humid period usually in the month of August. The mean annual rainfall is about 1750 mm, while mean relative humidity is 80%. The temperature ranged between 25 C to 31 C. Generally, sunshine duration during the rainy season varies between 8-10 hours (Ola-Adams, 2014). The soil is a mixture of Ferralile and Ferruginous soils and the Reserve is a mixed moist semi-evergreen rainforest with undulating terrain and elevation of 150 m above sea level, and with tropical ferruginous soil (Isichei, 1995). The most abundant tree species in the reserve are Funtumia elastica, Diospyros dendo, Phyllanthus discoideus, Neosgordonia papaverifera and Picralima nitida (Chenge and Osho, 2018, Chenge, 2021).

2.2 Data collection

Data for this study was collected using Systematic sampling (line transect) technique. For plot location, 20m from the forest boundary was measured to locate the first transect. The coordinates of the starting point of each transaction were determined with the aid of Geographic Positioning System (GPS) receiver. Three transects were laid out within the study area at 200 m intervals. Four 0.25ha (50 m x 50 m) plots were laid in alternate positions along each transect at 100 m spacing, which makes the total number of plots to be twelve. Diameter at breast height (DBH) of all trees in each plot were measured using diameter tape, while Diameter at the base (Db,,), Diameter at the middle (Dm), and Diameter at the top (Dt) and Height were measured using Spiegel Relaskop.

2.3 Data Analysis

The following diameter distribution models were fitted: Burr distribution, logit-logistic (LL), gamma, lognormal distribution (LN), and 3-P Weibull, using R statistical software, version 4.0.35 The distribution models were evaluated with Kolmogorov Smirnov (KS), Anderson Darling (AD) and Cramer-von Mises (CvM) goodness of fit and they were ranked accordingly. Summary statistics of the measured variables is presented on Table 1. The ecological status of the tree species was determined by calculating the Importance Value Index (IVI). The percentage values of the relative frequency, relative density and relative dominance are summed up together and this value is designated as the Importance Value Index or IVI of the species (Curtis, 1959, Oladoye et al., 2014, Oladoye et al., 2018).

$$\text{Relative Density} = \frac{\text{number of species}}{\text{Total number of species}} \times 100$$

$$\text{Relative Frequency (RF)} = \frac{\text{frequency of a woody plant species}}{\text{Total frequency of woody plant species}} \times 100$$

$$\text{Relative Dominance} = \frac{\text{Total basal area of all species}}{\text{Total basal area of all species}} \times 100$$

2.4 Model Validation

Model validation is important before they can be used with confidence. Validation involves the process of testing and comparing the

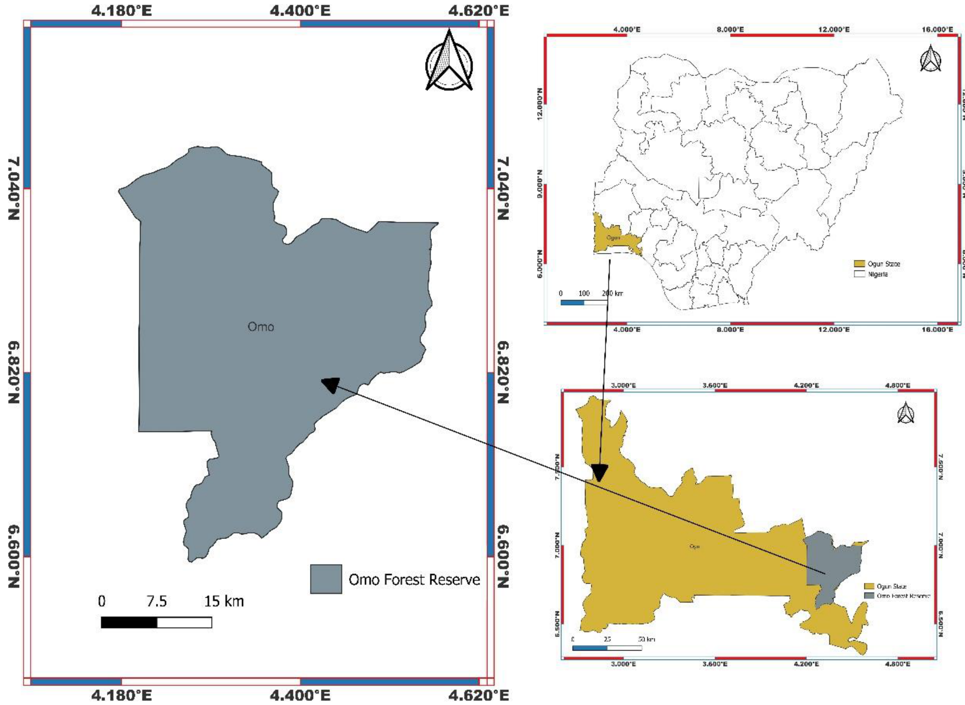

Figure 1: Map of the study area

models output with what is observed in the real world (Reynolds et al, 1981; Ige et al, 2014). The data were split into two sets randomly; the first set (i.e., n=298) was the calibration set which was used for model construction and the second was the validation set (i.e., n=99). (Maltamo and Kangas, 2008; Ige et al., 2014).

3 Results

3.1 Diameter Distribution for Omo Forest

The summary of the descriptive statistics for diameter at breast height is presented in Table 1. The Standard Error, kurtosis and skewness are 1.34 trees/ha, 6.43 and 2.28, respectively. The mean DBH is 36.40cm. A total of 395 trees (DBH $\geq$ 10cm) representing 56 species from 22 families were encountered and identified in the Biosphere Reserve. Among the identified tree species are Celtis zenkeri, Diospyros dendo, Diospyros hybridus, Sterculia rhinopatala, strombosia postulate, Desplatsia lutea, Diospyros mespiliformis, Pycnanthus angolensis, Celba pentandra, Cleistopholis philippensis, Cola gigantea, Cordia milleni, Diospyros canaliculata, Drypetes gilgiana, Entadrophragma cylindricum, Macaranga bateri, Nauclea diderichii, Picralima nitida, and Pterygota macrocarpa. Their density ranged from 0.33 to 22.67 trees/ha and the Important Value Index (IVI) ranged from 0.99 to 37.36 (Table 3). The results of the goodness of fit for the various diameter distribution models is presented in Table 4. The results showed that Burr model had the smallest values of Dn, AD and CvM of 0.046, 1.102 and 0.178, respectively followed by Log Logistic with 0.05, 2.769 and 0.258 for Dn, AD and CvM, respectively. The graph of the observed and predicted diameter distribution from 2P Weibull, Burr, lognormal, log logistic and Gamma is presented in Figure 1, the predicted distribution showed no significant difference between the empirical cumulative functions and the theoretical cumulative functions. Figure 2 presents the DBH frequency distribution class for the 395 trees encountered in the study area. The result showed that most of the trees are in the diameter class of 10-50cm (323 trees).

4 Discussion

A total of 395 trees representing 57 species from 22 families were encountered in this biosphere reserve, indicative of high species richness and abundance of woody species in the lowland rainforest of Nigeria. This is lower than the findings of Tang et al., (2010), who reported 109 species in secondary vegetation community of China, Komolafe et al., (2017) reported 93 species in a Nigerian forest and findings of Seyni et al., (2021) and Oladoye et al., (2014). The floristic richness of Omo Biosphere Reserve could be a function of the favourable climatic condition in addition to contributions from different vegetative typology (Oladoye et al., 2014), and conservation status of the forest reserve.

Importance value index (IVI) describes the overall importance of each species in its community structure (Olajuyigbe et al. 2018; Fayiah et al., 2018; Oladoye et al., 2014). Overall, the IVI of the species were generally low ranging from 0.99 to 37.36. Only 15 species have IVI value that is above 5. The relative dominance contributed greatly to the IVI of the species, this could be attributed to

Table 1: Summary of descriptive statistics of sampled trees in Omo Biosphere Reserve.

Variables	Fitting data (N trees = 296)				Validation data (N trees = 99)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
DBH (cm)	35.52	27.02	10.00	180.00	39.05	24.64	10.00	116.00
MHT (m)	15.55	6.65	4.00	45.00	16.83	7.17	4.00	35.00
THT (m)	22.74	7.61	8.40	40.00	24.37	7.99	7.20	42.00
VOL(m^3)	2.41	6.49	0.03	59.04	3.09	6.20	0.03	29.87
BA (m^2)	0.16	0.31	0.01	2.55	0.17	0.23	0.01	1.06
CL	7.19	3.09	1.00	32.50	75.78	3.35	28.53	180.00
CR	0.33	0.12	0.09	1.00	7.55	0.13	2.00	17.00
SLC	80.25	33.16	17.39	177.42	0.33	31.40	0.05	0.78
Skewness	1.34							
Kurtosis	6.43							

Table 2: Description of the probability distribution models

Diameter Distribution Models	Equations
1 Burr	$f(x)=\frac{ak\left(\frac{x-y}{\beta}\right)^{a-1}}{\beta\left(1+\left(\frac{x-y}{\beta}\right)^{a}\right)^{k+1}}$
2 Loglogistics	$f(x)=\frac{\alpha}{\beta}\left(\frac{x-y}{\beta}\right)^{a-1}\left(1+\left(\frac{x-y}{\beta}\right)^{a}\right)^{-2}$
3 Gamma	$f(x)=\frac{(x-y)^{a-1}}{\beta^{\alpha}\Gamma(\alpha)}\exp\left(-\frac{x-y}{\beta}\right)$
4 Lognormal	Form: $f(x)=\frac{1}{\sqrt{2\pi}}\frac{\sigma^{-1}}{x}\exp\left[-\frac{\sigma^{-2}}{2}(\log x-\mu)^2\right]$
	Parameter: $\mu\in(-\infty,+\infty),\sigma>0$
5 Weibull Distribution	$f(x)=\frac{c}{h}\left(\frac{x-a}{h}\right)^{c-1}\exp\left(-\frac{x-a}{h}\right)^{c}$

the high diameter at breast height and the general low IVI may also be attributed to low frequency and density of the species encountered.

For effective forest management and valid decision-making and forest growth indicator, diameters distribution model is usually needed. The distribution of trees by diameter class allows foresters and ecologists to understand structure and stand dynamics (Ezenwenyi et al., 2018; Ekpa et al., 2020; Ciccu et al., 2021).

The mean DBH of 36.40($\pm$1.34) cm for the biosphere reserve suggests that the majority of the tress are in the lower diameter class and a reflection of regeneration potentials of the forest estate. This agrees with the findings of Bobo et al., (2006); Aigbe and Omokhua, (2014) who reported similar trend in Southwestern Cameroon and Oban Forest Reserve in Nigeria, respectively. High positive skewness observed in the current study suggests that considerable number of trees are concentrated within the lower diameter classes and that a good number of these trees are suppressed due to canopy closure of the forest areas. This finding agrees with some previous studies (e.g., Adedoyin et al., 2021; Ekpa et al., 2020; Robson et al., 2016; Adekunle, 2002; Podlaski and Roesch, 2014; Aigbe omokhua, 2014).

High kurtosis coefficients of 6.44 imply that most distribution are platykurtic and correspond to the curves that are flatter than the normal curve with positive excess. This reflects the high concentration of diameter at breast height within the lower-class distribution. The result of this finding agrees with Lima et al., (2014; 2017); and Ruppert (2011). Out of five (5) distribution models that were tested, (t test), Burr (0.046) was adjudged the best using Kolmogorov – Smirnov statistics and followed by log-logistics (0.054) as shown in Table 9 suggesting that the data followed a specific distribution. This is similar to findings of the Aigbe and omokehina, (2014), in Orban forest reserve, where the D – value for all the models fitted were lower than the tabulated D-values. The findings of this study also corroborate the studies of Lima et al., (2017), who reported that Burr function showed good flexibility to describe the diameter structure at the stand in Brazilian tropical dry forest.

The pattern of DBH distribution is indicative of positive skewness as evidence in the values and a reflection of abundance of trees in the lower DBH class that are sufficient to replace the trees in the upper DBH class through regeneration. This agrees with the findings of Ekpa et al., (2020) in arboretum of the University of Uyo, Nigeria; Adekunle (2002) in Ala and Omo Forest; Bobo et al., (2006) in Cameroon; Ige et al., (2014) in Onigambari Forest, Nigeria and Boubli et al., (2004) in Congo. This may also suggest that the natural regeneration and recruitment are consistently on going which are vital indications of forest health and vigor (Jimoh et al., 2011; Ekpa et al., 2020). However, the presence of more trees in the lower DBH class may also reflect heavy and continuous disturbance of the forest.

The graphs of observed and predicted DBH class of distribution function showed that there is no significant difference (P>0.05. This finding is in agreement with Egomnwan and Ogana, (2020); Aigbe and Omokhua (2014); Adedoyin and Adeoti, (2021) and Ige et al., (2014).

Table 3: List of tree species encountered, families, stem density, and Importance Value Index for Omo Biosphere Reserve

Species	Family	Total	Density (ha^{-1})	IVI	Species	Family	Total	Density (ha^{-1})	IVI	
Adenopus breviflorus	Cucurbitaceae	1	0.33	1.40	*Hylodendron gabonense*	Fabaceae	1	0.33	1.12	
Albizia ferruginea	Fabaceae	3	1.00	3.01	*Irvingia wombolu*	Irvingiaceae	1	0.33	1.25	
Alstonia congoensis	Apocynaceae	1	0.33	4.61	*Khaya grandifoliola*	Meliaceae	3	1.00	5.93	
Brachystegia eurycoma	Fabaceae	1	0.33	2.30	*Macaranga barteri*	Euphorbiaceae	1	0.33	2.53	
Buckleya disticha	Santalaceae	1	0.33	1.08	*Macaranga grandifolia*	Euphorbiaceae	1	0.33	1.71	
Canthium huilense	Rubiaceae	3	1.00	2.46	*Macaranga sp.*	Euphorbiaceae	2	0.67	1.29	
Ceiba pentandra	Malvaceae	4	1.33	9.38	*Malacantha alnifolia*	Sapotaceae	1	0.33	1.30	
Cola mildbraedii	Sterculiaceae	3	1.00	1.67	*Maranthes glabra*	Chrysobalanaceae	11	3.67	6.46	
Celtis zenkeri	Cannabaceae	55	18.33	37.36	*Maesobotrya acuminata*	Rubiaceae	1	0.33	1.03	
Chrysophyllum albidum	Sapotaceae	1	0.33	1.49	*Milicia excelsa*	Moraceae	3	1.00	4.04	
Cleistopholis patens	Annonaceae	2	0.67	1.93	*Mimusops andongensis*	Sapotaceae	1	0.33	1.11	
Cleistopholis philippensis	Annonaceae	6	2.00	6.38	*Musanga cecropioides*	Urticaceae	1	0.33	1.04	
Cola gigantea	Sterculiaceae	3	1.00	4.65	*Nauclea diderrichii*	Rubiaceae	3	1.00	6.53	
Cordia millenii	Boraginaceae	2	0.67	4.34	*Nesogordonia papaverifera*	Malvaceae	1	0.33	1.66	: 395 131.67 300
Desplazia laurifolia	Icacinaceae	14	4.67	10.36	*Nuxia congesta*	Loganiaceae	6	2.00	5.08	
Diospyros canaliculata	Ebenaceae	6	2.00	3.21	*Pterocarpus mildbraedii*	Apocynaceae	3	1.00	2.56	
Diospyros dendo	Ebenaceae	68	22.67	31.81	*Pycnanthus angolensis*	Myristicaceae	2	0.67	3.62	
Diospyros hybridus	Ebenaceae	62	20.67	26.05	*Pyrenacantha angolensis*	Icacinaceae	7	2.33	6.97	
Diospyros macrophylla	Ebenaceae	9	3.00	7.11	*Rauvolfia vomitoria*	Apocynaceae	1	0.33	0.99	
Drypetes floribunda	Euphorbiaceae	10	3.33	6.53	*Ricinodendron heudelotii*	Euphorbiaceae	8	2.67	10.75	
Drypetes gerrardii	Euphorbiaceae	2	0.67	2.25	*Sterculia rhinopetala*	Sterculiaceae	15	5.00	14.36	
Drypetes gossweileri	Euphorbiaceae	5	1.67	2.47	*Strombosia pustulata*	Olacaceae	24	8.00	15.21	
Drypetes welwitschii	Euphorbiaceae	1	0.33	1.12	*Terminalia superba*	Combretaceae	2	0.67	4.02	
Entandrophragma cylindricum	Meliaceae	2	0.67	2.66	*Tetrapleura tetraptera*	Fabaceae	1	0.33	1.11	
Entandrophragma angolense	Meliaceae	1	0.33	1.54	*Trema orientalis*	Ulmaceae	2	0.67	1.36	
Fagara indica	Rutaceae	3	1.00	4.14	*Trichilia monadelpha*	Meliaceae	2	0.67	1.96	
Funtumia elastica	Apocynaceae	8	2.67	4.99	*Uapaca togoensis*	Euphorbiaceae	3	1.00	2.88	
Hunteria umbellata	Apocynaceae	7	2.33	4.59	*Xylopia aethiopica*	Annonaceae	1	0.33	2.88	

Table 4: Summary of goodness of fit of distribution functions for Omo Biosphere Reserve.

Distribution	Kolmogorov Smirnov	Anderson Darling	Cramer-von Mises
2p Weibull	0.125	13.582	2.157
Burr	0.046	1.102	0.178
Lognormal	1	inf	132.333
Log Logistic	0.054	2.769	0.258
Gamma	0.104	9.506	1.556

This is further explained as evident in the Figures 1 and 2, that this peculiarity associated to curves with more extended tails of the intermediate diameter classes with a sharper frequency peak to the left in the initial classes implies that the mode of distribution was clearly displayed which is typical of tropical forests as a reflection of forest dynamics.

In addition, some species stood out with their highest density within these lower classes hence the inverted – J shape. (Zheng and Zhou, 2010; Lima et al, 2017; Ekpa, et al., 2020). Omo Biosphere Reserve showed diameter distribution which depicts a single peak to the left with positive skewness and findings from this study have provided information on the ability of other distribution functions such as burr, logit logistic, etc. to describe the diameter structure of a natural forests as well.

5 Conclusion and Recommendations

Tree diameter distribution is an effective method of describing stand properties. Tree volume, value, conversion, cost, and product specification are dependent on stem diameter. The study provided information on tree population and regeneration potential, and strategies with reference to stem diameter classes. Hence the information from the study is important for effective and productive management of Omo Biosphere Reserve and forest reserve with similar ecological conditions. Further studies on comparative assessment based on the number of parameters to best fit the diameter in Omo biosphere reserve and reserves with similar ecosystem is advocated.

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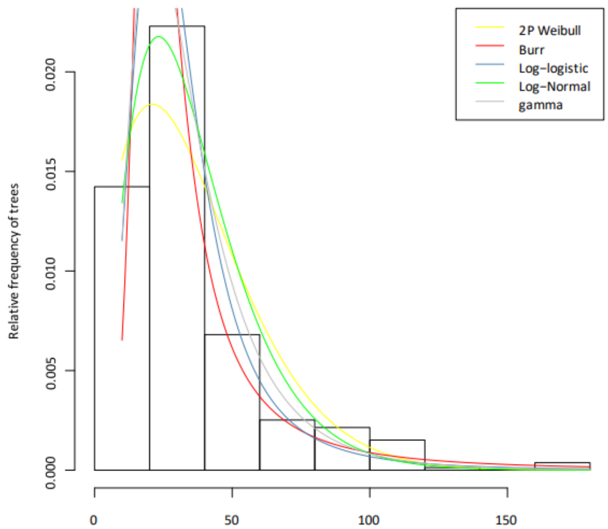

Figure 2: Graphs of observed and estimated probability function of DBH for Omo Biosphere Reserve.

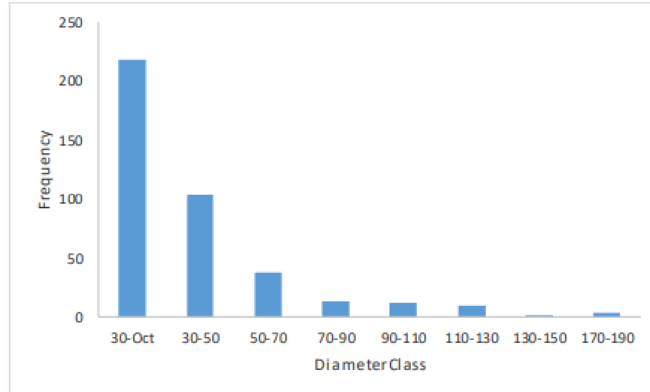

Figure 3: Tree diameter class distribution for Omo Biosphere Reserve.

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Research Article

Determinants of farmers' adoption of rainwater harvesting technologies in Boricha woreda of Sidama Regional State, Ethiopia

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Abstract

Stem diameter distributions is highly needed in most forest management decisions. This study developed some models for describing the diameter distribution of Omo Biosphere Reserve in lowland rainforest ecosystem, Nigeria. Systematic sampling design was used to lay three straight line transects, four temporary plots of 0.25ha (50 m x 50 m) were laid in alternating position along each transect at 100 m interval to make up a total of 12 plots for the study and Diameter at breast height (DBH) was measured for all trees with Dbh $\geq$ 10cm in every plot.A total of fifty-seven species were encountered and exploratory analysis of the collected data showed that the observation was right skewed consequently resulting in the choice of six probability diameter distributions functions using Maximum likelihood estimator. The selected distribution models are Weibull, Lognormal Distribution (LN), Gamma, Logit-logistic (LL) and Burr distribution. The Kurtosis and Skewness are 6.43 and 1.34 respectively with a mean Dbh of 36.40cm. Burr had the least values of Kolmogorov Smirnov (Dn) (0.046), Anderson Darling (AD) (1.102) and Cramer-von Mises (CvM) (0.178). This is followed by log logistics with 0.05, 2.769 are 0.258 for Dn, AD and CvM respectively. High and positive skewness and kurtosis values reflect abundance of trees in the lower Dbh class. These are sufficient to replace the trees in the upper dbh class through regeneration. Hence, the Burr and Log-logistic distributions were adjudged the most flexible to describe the diameter structure of Omo Biosphere Reserve.
Keywords: Omo Biosphere, Diameter Distribution, Parameter estimationn

1 Introduction

In the world, more marginal areas are being used for farming and most of this land is found in the arid or semi-arid belts where rainfall is variable (Mahoo et al., 2007). Water is a critically important and scarce resource in semi-arid and arid parts of the world. Aridity and climate change are the main problems faced by farmers who rely on rain-fed farming in arid and semi-arid areas (Kahinda et al., 2008). Implementing technologies for proper management of water in water-scarce areas could assist the livelihood of inhabitants.

Rainwater harvesting technologies (RWHT) have been applied to cope with water scarcity (Adham et al., 2016). Rainwater harvesting is a method of collecting, storing and conserving surface runoff for agricultural production and domestic use.

In arid regions, farmers face variability and low mean annual rainfall (Mahoo et al., 2007). Nowadays, inhabitants of North and South America employ relatively simple methods of water harvesting for irrigation (Sauerhaft et al., 2010).

Agriculture is the main economic activity in Sub-Saharan African

(SSA) countries, accounting for about 67%, which depends on rain-fed agricultural practices, generating 30-40% of the SSA countries' GDP (Ngigi et al., 2006). Since agriculture is the highest consumer of water in SSA countries, efficient and effective water utilization is necessary to sustain their livelihood (Yemeuu et al., 2014). However, rainfall is poorly distributed in the SSA. The irregularity and variability in the distribution of rainfall have made agriculture unable to sustain food production to meet the increasing demand in the region (Mutiga et al., 2011). Recurrent drought and food insecurity has become a common phenomenon that threatens the lives of millions of poor people in Sub-Saharan African countries (Shiferaw et al., 2005). Rapid population growth, high unemployment, dependence on the primary sector economy, export commodities, and underutilization of natural resources worsen the problems in SSA. These factors may threaten the lives of many people in the region unless rain-fed agriculture is augmented with RWHT adoption (Kahinda et al., 2011).

In Ethiopia, approximately 42% of the country's GDP, 85% of the labor force, and 90% of national export earnings are from agriculture (CSA, 2018). Moreover, in Ethiopia the agriculture sector heavily relies on rain-fed agriculture, characterized by low use of modern agricultural inputs, low output levels, highly vulnerable to drought and low augmenting with RWHT (Degefu and Bewket, 2014). Floods and drought are recurrent, every 3 to 5 years, with increasing frequency compared to two or three decades ago, which forced the country to rely on imports of food and food aid (Awulachew et al., 2005; Tofu and Wolak, 2023).

Rain water harvesting technologies can minimize the problems associated with water scarcity for crop production. Adoption of rainwater harvesting is essential in food insecure areas (Tasisa et al., 2020). Since many areas of Ethiopia are characterized by the erratic nature of rainfall and dry spells during the crop growing season, RWHT should support rain-fed farming in order to alleviate the moisture stress during the critical crop growing season. Improving rainwater harvesting can improve agricultural production by making water available during dry periods. The RWHT most practiced in Ethiopia are runoff irrigation (runoff farming), flood spreading (spate irrigation), in-situ water harvesting (ridges, micro basins, etc) and roof water harvesting (Degefu and Bewket, 2014).

According to Dile et al. (2016), small-scale RWHT has been practiced almost all over the world for millennia. Recent research findings indicated that RWHT adoption can increase agricultural productivity, provide an opportunity to stabilize agricultural production, particularly in arid, and semi-arid areas where water is limited and ensure food security (Gowing et al., 2003). The widespread droughts have led to growing awareness of the opportunity for rainwater harvesting adoption that focused on combating the effects of droughts by adopting small-scale rainwater harvesting technologies (Critchley et al., 2013). Some factors including slope, land use/cover, soil type, rainfall, distance from settlement to stream/river, and cost can determine farmers' adoption and management of rainwater harvesting (Adham et al., 2016; Girma, 2020). Although small-scale RWHT adoption has been the center of attention for the water policy of Ethiopia (Eleni et al., 2004), little has been gained to feed those drought-prone areas at household level. The practice of rainwater harvesting technologies has been poorly documented in the country. Problems related to food security and climate variability as well as soil fertility decline have been documented in the rural areas around the study site (Atara et al., 2019; Majo, 2021; Dangiso and Wolka, 2023). However, in the Boricha area, and in the country in general, there are limited studies on rainwater harvesting and factors affecting RWHT adoption, which are important to cope with climate variability and food insecurity. The objective of this study was to document and identify determinants of the adoption of rainwater harvesting technology.

2 Materials and methods

2.1 Description of the study area

The study was conducted in Boricha woreda, Sidama regional state of Ethiopia. Boricha woreda is located at 32 Km from Hawassa (Regional capital city) and 307 km from Addis Ababa. The area is geographically located 6030'–7005' N latitude and 38005'–38025' E longitude. The topography of the area comprises 78 and 22 percent plain lowland and rugged land, respectively. The elevation of the area ranges from 1700–2000 m above sea level. The rainfall distribution of the woreda lies between 700 mm and 1242 mm per annum, which is characterized by erratic distribution.

The rainy season is divided into two major categories i.e. "belg" and "meher". The "belg" season starts in February and ends in May, during which rainfall is erratic. The "meher" season starts in June and ends in mid-September, which is characterized by normal types of rainfall. The rainfall share of the ''belg" season is about 80 percent. The area is considered semi-arid due to high temperature and low rainfall. About 78% of the woreda has usually been affected by drought at an interval of 5 to 10 years.

The main livelihood of the people in the area is mixed agriculture, growing crops and rearing animals. Most of the community members couldn't get enough agricultural produce for their livelihood as they owned less than 0.5 hectare of land. In the normal year, a significant number of the population can get their livelihood by selling maize and haricot bean. The community usually produces potato and haricot beans twice and maize once a year.

2.2 Sampling procedure and sample size

The study employed a mixed research design, which is a combination of qualitative and quantitative approaches. In this study, multistage sampling technique was employed to select sample households. In the first stage, three kebeles (lowest government administrative unit), namely Hanja Chafa, Gonowa Bulano and Aldada Dela were purposely selected based on rainwater harvesting practices in the area. The sample size was determined using 5% degree of precision in the formula below:

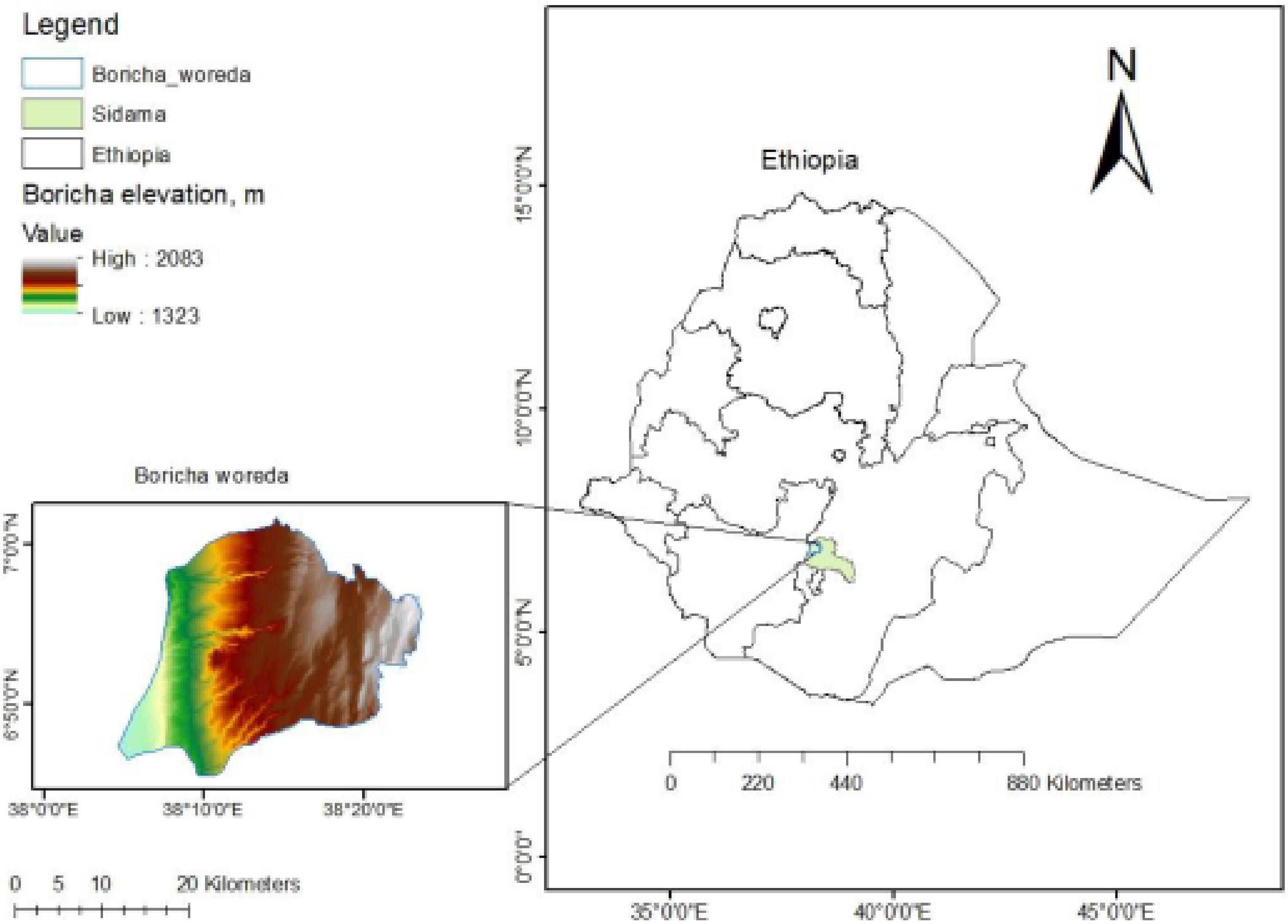

Figure 1: Location map of Boricha woreda in Sidama regional State of Ethiopia

$$n = \frac{Z^2 p \cdot q}{e^2} = \frac{(1.96)^2 0.5(0.5)}{(0.07)^2} = 196$$

Where
n = Sample size
Z = Standard normal deviation, i.e., 1.96 for 95% confidence level
P = 0.5 (The proportion of the population)
q = 1-P = 0.5 (50%) due to unknown variability
e = is margin of error or degree of accuracy desired, i.e., 0.07.

Therefore, by taking design effect and non-response rate into consideration, the researcher took a total of 196 sample households.

To have proportional sample size for each kebele, the following formula is used:

$$n1 = \frac{N1 \times S}{\sum N}$$

Where,
$N1$ = Total households of each kebele
S = Total number of sampled households in the study area
$\sum N$ = Summation of total number of Households in the study area.

In each kebele, the list of households was obtained from the respective kebele office, and the households were selected randomly by using lottery method. Furthermore, in each kebele, one focus group discussion comprising 6-8 farmers were conducted. A total of 18 key informants (kebele leaders, agriculture, and natural resource experts) were selected purposively and interviewed.

2.3 Data source, type, and collection techniques

2.3.1 Primary data collection

The primary data was mainly collected from interviewed households. Semi-structured questionnaire-based interview, and obser-

Table 1: Distribution of sample kebele and household sample size

No.	Kebele	Total population	Total Household	Formula —	No. of sampled HH
1	Hanja Chafa	9157	682	682*196/1631	82
2	Gonowa Bulano	6540	767	767*196/1631	92
3	Aldada Dela	6283	182	182*196/1631	22
Total	21980	1631	196		

vations were used. Questionnaires were preferred because they were useful instruments to collect sufficient data. The questionnaire mainly contained close-ended questions, which were followed by some open-ended ones to give opportunities for the respondents to explain answer. The questionnaire was prepared in English and then translated into Amharic to ease data collection with the local experts. The questionnaire was administered by development agents and high school graduate enumerators who are familiar with the study area. Enumerators were trained regarding data collection.

The key informants interviewed for this study include elderly people, model farmers, development agents, kebele administrators, woreda officials, and zonal experts. The composition of the kebele focus group discussants included both male and female households, elders and youth. The focus groups discussed the experiences, challenges and prospects of the adoption and intensity of RWHT and possible recommendations for future action. Field observation was conducted during field data collection. Obtaining data from different sources such as observations, questionnaire, documentation and focus group discussion helps to bind diverse ideas about the same issue and assist in tabulating the results.

2.4 Method of data analysis

The collected data were analyzed in terms of the study objectives. The process of analysis was carried out using mixed approach as both qualitative and quantitative data were collected. The qualitative data was analyzed manually by categorizing texts into themes; contents were analyzed and presented with narratives. It served to triangulate data gathered through a questionnaire in a way that helps to improve research reliability. The quantitative data, which were the primary data collected from questionnaires, were analyzed using both descriptive and binary logistic models. Using descriptive statistics, the mean, frequency and percentage values of variables were indicated. The results obtained from descriptive analysis were used as an indicator of the relationship between the independent variables and the dependent variable. Binary logistic (logit) regression analysis was used to determine factors that affect adoption of RWHT. This regression was more appropriate and made it possible to study for confounders affecting the adoption of RWHT. A set of independent variables influences the decisions of adoption of rainwater harvesting (Table 2). The characteristics of sample households such as age, sex, marital status, education, family size, farmland size, knowledge, access to information, access to credit, and social position were hypothesized to play major roles in determining the adoption of RWHT by farmers in the study area. In estimating the logit model, the dependent variable is the adoption status of rainwater harvesting, which takes a value of 1 if the household is adopter and 0 otherwise. According to (Gujarati, 2003), the logit model is specified as follows:

$$P = \frac{e^{Z_i}}{1 + e^{Z_i}}$$

Where P is the probability of adopting rainwater harvesting

$$Z_i = \beta_0 + \sum_{i=1}^{p} \beta_i X_i + u_i$$

Where, $i = 1, 2, 3 \ldots n$
β_0 = Intercept
β_i = Regression coefficient to be estimated
X_i = Household characteristics that affect adoption of the technology
u_i = a disturbance term

The probability that a household being non-adopter is

$$1 - P = \frac{1}{1 + e^{X_i}}$$

3 Results and discussion

3.1 Socio-economic characteristics of the respondents

Many of the respondents (53%) were adopters of rainwater harvesting technology and the rest were non-adopters. This implies that farmers have an interest in solving the problem associated with water scarcity by adopting water harvesting options. The majority (80%) of the respondents were male-headed households as the head of the household was allowed to respond (if present during the interview).

Table 2: Description of variable used in testing adoption of rainwater harvesting technology in Boricha woreda, Sidama region.

Independent variables	Data type	Categories
Age of the household head in years	Continuous	
Sex of household head	Dummy	Male; Female
Marital status	Dummy	Married; Single; Divorced; Widowed
Family size of respondent	Continuous	
Educational status of respondent	Dummy	Illiterate; Elementary; High School; College
Income source	Dummy	Agriculture; Government worker
Social position	Dummy	Yes; No
Size of farmland, ha	Continuous	
Access to credit	Dummy	Yes; No
Knowledge towards RWHTs	Dummy	Yes; No
Training Access	Dummy	Yes; No
Type of RWHT	Dummy	Pond; Flood
Information source	Dummy	Training; Meeting; Observation; Television
Period in using RWHT	Continuous	
Slope of the land	Dummy	Gentle; Steep

Regarding the educational status of the respondents, the majority of the respondents (65.8%) were illiterate, implying the challenge of searching for and using information related to different technologies for water harvesting. About 75% of adopter and 67% of non-adopter households have a family size of 3–9 persons. The size of a family, to a certain extent, implies labor availability as well as the demand for resources. Supplying sufficient basic needs including food from a small area, where 70% of the farmers possess 1–2 ha (Table 3), demands productive management including rainwater harvesting for production of crop and livestock. About 70% of the farmers in the study area (both adopters and non-adopters of the technology) perceived that they got awareness creation opportunities for rainwater harvesting through different means. This could be due to the water shortage in the area where rainwater harvesting technology has been promoted widely.

3.2 Water Harvesting Practices and Farmers Perception

Farmers in the study area replied that they have water scarcity problem, which primarily causes food shortages. Due to topographic conditions, knowledge, resources or lack of runoff-inducing precipitation, macro catchment water harvesting techniques may not be appropriate everywhere. Looking for site-specific water harvesting techniques is important. As observed in the field and from the interview and focus group discussions, water harvesting technologies such as run-off and flood water harvesting could importantly support the life and livelihood of the farming community in the area (Table 4). Rainwater harvesting has been vital for livestock, domestic use, and agricultural purposes in Boricha woreda, according to responses from sample households. Farmers practice in-situ rainwater harvesting techniques by furrowing the farmland with oxen-driven traditional 'maresha' plough during sowing seed. This traditional technique could temporarily retain moisture and support crops. Biazin and Stroosnijder (2009) reported the positive role of such practice in crop performance in the Rift Valley area of Ethiopia. In the study area, communal and private ponds are mainly used for livestock since natural springs are either rare or far from place of residence. Farmers travel as far as Lake Hawassa regularly to get water for their cattle when the harvested water in the ponds is used up, which is a burden and time-consuming. Focus group discussions and key informants underlined the importance of traditional as well as introduced water harvesting for livestock as well as for domestic use.

Understanding the perception of the community is basically pertinent for making development endeavors sustainable. Agriculture and natural resource offices promoted water harvesting on a smaller scale on private farms. Large communal ponds that were managed traditionally exist in different areas to supplement water shortage mainly for livestock. According to the view of focus group discussants, water harvesting and making it community-need-based is useful as it is a source of drinking water for their animals. Some focus group discussants and interviewees have claimed that the advantages and sense of belongingness were not in place for communal-based water harvesting and on those introduced by the government. Other study showed less attention of farmers for government introduced and communal resources (Mengistu, 2021).

3.3 Factors Affecting Adoption of RWHT in Boricha

In the study area, rainwater harvesting has been affected by different factors (Table 5). Several factors were hypothesized to influence the adoption of water-harvesting structures in the study area. However, the socio-economic and institutional factors such as family size, source of income, training on rainwater harvesting, perceived benefits of rainwater harvesting, and farmers' perception of rainwater harvesting were significant ($p < 0.05$) and positively influence the adoption of rainwater harvesting technology (Table 5).

Family size was positive and statistically significantly ($p < 0.05$) influence adoption of RWHT. This means that as farmers have a larger family, the probability of using RWHT increases. There could be a larger active worker in a large family. The odds ratio of 0.029 in-

Table 3: Socio-economic characteristics of farm household in Boricha woreda, Sidam Regional Stae of Ethiopia.

Variables	Categories	Adopter, n=102	Non-adopter, n=94		
		Freq. %	Freq. %		
Sex	Male	82	80.4	76	80.9
	Female	20	19.6	18	19.1
Age, year	19-30	24	23.5	21	22.3
	31-45	29	28.4	32	34.0
	46-60	29	28.4	28	29.8
	¿60	20	19.6	13	13.8
Educational status	Illiterate	70	68.6	59	62.8
	Elementary	16	15.7	19	20.2
	High School	12	11.8	12	12.8
	College	4	3.9	4	4.3
Family size	3-9	77	75.5	63	67.0
	¿9	25	24.5	31	33.0
Farm area, ha	¡1	70	68.6	65	69.1
	1-2	28	27.5	25	26.6
	¿2	4	3.9	4	4.3
Credit beneficiary	Yes	84	82.4	90	95.7
	No	18	17.6	4	4.3
Irrigated farm, ha	0	80	78.4	94	100.0
	0.5-1.5	14	13.7	0	0.0
	1.5-2.5	6	5.9	0	0.0
Received awareness creation/training	Yes	79	77.5	57	60.6
	No	23	22.5	37	39.4
Access to information	Yes	82	80.4	72	76.6
	No	20	19.6	22	23.4

dicated that, keeping other factors constant, the decision in favor of the use of RWHT increases by a factor of 1.016 as family size increases. Mume and Kemal (2014) also reported significant influence of family size on adopting rainwater harvesting in eastern Ethiopia.

Household income has a statistically highly significant ($p < 0.05$) positive effect on the adoption of RWHT. That is, farmers with higher family incomes are more likely to adopt RWHT. The odds ratio for income is 0.537, implying that an increase in households' income increases the probability of adoption of RWHT by 3.238. The results show that many farmers in the study area were low-income earners. A higher level of household income implies a greater incentive for investment in agricultural technologies and the ability to bear the risk associated with their adoption. The results imply that households with better economic standing, measured by the total value of their monthly income, are more likely to adopt labor-intensive technologies such as water harvesting structures. This is because such households are expected to have more disposable income and are therefore able to afford the hired labor required for the construction and management of the technology. As reported by Manyeki et al. (2013), labor costs for construction and maintenance of water harvesting technology are one of the most important factors that determine the adoption of such technologies at the farm level. Our result agrees with the results reported in other areas (Birungi and Hassan, 2007; Katungi et al., 2007; Kelenewerk et al., 2020).

Those households that attend trainings can benefit on implementation of RWHT and can better adopt these technologies and implement more compared to those households who do not attend trainings. The training access was statistically significant ($p < 0.05$). And the odds ratio of 0.648 indicated that keeping other factors constant, the decision in favor of the use of RWHT technology increases by a factor of 3.472 as training access of the farmer increases. Training could provide information and improve awareness. A study in south Africa also reported positive effect of training on RWHT adoption (Campisano, 2017).

The perceived benefit from RWHT was found to significantly influence the adoption of water harvesting structures of the households ($p < 0.05$). When the farm family expect positive and considerable benefit from the harvesting of rainwater, their probability of adopting the technology could increase. This might be affected on the location of the farm household, example, distance from the natural river or lake and other options to access the water.

Age was measured as the number of years since birth of the household head. The age of the household head positively affected the probability of adopting rainwater harvesting of farm households but not statistically significant ($p > 0.05$) (Table 5). Moreover, the odds ratio of 0.215 indicated that keeping other factors constant, the decision in favor of the use of RWHT increases by a factor of 1.208 as age level increases by one year. According to the theory of human capital, young heads of household have a greater chance of being taught new knowledge (Sidibe, 2005) and, hence, are better prepared for the adoption of technological innovations (Akroush, 2017). In contrary, the older farmers might be experienced with the challenge of water scarcity in their life, while the younger farmers inclined to take non-farming options. Young people may also

Table 4: Farmers experience in rainwater harvesting in Boricha woreda, Sidama region of Ethiopia.

Variable	Adopter, n=102		Non-adopter, n=94	
	Frequency	%	Frequency	%
Know RWHT				
practice Male	81	79.4	68	72.3
Female	21	20.6	26	27.7
Types of RWHTs Pond	77	75.5	0	0.0
Flood	25	24.5	0	0.0
How long RWHT				
have been? 1-5 years	62	60.8	0	0.0
6-10 years	36	35.3	0	0.0
>10 years	4	3.9	0	0.0

Table 5: Binary logit model of farmers affecting rainwater harvesting technology in the Boricha woreda, Sidama region of Ethiopia.

Parameters	B	S.E.	Wald	Sig.	Exp(B)
Age	0.189	0.215	0.771	0.380	1.208
Sex	0.288	0.477	0.364	0.546	1.334
Marital status	0.106	0.258	0.168	0.682	1.112
Family size	0.016	0.029	2.162	0.013	1.016
Education status	0.136	0.233	0.342	0.559	1.146
Income source	1.175	0.537	0.581	0.003	3.238
Social position	-0.349	0.372	0.881	0.348	0.705
Land size	0.887	0.713	1.547	0.214	2.429
Credit access	0.483	0.612	0.623	0.430	1.621
Type of RWHT	-0.378	0.405	0.870	0.351	0.685
Training	1.245	0.648	0.876	0.012	3.472
Information source	-0.019	0.498	0.001	0.970	0.982
Perceived benefit of RWHT	-2.782	0.443	39.450	0.000	0.062
Period in using RWHT	0.727	0.478	2.309	0.129	2.068
Slope of the land	0.563	0.694	0.659	0.417	1.756
Farmers perception	1.082	0.695	1.45	0.005	2.95
Constant	1.137	1.138	0.99	0.318	3.118

be more receptive to new ideas and are less risk averse than the older people. Young household heads have exposure for information and higher acceptance of the technology. Other studies revealed that age of household head negatively influence adoption of RWHT (Lutta et al., 2020). About 80.6% of the total household heads were male and 38 (19.4%) females. Whereas the proportion of the male-headed households for adopter and non-adopter were about 51.9% and 48.1%, respectively. In Boricha, sex of the head of household was statistically non-significant at ($p > 0.05$), which is in line with Tizazu (2017) Traditionally, in Ethiopia, sex determines access to resources (Omollo, 2010). Male headed households have more access to productive resources such as land and livestock compared to female counterparts who are constrained by low access to natural resources (Wasonga, 2009). Male headed households were therefore expected to adopt the water harvesting structures more than their female counterparts (Kelennewerk et al., 2020).

Education level of household head was positive and not statistically significant ($p > 0.05$) in influencing adoption of RWHT. This positive coefficient implies that farmer's access to education increased the ability of farmers to acquire important RWHT information as well as other related agricultural information which in turn increases farmer's ability to choose the RWHT. Therefore, the probability of adopting RWHT is increased with farmer's education level. Moreover, the odds ratio of 0.136 indicated that keeping other factors constant, the decision in favor of the use of RWHT increases by a factor of 1.146 as education level increases by one year. Mume and Kemal (2014) reported significant positive influence of education in RWHT in eastern Ethiopia.

The result of present study showed that the farmland size in the study area was insignificant ($p > 0.05$). The odds ratio of 0.713 indicated that keeping other factors constant, the decision in favor of the use of RWHT increases by a factor of 2.429 as farmland size of the farmers increases. The large farm size could give opportunity for farmers to test different technology. On one hand, lack of farmland would make people reluctant to invest in water harvesting structures.

Access to credit was not significantly affect the adoption of RWHT. The odds ratio of 0.612 indicated that keeping other factors constant, the decision in favor of the use of RWHT increases by a factor of 1.621 as credit access of the farmer increases. Household's endowment of financial capital (e.g. household saving and access to credit service), is obviously expected to have a positive relationship with agricultural input intensity (such as labor, oxen, seed, and fertilizer), and a farm household's investment decision on RWHT. That is, households with savings and/or credit access could hire labor during farming and/or construction of the RWHT, and have the purchasing power to buy oxen, seed, and fertilizer Campisano, 2017. The likelihood of level of adoption of RWHTs was higher among respondents who have access to training, credit and information via meeting compared to their counterparts. The finding was supported by the study report from Kenya (Recha et al., 2015), in which these accesses escalate their knowledge, perception towards adoption and sustainable practices of RWHTs. As a similar study revealed in Tanzania farm size was more significant and positively explained the level of adoption (Senkondo et al., 1998). Other study reported in South Africa revealed that a credit access (finance/income) is positively associated with the adoption of RWHT (Deressa et al., 2009).

Farm experience of household head showed positive and insignificant effect on the adoption of rainwater harvesting technology. This implies that farmers who have longer years of experience in farming have adopted RWHT than those who have fewer years of experience in farming activities. Moreover, the more experienced farmers recall the historic challenges of water scarcity and may use the advantages of rainwater harvesting during the rainy season. The odds ratio of 0.478 indicated that keeping other factors constant, the decision in favor of the use of RWHT increases by a factor of 2.068 as farm experience increases by one year. Aziz and Tesfaye (2013) reported a positive relationship of farm experience with adoption of RWHT.

4 Conclusions

This study aimed to identify factors influencing smallholder farmers' adoption of rainwater harvesting technologies for enhanced resilience to drought and thereby improved welfare. RWHT are important in semi-arid areas such as Boricha woreda. Farmers opinions were analyzed using descriptive statistics and the binary logistic regression model. The result showed that many of the farmers have been practicing traditional rainwater harvesting systems in Boricha Woreda. Different technologies exist for rainwater harvesting, but implementation and management could be affected by socio-economic and environmental factors. The result of the binary logistic regression model indicates that family size, income, training access, and perceptions on benefits of RWHT were statistically significant in explaining farmers' adoption of RWHT in the study area. Therefore, there is a need for development planners to target farmers' socio-economic situations when assisting and promoting adoption. Sustainable utilization and effective implementation of RWHT require continuous technical and awareness-creating support. Thus, the government and development partners need to understand the socio-economic situation of the farm household at grass-root level.

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Research Article

Socio-economic and Institutional Determinants of Farmers' Adaptation Strategies to Climate Change and Variability in Sidama Region, Ethiopia

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Abstract

The fact that climate has been changing in the past and continues to change in the future implies the need to understand how farmers perceive climate change and adapt to guide strategies for adaptation. This study aimed to identify determinant factors that influence farmers' choice of adaptation in response to climate change. Multi-stage sampling techniques were used to select the study area purposely and systematic sampling to select 149 households. Primary and secondary data collection methods were used. Descriptive statistics and multivariate probit model were used to analyze quantitative data. To detect the trend of climate change and variability, Mann-Kendall's trend test was used as a tool. The result shows that annual and 'belg' rainfall show a statistically significant decline trend ($p < 0.05$) whereas both minimum and maximum temperature indicate significantly increasing trend ($p < 0.001$). Multivariate probit model shows that the major climate change adaptation strategies in the study area include soil and water conservation, planting trees, use of improved crops and livestock varieties and use of crop diversification were 77.8%, 70.4%, 61.03% and 50.3%, respectively. The joint probability of using all adaptation strategies was 42.2% and the joint probability of failure to adopt all the adaptation strategies was less than 1%. Multivariate probit model revealed that the household head age, family size, educational level, farm income, off/non-farm income, tropical livestock unit, access to extension and access to climate information were among the significant determinants of choice of climate change adaptation strategies. Government policies should be initiated to improve household income, literacy status, access to extension services, credit, and information, that would enhance and diversify farmers' knowledge of climate change to improve their adaptation strategies.
Keywords: Adaptation; Climate change; Multivariate probit model

1 Introduction

Scientific evidence indicates that the earth's climate is rapidly changing, owing to increases in greenhouse gas emissions (Stern, 2008; IPCC, 2014). The increased concentration of greenhouse gases has raised the average temperature and altered the amount and distribution of rainfall globally (IPCC, 2007, 2014). There are growing facts that extreme events, such as droughts and floods, have been common incidences (IPCC, 2014). Sub-Saharan Africa is expected to experience decreased precipitation and increased temperatures in future predicted climate scenarios, which will cause production instability amongst small-scale farmers. With rain-fed agriculture being the most practiced form of agriculture in sub-Saharan Africa, variations and changes in temperature and rainfall will pose a serious problem to the mostly agriculture-reliant economies of this region.

According to the Inter-Governmental Panel on Climate Change (IPCC), vulnerability to climate variability and change is a function of exposure to extreme climate events, sensitivity to the events and adaptive capacity of the affected community (IPCC, 2007). The high vulnerability of these small-scale farmers completely wears away their resilience when faced with an increasingly variable and changing climate (FAO, 2010). The amount and seasonal distribution of rain vary annually and are difficult to predict, while the temporal distribution of rainfall during the growing season is an important factor influencing crop yield. Rains can be delayed by several weeks or stopped during critical germination periods, leading to short and long-term droughts with crop failures, food shortages and famines (Abebe, 2007). Increasing temperature and rainfall variability in different parts of Ethiopia adversely influence the agricultural production of smallholder farmers.

To minimize the shock of climate change on smallholder farmers' adaptation strategy is an essential instrument. The main significant points such as social, economic, technological, and environmental trends enable smallholder farmers to perceive and adapt to climate change (Temesgen et al., 2009). In addition, knowledge of the adaptation method and determinants of farmers' choice of adaptation strategies are enhancing efforts directly towards tackling the impact of climate change. Micro-level studies at the farm level on how rural farmers perceive these changes and how they are responding to the effects of a changing climate are limited in the study area. The objective of this study was to assess socioeconomic and institutional factors (age, gender, education, household size, farming experience, off/non-farm income, extension service, access to credit facilities, etc) that influence smallholder farmers' adaptation strategies to climate change in Loka Abaya woreda Sidama Region.

2 Empirical Literature on the Determinants of Farmers' Adaptation Strategies to Climate Change

In three Tigrai districts in northern Ethiopia, a study by (Tagel, 2013) used a multinomial logit model to examine how farmers perceived climate change and what factors influenced their decision to choose adaptation strategies. The findings showed that a farmer's choice of adaptation is influenced by a variety of factors, including education level, age, and wealth of the household's head, access to credit for agricultural services, and climate information. Additionally, the main barriers preventing adaptation to climate change are a lack of information about adaptation strategies and finance.

The finding of Belaineh et al. (2013) in a similar study in Doba district, western Hararghe, Ethiopia, found that agro-ecological location, sex, family size, plot size, off-farm income, livestock holding, frequency of extension contact, and training are the determinant of factors influencing adaptation strategies. The study also identified crop diversification, the use of soil and water conservation techniques, integrated crop, and livestock diversification, participating in off-farm income activities, and rainwater harvesting as common adaptation strategies.

According to Asrat and Simane (2018), the use of improved crop varieties, agroforestry practices, soil conservation practices, irrigation practices, and adjusting planting dates are the most important adaptation strategies by smallholder farmers. However, adaptation decision is location-specific and influenced by key drivers such as socioeconomic, environmental, and institutional factors.

3 Materials and Methods

3.1 Description of the Area

The study was carried out in Loka Abaya woreda at the western border of the Sidama region located about 62 km southwest of Hawassa and 337 km from Addis Ababa. The woreda is situated at 6°26'0"-6°48'0"N latitude and 37°59'0"- 38°21'0" E longitude (Figure 1). The total area is 1,190 km^2 and it represents moist kola agroecology in Sidama region with altitude ranging from 1170 up to 1500 meters above sea level (m.a.s.l.). Annual rainfall for Loka Abaya ranges between 670-1050 mm and the temperature ranges from 26–33 °C (USAID, 2005). According to the projected population by CSA (2019), the total population of the woreda is 123,705, of which 63,107 are male and 60,598 are female. Mixed crop-livestock is the main farming system in the woreda.

3.2 Data Collection Method

To meet the objectives of the study, both primary and secondary data were collected and utilized by employing qualitative and quantitative methods. This study employed a multi-stage sampling procedure. In the first stage, Loka Abaya woreda was selected purposely because it is the most climate change-affected area in the Sidama region. In the second stage, four kebeles were selected randomly out of the total 26 rural kebeles in the woreda since the kebeles are in a relatively similar agroecological zone (almost lowland kebeles); characterized by hot conditions and experienced climate-induced risks (USAID, 2005). In the third stage, about 149 sample households were selected using a systematic random sampling technique (Israel, 1992).

This study was based on a cross-sectional household survey, consisting of 149 sample households. It was the collection of data mainly using questionnaires to capture quantitative or qualitative data at a single point in time. Qualitative data from 10 key informant interviews and 4 focus group discussions were transcribed, categorized, looked for relationships and interpreted.

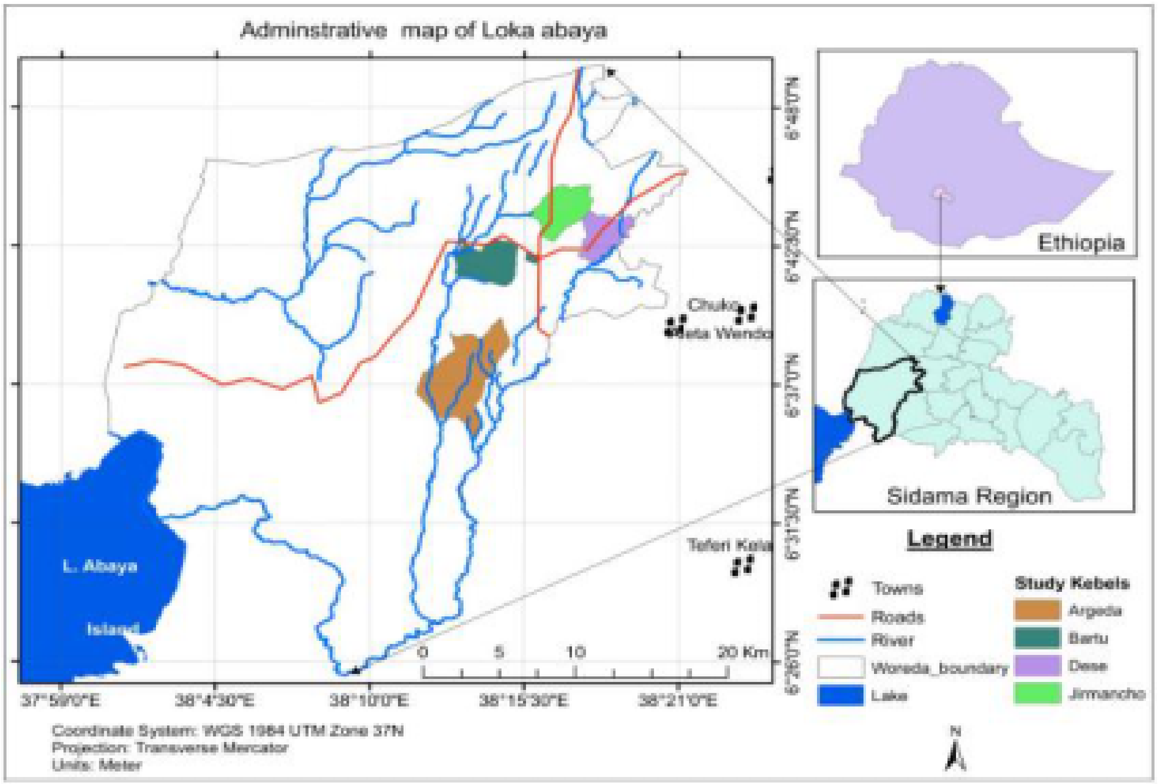

Figure 1: Map of the study area, Loka Abaya woreda

3.3 Methods of Data Analysis

Quantitative data was entered into Statistical Package for Social Sciences (SPSS) 20.0 version. This kind of data was analyzed using descriptive statistical methods such as frequency, percentage, tables and mean with the help of Microsoft Excel. A multivariate probit model was used to explain the different determinants of the sample respondent households with STATA version 14.4.

3.3.1 Mann-Kendall Trend Test

The Mann-Kendall statistical test was used to analyse the monthly, seasonal and annual rainfall and temperature data trends at 0.1%, 1% and 5% level of significance. Climate data trend analysis determines whether the measured values of a variable increase or decrease during the period. As recent study indicates that the most widely used method is the non-parametric Mann-Kendall test (Mann, 1945).

The Mann-Kendall test statistic(S) is calculated according to:

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \operatorname{sgn}(x_j - x_i)$$

Where: N the is number of data points Assuming $(x_j - x_i) = 0$, the value of sgn (θ) is computed as follows:

$$\operatorname{sgn}(\theta) = \begin{cases} 1 & \text{if } \theta > 1 \\ 0 & \text{if } \theta = 1 \\ -1 & \text{if } \theta < 1 \end{cases}$$

This statistic represents the number of positive differences minus the number of negative differences for all the differences considered. For large samples (N¿10), the test is conducted using a normal distribution with the mean and the variance as follows: E[S] = 0

$$\operatorname{Var}(S) = \frac{N(N-1)(2N+5) - \sum_{k=1}^{n} t_k(t_k-1)(2t_k+5)}{18}$$

Where: n is the number of tied (zero difference between compared values) groups and t_k is the number of data points in the k^{th} tied group.

3.3.2 Econometric Model Specification

The empirical specification of choice decisions over the four categories of climate change adaptation can be modeled in two ways, by either multinomial logit regression or multivariate regression analysis. One of the underlying assumptions of multinomial logit regression models is the independence of irrelevant alternatives that is error terms of the choice equations are mutually exclusive (Surabhi and Mamta, 2015). However, the choices among the adaptation strategies are not mutually exclusive as farmers are using more than one adaptation strategy at the same time and therefore the random error components of the adaptation choice may be correlated. So, using a multivariate probit model allows for the possible at the same time correlation in the choice to access the four different adaptation strategies simultaneously. Addressing the correlations of the error terms among unobserved adaptation choices, the multivariate model ensures statistical efficiency in the estimations of available choices (Lin et al. 2005). Empirically the model can be specified as follows:

$$Y_{ij} = \begin{cases} 1 & \text{if } Y_{ij}^* > 0 \\ 0 & \text{otherwise} \end{cases}$$

Where i = farmer ID, Y_{i1} = 1, if the farmer uses soil and water conservation practice (0 otherwise), Y_{i2} = 1, if the farmer uses improved crop and livestock varieties (0 otherwise), Y_{i3} = 1, if the farmer uses crop diversification (0 otherwise), Y_{i4} = 1 if the farmer uses planting trees (0 otherwise) and n is the number of observations. The hypothesis can be tested by running four different independent binary probit or logit models by assuming that error terms are mutually exclusive. However, the decision to use different strategies may be correlated, thus the elements of error terms might experience stochastic dependence. In this situation, a multivariate probit model of the following form is used to test the hypothesis.

$$Y_{ij} = X_{ij}\beta_j + \epsilon_{ij}$$

where Y_{ij} (j =1… 4) represent the four different adaptation option faced by the i^{th} farmer (i=1,…, 1,149), X_{ij}' is a 1 x k vector of observed variables, $\beta_1, \beta_2 ... \beta_n$ are conformable parameters that affect the adaptation choice decision of farmer β_j is a k x 1 vector of unknown parameters (to be estimated), and ϵ_{ij} is the unobserved error term, $\epsilon_1, \epsilon_1 .... \epsilon_n$ are distributed as multivariate normal distribution with zero means. The unknown parameters in Equation (2) are estimated using simulated maximum likelihood.

4 Results and Discussion

4.1 Demographic and Socio-economic Characteristics of Respondent

For this study, primary data were collected from a total of 149 sampled households. Out of the total sample households surveyed, 82.6% were male-headed and 17.4% were female-headed. This result indicated that the majority of respondents in the study area were male. Out of the total sample HHs, the majority 85.9% were married and 7.4% were single. Regarding the education status, 45.6% of the respondents did not attend school while 4% of the respondents were college or university graduates. Most respondents (74.5%) have farm experience between 11-30yrs. Concerning landholding, the majority of respondents (60%) owned land size of ¡ 1 ha and 9.4% owned ¿ 2 ha (Table 1).

The mean age of the household heads was 44.09 years with a maximum of 65 and 28 years as a minimum (Table 2). This suggests that working age or active labor dominates farming activities indicating the potential for implementation of climate change adaptation practices. Farmers in the study area are engaged in mixed farming activities, including crops like chat, and coffee, and rearing of domestic animals such as cows, oxen, goats, sheep and chickens. Moreover, the survey result revealed that the mean livestock holding of the sampled households in terms of tropical livestock unit (TLU) was 4.47, and minimum and maximum values range from 0 to 16.37 TLU, respectively (Table 2). Farm income of the surveyed households ranges from 0 to 113,000.00 birr with an average of 24,488.59 birr per annum. Major sources of income in the study area are on-farm activities mainly from the sale of crops, sales of livestock and livestock products (milk and butter). Regarding this, maize, chat, coffee, and haricot beans are the most common sources of on-farm income in the study area. Non-farm income refers to non-agricultural income sources, either in secondary and tertiary sectors (Barrett et al., 2001). Non-farm activities relate to all other activities that are not related to crop and livestock production, e.g., petty trading in non-agricultural activities, barbering, building construction, etc (Kankam-Boadu,2023).

Surveyed farmers' income from off/non-farm activities ranged from 0 to 16,200.00 birr with an average of 4,209.73 birr per annum (Table 2). On the other hand, petty trading, daily labor, handcraft, remittance, and government/NGO aid are sources of off-farm income for some of the sample households. The survey data indicated that the household size of the sampled households varies from 1 to 12 with an average household size of 5.27, which is higher than the national average family size of 4.93 (CSA, 2007). The mean distance from the market center of the sample households at the time of the survey was about 7.23 km. Market access minimizes risks that occur due to the distance for transporting agricultural inputs and their production.

4.2 Climate Data Analysis

4.2.1 Changes in the Rainfall and Temperature in Loka Abaya Woreda

Climate is determined by rainfall, temperature, wind, and clouds. However, temperature and precipitation are major elements of weather. The rainfall and temperature data of the one station were obtained from Ethiopia Meteorological Agency for the aim of this study (1990-2019).

Table 1: Distribution of respondents by their socio-economic characteristics in the study area

Variables	Frequency	Percent
Gender		
Male	123	82.6
Female	26	17.4
Marital status of household		
Single	11	7.4
Married	128	85.9
Divorced	4	2.7
Widowed	6	4.0
Educational level of household		
Cannot read and write	68	45.6
Primary school	53	35.6
Secondary school	22	14.8
College and university	6	4
Farm experience of household		
5-10yrs	17	11.1
11-20yrs	62	41.6
21-30yrs	49	32.9
Above 31yrs	21	14.1
Farmland size in hectares		
¡0.5ha	44	29.5
0.5-1ha	46	30.9
1-1.5ha	29	19.5
1.5-2ha	16	10.7
Above 2ha	14	9.4

Table 2: Distribution of socio-economic characteristics of respondents

Variable	Minimum	Maximum	Mean	Std. Deviation
Age of household	28	65	44.0940	7.99691
Household size	1	12	5.2752	2.01300
On-farm income	0	113,000	24,488.59	29,432.97
Off/non-farm income	0	16,200	4,209.73	5,465.67
Livestock (TLU)	0	16.37	4.4753	4.23739
Distance of market (km)	4	10	7.2315	2.19299

4.2.2 Annual and Seasonal Rainfall Variability

The coefficient of variation is used to classify the degree of variability of rainfall events into three less (CV ¡ 20), moderate (20 ¡ CV ¡ 30) and high (CV ¿ 30) inter-annual variability of rainfall (Asfaw et al., 2018). The data obtained from Ethiopia Meteorological Agency revealed that the coefficients of study area were 28.16, 31.04 and 21.57 for *kiremt* (local in *Hawado*), *belg* (local in *Badheessa*) and annual rainfall, respectively, which indicate that there was moderate to high inter-annual variability of rainfall between 1990-2019 (Table 3). The degree of variation in the amount of rainfall for *kiremt* season is less than *belg* (Table 3). The finding is consistent with Kassie (2014), who reported moderate to high concentrations of rainfall in the Central Rift Valley of Ethiopia. Besides, the year-to-year of *belg* rainfall variability over the study area is high compared to the year-to-year variability of annual and *kiremt* rainfall.

4.2.3 Annual and Seasonal Rainfall Trend Analysis

The annual rainfall in Loka Abaya woreda over the past 30 years decreased by about 11.9 mm annually (Figure 2). This is also confirmed by the respondents on the trend of rainfall. According to the data obtained from the National Meteorological Agency, the *kiremt* rainfall in the study area decreased by 1.69 mm. The trend line shows that about sixteen years of rainfall amount is below average and fourteen years the amount of *kiremt* rainfall is above the average. In general, it is believed that within these sixteen years, there was less amount of rainfall than the other fourteen years within thirty years. This result is in line with Getenet (2013) who confirmed decreasing trends of rainfall volume in western and eastern arid and semi-arid areas of the country. The *belg* rainfall in Loka Abaya woreda over the past 30 years decreased by 6.76 mm (Figure 2). More than sixteen months have shown below average *belg* rainfall in the study area.

Table 3: Descriptive statistics of seasonal and annual rainfall for the period 1990–2019

Parameters	*Kiremt*	*Belg*	Annual
Maximum rainfall	574.30	601.10	1309.6
Minimum rainfall	107.66	139.40	406.3
Average	376.22	379.71	949.16
SD	107.66	117.89	204.80
CV %	28.61	31.04	21.57

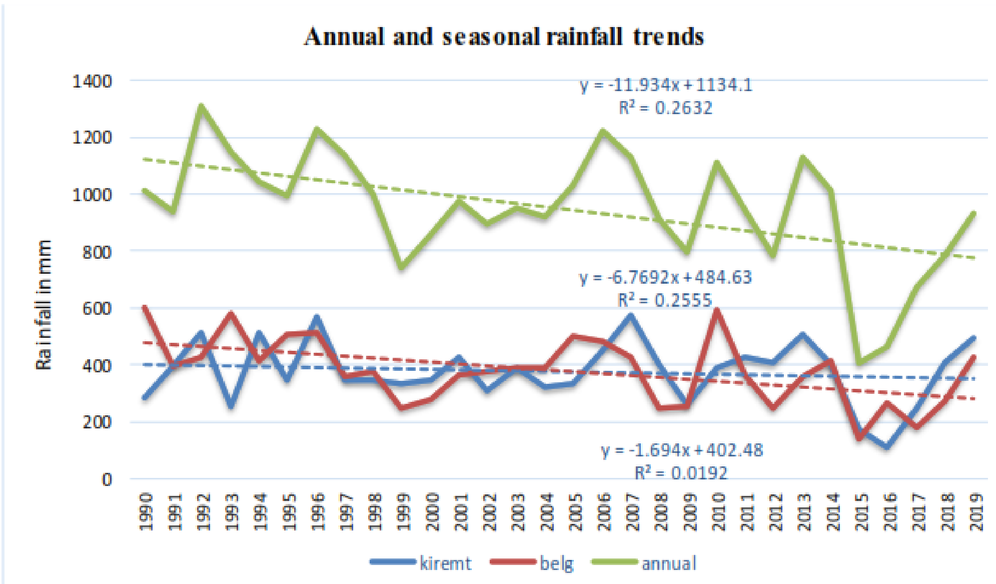

Figure 2: Trends of annual and seasonal rainfall variability in the study area.

4.2.4 Annual and Seasonal Mann-Kendall Trend Test of Rainfall Analysis

According to the Mann–Kendall trend test, seasonal trend analysis results showed significant decreasing trend of *belg* rainfall at $\alpha = 0.05$ significant level. The Sen's slope estimator indicated that the *belg* rainfall decreased by 6.63 mm per season (Table 4). Generally, the most important rainfall season in the study is *belg*, which showed a tendency of decreasing trends for the period 1990–2019 but not in *kiremt*. The result agrees with the findings of (Nater, 2010; Jury and Funk, 2013;) who indicated decreasing trends of spring season rainfall in Ethiopia. The annual rainfall trend also showed significant decreasing trend at $\alpha = 0.001$ and rainfall decreased by 10.17 mm per year. Annual and seasonal rainfall at Loka Abaya generally exhibited a slight decline over 1990-2019. From the Mann–Kendall trend test, annual rainfall and *belg* season rainfall in Loka Abaya wore a severe significantly decreasing. The result is inconsistent with (Eshetu et al., 2016), which pointed out that a non-significant trend in annual and seasonal rainfall was reported in in high rainfall area of southwestern Ethiopia. The outcomes FGD and key informant interviews also revealed that rainfall amount, particularly the *belg* rains, is declining and the distribution has been erratic (for details see the section on farmers' perception on climate change and variability). On the other hand, the *kiremt* rainfall indicated a non-significant increase. In all, such seasonal and inter-annual variability in rainfall amount could negatively affect the ability of farmers to mitigate the effects of climate change and variability (Ayalew et al., 2012).

4.2.5 Trends of Temperature in the Study Area (1990-2019)

The average yearly maximum temperature of the woreda was 25.35 °C, while the average minimum temperature was 12.4 °C. As indicated in Figure 3, the maximum temperature of Loka Abaya wore a over the past 30 years increased by about 0.064°C annually. This result is in line with the survey results of respondents regarding the increment in temperature over the past thirty years.

The trend analysis of the meteorological data record of temperature for the period (1990-2019) also showed that increasing trend in yearly minimum temperature over the past thirty years. Figure 4 indicates that the average annual minimum temperature increased by 0.04 °C per year.

4.2.6 Annual Mann-Kendall Trend Test of Maximum and Minimum Temperature

The Mann-Kendall test showed that a significant increasing trend of annual mean maximum temperatures was observed at 0.069 °C per

Table 4: Mann-Kendall results of seasonal and annual rainfall

Parameters	*Kiremt*	*Belg*	Annual
Mann–Kendall	0.04	-2.46*	-2.64***
Sen's Slope	0.140	-6.633	-10.178

*** 0.001 significance level, *0.05 significance level

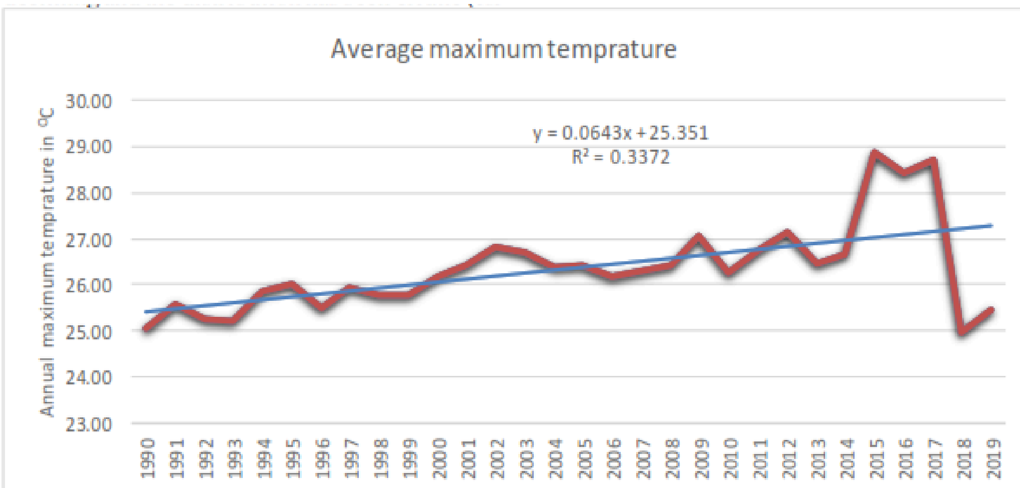

Figure 3: Trend of maximum temperature

year (Table 5). This result is in line with the finding of Fenta (2017) who reported an increasing trend of annual maximum temperatures at Amibara and Gewane districts in the Afar region, Ethiopia. The annual mean minimum temperature also indicates an increasing trend at a rate of 0.062°C per year. This result exceeds the findings reported by NMSA (2001) which showed that the mean annual minimum temperature in Ethiopia increased by 0.025 °C per year. Hence, the study area was warming at a faster rate than the country's warming trend. Furthermore, according to studies in Ethiopia, it is assumed that the temperature has been increasing annually at the rate of 0.2 °C over the past five decades (Yohannes et al., 2009). Table 5 indicates that the annual minimum temperature increased by 0.062 °C per year.

4.3 Farmers' Perception on Climate Change and Variability

Climate change will bring about substantial welfare losses especially for smallholders whose main source of livelihood derives from agriculture (Asrat and Belay, 2018). Despite the policy provisions and institutional (re)arrangements, climate change-induced impacts have been undermining the national economic performance and the country's endeavor to reduce poverty (Echeverría and Terton, 2016). The households were asked whether they have perceived changes and variability of climate mainly in terms of rainfall and temperature in the study area. Accordingly, 79.9% of the respondents perceived a changing climate, 11.4% have not noticed any changes and 8.7% don't know whether there is a change in the climate or not. Addison (2006) confirmed that understanding the local people's perception on climate change and variability is important to designing appropriate adaptation and coping strategies for many poor countries that are highly vulnerable to the impact of climate change and variability is important to designing appropriate adaptation and coping strategies for many poor countries that are highly vulnerable to the impact of climate change and variability. About 81.7% of the respondents perceived an increase in temperature while only 9% noticed the contrary or decrease in temperature 8.7% noticed no observable change and 3.4% of the respondents did not perceive any temperature change. This result is similar to Deressa et al. (2008), who indicated that the majority of farmers in Ethiopia are aware of climate change and perceive an increased temperature. The FGD participants and interviews with key informants also confirmed the presence of increased temperature during recent periods to recent past. As the survey indicated, 65.1% said that rainfall decreased, 12.8% increased, 20.8% fluctuated and 2.3% did not perceive the change (Table 6). Thus, the result of this study indicated that farmers' perception was in line with the meteorological data analysis.

4.4 Adaptation Strategies Used by Farmers

In addition to reducing soil erosion and runoff, soil and water conservation practices help keep nutrients on the field. Physical and biological soil and water conservation measures increase water-use efficiency (increasing soil moisture by reducing the speed of the runoff and using water harvesting structures which is useful in drier areas) and protect water quality. Surface residue and plant cover improve soil carbon concentration and provide additional environmental benefits. Considering the magnitude of the moisture stress in the woreda, soil and water conservation techniques are widely adopted by farmers. Out of the total sampled households, 77.8% used soil and water conservation as an adaptation strategy to reduce the adverse effect of climate change on farm productivity. Accord-

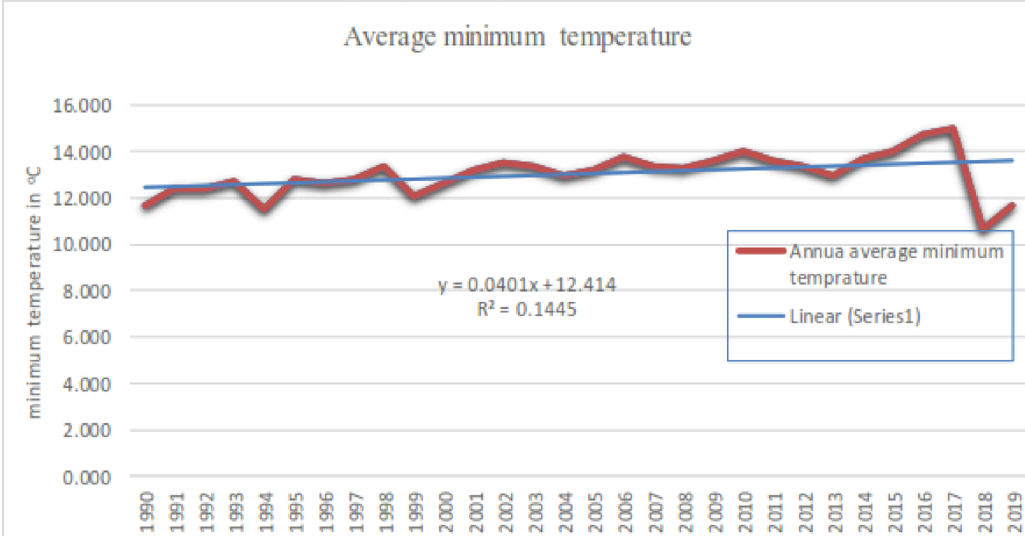

Figure 4: Trend of minimum temperature

Table 5: Annual Mann-Kendall results of maximum and minimum temperature for 1990-2019

Parameters	Mann-Kendall	significance	Sen's slope
maximum temperature	3.96	***	0.069
Minimum temperature	3.62	***	0.062

NMA, Ethiopia (2019); *** = 0.001 level of significance

ing to focus group discussions, soil and water conservation practice includes soil erosion protection, management, and care of the soil in order to make it suitable for their crops, conservation of rainwater for watering the crops in times of too little rain, groundwater harvesting and agro-forestry to reduce soil loss from farm plots, preserving critical nutrients and increasing crop yields. The result is similar to Tibebu et al. (2018) who assessed soil erosion control efficiency of land management practices implemented through free community labor mobilization in systematically selected watersheds of Ethiopia.

4.4.1 Planting Trees

Through photosynthesis, trees absorb and store atmospheric carbon dioxide (CO2), making them natural carbon capture and storage devices. For this reason, tree planting is frequently praised as an important solution to climate change. In the study area, planting trees on bare and eroded land is one of the best adaptation options in combination with other options. About 70.4% of respondents prefer and used planting trees for own uses and as adaptation option to reduce the negative effect of climate change. Discussion of focus group emphasized that planting trees is recognized as farmers believe that planting trees can attract rainfall and can increase water retention by reducing runoff. The other scenario is that trees provide natural shade for their livestock when the temperature is hot. Temesgen et al. (2009) identified tree planting to be one of the major methods used by farmers to adapt to climate change in the Nile Basin of Ethiopia.

4.4.2 Improved Crop and Livestock Varieties

Improved crop varieties in the context of climate change adaptation offer higher and more stable yields, increased tolerance or resistance to pests, diseases, drought, heat, and other stress factors, and therefore strengthen the resilience of rural farmers to climate change. Improved crop varieties were used as adaptation options in combination with other options and about 61.03% of respondents used them to reduce the negative effects of climate change. The farmers are practicing mixed farming that is crop and animal husbandry. During the focus group discussion farmers indicated the criteria for selecting to use improved crop variety which has different qualities that help to adapt to the changing climate such as productive, early maturing variety, disease and pest resistance and crops that have more product for their livestock feed. Yield performance, yield stability and drought tolerance are particularly important variety properties (Macholdt and Honermeie, 2016). Key informant interviews said that the government is supplying improved varieties of crops, livestock, and inorganic fertilizer to cope with the adverse effects of climate change.

4.4.3 Crop Diversification

Crop diversification is the practice of cultivating more than one variety of crops belonging to the same or different species in a given area in the form of rotations and or intercropping and enhances crop productivity and consequently resilience in rural smallholder farming systems (Makate et al., 2016). Crop diversification (mixed cropping, intercropping) is a common practice in the study area. The system is

Table 6: Pattern of perceived temperature, and rainfall in the study area

Variable	Frequency	Percent
How do you perceive climate change in your district?		
Changed	119	79.9
Not changed	17	11.4
Don't know	13	8.7
Pattern of temperature		
Increasing	122	81.7
Decreasing	6	9
No observable change	13	8.7
I don't know	5	3.4
Pattern of rainfall		
Increasing	19	12.8
Decreasing	97	65.1
Fluctuating	31	20.8
I don't know	2	2.3

commonly practiced in the woreda where cereals (maize), legumes (haricot beans, soybeans) and vegetables (pepper) are grown together. From Focus Group Discussions made with farmers, it was noted that they have a wide knowledge of the advantages of mixing crops with varying attributes in terms of maturity period, drought resistance, input requirements and end use of the product. Of the total sampled households, 50.3% use crop diversification as adaptation strategy to reduce the adverse effect of climate change on farm productivity (Table 7). This is why Michler and Josephson (2017) revealed that crop diversification is the best strategy for households as a source of income, risk reduction, and poverty alleviation. As an adaptation option, it is used to cope with the hostile effects of climate change.

4.5 Determinants of Farmers' Choice of Adaptation Strategies

Results from the multivariate probit model of determinants of choice adaptation measures using data from a cross-sectional survey of 149 sample households are presented in Table 8. The correlation coefficients are statistically different from zero in 3 of the 6 cases, confirming the appropriateness of the multivariate probit specification and choice of climate change adaptation strategies are not mutually independent. The results on correlation coefficients of the error terms indicate that there is complementarity (positive correlation) and substitutability (negative correlation) between the two adaptation options being used by farmers. Multicollinearity was tested by using the variance inflation factor (VIF), so the mean value of 1.89 proved the absence of multicollinearity between covariates. The result of multivariate probit model shows that the likelihood of households adopting soil and water conservation, planting trees, using improved crop and livestock varieties and crop diversification were 77.8%, 70.4%, 61.03% and 50.3% respectively. The result also shows that the joint probability of using all adaptation strategies was 42.2% and the joint probability of failure to adopt all the adaptation strategies was less than 1%. This implies that most farmers in study areas used more than one adaptation choice to minimize the adverse effect of climate change.

The simulated maximum likelihood (SML) estimation results suggested that there was positive and significant interdependence between household decisions to use soil and water conservation and using the improved crop and livestock varieties, soil and water conservation and planting trees, using improved crop and livestock varieties, and crop diversification.

4.5.1 Age of household head:

The age of the household head is a key variable affecting adaptation decisions at the farm level. The age of the household head is usually taken as a proxy for experience with farming. A farmer's age may influence adoption in one of several ways. The direction of influence is not, however, very clear and there are always mixed results from empirical analysis (Admassie and Ayele, 2010). In this study, an increase in the age of a household head was positive and significantly increased the use of improved crop and livestock varieties as an adaptation strategy to reduce the impact of climate change. This result is also consistent with the findings of (Aemro et al., 2012; Taruvinga et al., 2016). Contrary to the findings of this study, the age of the household head is negatively related with the implementation of adaptation measures indicating that older farmers are less likely to change their farming system in response to perceived climate change (Waibel et al. 2018).

4.5.2 Educational level:

The education level of the farmer increases the probability of uptake of adaptation options to climate change. As can be observed in Table 8, education level significantly increases improved livestock and crop varieties as an adaptation method in the study area. Moreover, the coefficient of improved crop and livestock varieties is positive indicating a positive relationship between education and improved crop and livestock varieties as adaptation methods to climate change. This result is consistent with findings by (Getachew et al., 2014; Seid et al., 2016). Household size: The model result shows that family size has positive and significant impact on the likelihood

Table 7: Summary of common adaptation strategies used by farmers in the study area.

Adaptation strategies	Frequency	Percent
Soil and water conservation	116	77.8
Planting tree	105	70.4
Improved crop and livestock varieties	91	61
Crop diversification	75	50.3

of improved crop and livestock varieties as adaptation strategy to reduce the negative impact of climate change. The possible reason is that large family size is normally associated with a higher labor endowment, which would enable a household to accomplish various agricultural tasks that are labor-intensive. Croppenstedt et al., (2003) argue that households with a larger pool of labor are more likely to adopt agricultural technology and use it more intensively because they have fewer labor shortages. Nonetheless, family size has negative and significant effects on the likelihood of soil and water conservation practices as adaptation strategies to reduce the negative effects of climate change. The reason is that soil and water conservation practices require more labor. This could be as households with large families from this study area migrate to urban areas (Addis Abeba) to engage in non-farm activities to earn income and ease the consumption pressure imposed by a large family. This result is consistent with the findings of (Gbetibouo, 2009; Belaineh et al., 2013 and Taruvinga et al., 2016).

4.5.3 *On-farm income:*

It has a positive and significant impact on soil and water conservation practices and planting trees as an adaptation strategy. Higher farm income significantly increased the probability of conducting measures such as soil and water conservation and planting trees. In addition to this, higher income allows farmers to adopt measures, especially soil and water conservation are expensive and probably more effective responses to climate change. Furthermore, income is normally found to contribute positively to the adaptation of agricultural technologies. This result is consistent with (Deressa et al., 2009; Temesgen et al., 2008).

4.5.4 *Off/non-farm income:*

The term off/non-farm refers to economic activities that are not directly related to agricultural activities. For instance, handicrafts, spinning of cotton or wool, cloth weaving, pottery, distilling local brews, masonry, blacksmiths, woodwork/carpentry, house construction, petty trade, etc (Tafesse et al., 2015). The result of the model indicates that off/non-farm income significantly and negatively affects the uptake of soil and water conservation and planting trees as adaptation strategies to climate change. However, off/non-farm income is associated with crop diversification significantly and positively. This indicates that when farmers have non/off-farm incomes, they can afford the cost by using fewer practices such as soil and water conservation techniques and can buy improved crop and livestock varieties which increases productivity. On the other hand, off/non-farm income showed a negative relationship with adaptation by using tree planting with other measures. In short words, the existence of non-farm income serves as adaptation measure by itself and may delay other responses. This result is similar to (McNamara et al., 2001) who confirmed that off-farm employment may pose a constraint to adoption of technology because it competes for labor and time needed for on-farm activities. Therefore, in this study, the variable off-farm employment was found to be negatively related to climate change adaptation. The result does not confirm the hypothesis which states that off/non-farm income has a positive influence on the SWC and planting trees and the result contradicts the findings of Aemro et al. (2012 and Legesse et al. (2013). In general, the probability of engaging in non-farm activities is higher for younger, better-educated, household heads who have better contact with extension agents and who have access to microfinance (Asfaw et al., 2017)

4.5.5 *Tropical Livestock Unit (TLU):*

The result of the model indicates that livestock holding has positive and significant effect on the likelihood of using improved crop and livestock varieties as adaptation strategies. In this case, livestock is considered a source of income for the farmers to purchase improved crop and livestock varieties by providing draft power (like oxen, horses, etc.) and their manure essential for soil fertility maintenance. Similarly, other studies concluded that farmers who have large number of livestock significantly increases the ability and choice of climate change adaptation strategies (Chilot, 2007; Aschalew, 2014; Francis et al., 2016). Access to extension service: Extension visit has significant positive effect on climate change adaptation options like improved crop and livestock varieties. Farmers frequently visited by development agents had a high likelihood of participating in climate change and adaptation. The finding is in line with (Temesgen et al., 2009; Belaineh et al., 2013). Moreover, agricultural extension service is the main source of information concerning agricultural activities and natural resource conservation for farming households (Deressa et al, 2010; IPCC, 2014). Access to climate information: Even though service on climate information delivery is not formal. Access to information from different sources has significantly and positively influenced the adaptation combination of improved crop and livestock varieties. The availability of better climate information helps farmers make comparative decisions among alternative adaptation practices and hence choose the ones that enable them to cope better with climate change. This indicates that the information on weather or climate forecasting increases the likelihood of adaptation to climate change. This finding is consistent with other studies (Baethgen et al., 2003; Jones, 2003; Temesgen et al. 2009).

Table 8: Multivariate Probit Model Results for Households' Choice of Adaptation Strategies

Explanatory Variables	**Soil and Water Conservation Coeff. (Std. Err.)**	**Improved Crop and Livestock Varieties Coeff. (Std. Err.)**	**Crop Diversification Coeff. (Std. Err.)**	**Planting Trees Coeff. (Std. Err.)**
Age	-0.022 (0.045)	0.085** (0.037)	0.044 (0.028)	-0.006 (0.031)
Gender	-0.0525 (0.804)	0.0396 (0.481)	0.707 (0.436)	-0.552 (0.484)
Education Level	-0.4002 (0.290)	0.5174* (0.304)	0.125 (0.242)	0.284 (0.221)
Household Size	-0.418* (0.217)	0.238* (0.141)	0.178 (0.123)	-0.016 (0.117)
Farm Experience	0.346 (0.409)	0.122 (0.359)	-0.331 (0.277)	0.185 (0.279)
On-Farm Income	0.000** (0.000)	-0.000 (0.000)	9.28e-06 (0.000)	0.000** (9.04)
Off/Non-Farm Income	-0.0001* (0.000)	0.000 (0.000)	0.000*** (0.000)	-0.000* (0.000)
Land Size	-0.531 (0.333)	0.326 (0.287)	0.017 (0.252)	0.177 (0.222)
TLU	-0.082 (0.086)	0.479** (0.237)	-0.088 (0.077)	-0.056 (0.069)
Distance	-0.068 (0.177)	-0.017 (0.088)	-0.017 (0.088)	-0.086 (0.096)
Extension Service	-0.038 (0.731)	1.184*** (0.440)	0.1909 (0.346)	0.551 (0.406)
Climate Information	-0.954 (0.626)	0.859* (0.445)	-0.103 (0.381)	0.223 (0.391)
Credit	0.267 (0.509)	-0.418 (0.379)	-0.167 (0.321)	0.1510 (0.329)
_cons	2.997 (3.205)	-5.11** (2.115)	-1.224 (1.783)	0.342 (1.872)
Rho21	-0.705** (0.322)			
Rho31	0.216 (0.276)			
Rho41	0.571** (0.238)	-0.171 (0.302)		
Rho32			0.116* (0.259)	
Rho42	0.020 (0.239)			
Rho43				
Predicted Probability	0.778	0.740	0.6103	0.503
Joint Probability (Success)	0.4226			
Joint Probability (Failure)	0.0006			
Number of Observations	149			
Number of Simulations	5			
Wald Chi2 (56)	77.16			
Log Likelihood	-130.368			
Likelihood Ratio Test of Rho ii=0, p¿x2	0.0017**			

Note: *= p¡0.1 (10%), **= p¡0.05 (5%), ***= p¡0.01 (1%); Coeff. = Coefficient; Std. Err. = Standard Error.

5 Conclusion and recommendation

Climate change highly affects smallholder farmers' agriculture as the consequence of higher temperature and increased rainfall variability that reduces crop production. A better understanding of the local dimensions of adaptation is, therefore, essential to develop appropriate adaptation measures that tackle the adverse effects of climate change impacts. This study attempted to identify factors affecting the choice of climate change adaptation strategies by farmers. The model allows for the simultaneous identification of the determinants of all adaptation options, thus limiting potential problems of correlation between the error terms. Multivariate probit model displayed that the likelihood of households to adopt soil and water conservation, planting trees, use of improved crop and livestock varieties and crop diversification were 77.8%, 70.4%, 61.03% and 50.3%, respectively. The joint probability of using all adaptation strategies was 62.2% and the joint probability of failure to adopt all the adaptation strategies was less than 1%. The model also confirms that household size, off/non- farm income and on-farm income have a significant impact on the use of soil and water conservation as climate change adaptation strategy. Likewise, age, educational level, household size, livestock holding, access to extension service and access to climate information significantly affect the use of improved crop and livestock varieties to adapt to

climate change. In addition, off/non-farm income significantly influenced practicing crop diversification. Moreover, on-farm income and off/non-farm income significantly affect farmers' use of planting trees to adapt to climate change impacts whereas some variables in the findings such as gender, marital status, farm experience and distance to market were insignificant in this study. Thus, the results of the study provide information to policymakers and extension workers on how to improve farm-level adaptation strategies and identify the determinants for adaptation strategies. It appears that improving educational status would do most to hasten adaptation and increase households' decision-making regarding the key adaptation strategies. Livestock holding which influences farmers' likelihood of adopting adaptation measures should be harnessed and properly utilized. Building the capacity of agricultural extension systems and making climate change education a priority through Information and Communication Technologies (ICT) innovations is crucial. Improving farm and off/non-farm income-earning opportunities is needed for smallholder farmers. Access to media should be strengthened to ensure accurate information is available and widely distributed.

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Journal of Forestry and Natural Resources (JFNR)

Authors Guideline

Abbreviation J. for. nat. resour.

ISSN 3005-4036

1. Editorial policy and Author's Guidelines

1.1. Background

The Journal of Forestry and Natural Resources (J. for. nat. resour., or JFNR) (JFNR) is a peer- reviewed online open-access published annually by the Wondo Genet College of Forestry and Natural Resources, Hawassa University. JFNR publishes original research findings in all subject-matter areas of forestry and natural resources. It seeks disciplinary and interdisciplinary research articles, review articles, featured articles, and short communication.

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1.2. Aims and Scope

Aims:

- serve as a communication medium among scientific communities in forestry, natural resources research, and other related fields
- publish original and innovative scientific works relevant to forestry and natural resources situation of Ethiopian as well as global problems
- encourage Ethiopian researchers, graduates, and postgraduate students to align their disciplinary and interdisciplinary researches in the direction of solving major problems in the areas of forestry and natural resources and conservation needs of the country, and
- serve as a platform to foster scientific knowledge sharing among researchers, scientists, policymakers, and practitioners working on sustainable forestry, green economy transition, issues of sustainable development goals, desertification, and dryland agriculture and forestry, combating desertification and drought, natural resource management, and conservation and other related topics.

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2.1. Research articles

These papers treat both disciplinary and interdisciplinary (thematic) types of researches encompassing basic and applied researches, graduate and postgraduate studies researches related to forestry and natural resources. JFNR will consider for publication articles from the regional and international forest and natural sources covering tropical and subtropical regions.

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Encompass critically reviewed scientific papers covering the state of the art knowledge in various aspects of forestry and natural resources. Review articles will be submitted by experts in the fields of forestry and natural resources with their expertise and experiences or invited by the editor-in-chief, associate editors, or editorial board.

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This includes articles of brief scientific notes on preliminary results, scientific observations, experimental techniques, and recent technological advances in forestry and natural resources. It also included information on specific cases and limited applications. Manuscripts for this column should not be more than six typed pages. They should have a brief abstract and not contain more than two figures and/or two tables.

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And also, the way references are presented both in the text and reference lists. Reviewers are expected to give their comments and suggestions clearly (referring to the line numbers in the paper) to the authors to assist the author (s) to address all comments and suggestions given. Language correction is not part of the review process but suggestions can be made by reviewers.

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- The manuscript has been ‘spell checked’ and ‘grammar checked’
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Where the family name may be ambiguous (e.g., a double name), please indicate this clearly. Present the authors’ affiliation addresses (where the actual work was done) below the names. Indicate all affiliations with a lower-case superscript letter immediately after the author’s name and in front of the appropriate address. Provide the full postal address of each affiliation, including the country name, and, if available, the e-mail address of each author.

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Change in authorship requests is only made by the corresponding author to editor-in-chief.

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The manuscript should be prepared in Times New Roman with 11 font sizes, double space, and 2.5 cm marginal indentions on all sides. The maximum number of words should be 8000. The first page should contain the full title of the manuscript, the name(s) of the author(s) including address (es), and the institution(s) in which the research was carried out. For ease of communication, authors are requested to include their email addresses. For manuscripts with multiple authors, an asterisk should indicate the author to whom all correspondence is to be addressed.

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This section of the manuscript should include state of the art of background on the topic being studied, an in-depth description rationale of the study, objectives of the study, hypothesis, and significance of the study. It should provide a brief review of literature, limited to information essential to orient the reader.

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The major findings in response to objectives set in the study. Be selective and focus on reporting your results.

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It should follow your major findings. Interpret the findings, show relationships and implications, and compare with other studies in similar topics and relevant to the study. It should explore the significance of the results of the work and don't repeat what has been already described in the results. In some cases, results and discussion can be merged. (Results and discussion part could also be written as a separate chapter optionally)

4.7. Conclusions:

This can be written in a separate section or can be part of the discussion. It should also be concise, clear, and align to stated objectives and major findings.

4.8. Funding

Information that explains whether and by whom the research was supported

4.9. Conflicts of interest/Competing interests

Include appropriate disclosures

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Collate acknowledgments in a separate section at the end of the article before the references and do not, therefore, include them on the title page, as a footnote to the title or otherwise. List here those individuals who provided help during the research (e.g., providing language help, writing assistance or proof-reading the article, providing finance, logistics, etc.).

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This follows author-year style taking the last author's last name in the text and alphabet refereeing system in the reference lists. As much as possible, recent references should be cited and the numbers kept to a minimum. It is the responsibility of the authors to check the accuracy of references. Papers by one or two authors are given as shown in the examples below:

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- (Kumar and Nair 2012)
- (Dhyani 2014; Kahiluoto et al. 2014; Lasco et al. 2014; Mbow et al. 2014a) - chrono- logically.
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Examples of acceptable formats for listing references in the reference section are shown below.

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Kuyah S, Dietz J, Muthuri C et al (2012a) Allometric equations for estimating biomass in agricultural landscapes: I. Aboveground biomass. Agric Ecosyst Environ 158:216–224.

Assegid Assefa and Tesfaye Abebe (2014). Ethnobotanical study of wild medicinal trees and shrubs in Benna Tsemay district, Southern Ethiopia. J. Sci. Dev. 2, 17–33.

Book

Chapman DH and Pratt PF (1961) Methods of Analysis for Soils, Plants, and Waters. University of California, Riverside, California.(N.B. initials appear before the last author's family name).

Chapter in book

Cunningham AB, Shanley P, Laird S (2008). Health, habitats, and medicinal plant use. In: Pierce CJ (Ed.), Human Health and Forests: A Global Overview of Issues, Practice, and Policy.Earthscan, London, pp. 35–62.

Paper in proceedings

Tesfaye Awas, Sebsebe Demissew (2009) Ethnobotanical study of medicinal plants in Kafficho people, Southwestern Ethiopia. In: Svein Ege, Harald Aspen, Birhanu Teferra and Shiferaw Bekele, Trondheim (Eds.), Proceedings of the 16th International Conference of Ethiopian Studies. Addis Ababa, Ethiopia.

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