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Types of Agroforestry Systems, Practices and Local Indicators for Farmers' Adaptation to Climate Change in the Hadiya Zone, Ethiopia

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Abstract

Climate change negatively affects agricultural production, the natural resources base, and the livelihoods of communities. As such, adapting to climate change through agroforestry practices is important for sustainable agriculture. This study aimed to assess farmers' adaptation to climate change through agroforestry practices in the Hadiya zone, in Ethiopia. Stratified random sampling techniques were employed. Data were collected through structured and semi-structured questionnaires. Data were analyzed using Participatory Learning Action tools. In this study, three major agroforestry systems, five common agroforestry practices, six major and seven minor associated food and cash crops, more than 14 common multipurpose tree species, four common tree propagation or seedling sources, nine common tree niches versus population and five common tree management practices were identified, analyzed and recorded in the order of priority in adapting to climate change. The major finding from the focus groups or key informant interviews is that income generation is of primary importance in deciding whether to plant trees. Farmers preferred *Grevillea robusta* as the best agroforestry or multi-purpose tree species compared to other existing indigenous or introduced multi-purpose tree species. *Mellia azedarach* and *Cupressus lusitanica* were the least preferred tree species. Agroforestry systems and practices should be encouraged in the study area to enhance adaptation to climate change by addressing food, wood, and income needs. Consequently, this helps farmers to develop their livelihood assets.

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Introduction

Ethiopia's livelihood and national economy are primarily dependent on its natural resources' productive potential, of which soil and water are the most essential. The productive potential of the lands in the country rooted in climatic conditions, however, has been severely affected due to land degradations, resulting not only in reduced productivity but in some areas in the total loss of the land (Adimassu *et al.,* 2012). This scenario is almost similar to that of Hadiya zone. This on-going degradation (degradation of natural capital) threatens millions of Ethiopians and poses a long-term threat to human survival in both the country's highlands and lowlands (Adimassu *et al.,* 2012). It is recognized that growing trees in the agricultural landscape (agroforestry) is probably the only sustainable way in which the climate amelioration, production of construction materials, and firewood can be increased (Berry, 2014), particularly in Ethiopia and in the Hadiya zone. These seen and unseen facts or existing problems led the researcher to investigate adaptation to climate change through agroforestry practices. As condition changes, so should people's actions (Jurin *et al.,* 2010).

According to the Agriculture and Natural Resources Development Department (DAaNRD) (2012) in the Hadiya zone, various agroforestry practices for soil and water conservation have been carried out by the government and the World Food Program (WFP) for many years. A report from the Agriculture and Natural Resources Development indicated many hectares covered by tree seedlings and soil erosion control structures. Moreover, since 2004, more agroforestry systems and practices have been introduced and adopted by farmers, but the effects in adaptation to climate change have not yet been investigated and documented in the Hadiya zone (DAaNRD, 2016). Consequently, this study seeks to investigate the existing agroforestry practices and their implication on climate change adaptation. Thus, the present study intended to investigate local farmers' role in adaptation to climate change through agroforestry practices in Ethiopia's Hadiya zone. Agroforestry practices promote tree planting that could contribute to climate change mitigation in the Hadiya zone. The adoption of agroforestry could directly enhance adaptation to climate change.

This study focuses on agroforestry systems and practices in the Hadiya zone with the aim to identify the agroforestry practices in the Hadiya zone and their implication on adaptation to climate change.

There are various types of agroforestry systems and practices across the zone. Parkland (scattered trees on cropland) agroforestry practice involves crops grown under the shade of dispersed tree species or around them. The dispersion of the trees varies from place to place, and in some areas, trees are located in more expansive spaces, whereas, in some places, they are scattered systematically (Bishaw *et al.,* 2013). Woodlot and area closure agroforestry practices act as an erosion control measure for sloping bare land, and provide useful products and enrich the soil (Eshete and Mamo, 2016).

There are also some other agroforestry techniques like planting trees and shrubs on borderline and boundaries, trees and shrubs around houses, and in public places, trees and shrubs along roads and paths that are indicating local farmers are using natural resources management as strategies to adapt to climate changes (Rocheleau *et al.,* 2012). The results of wealth characterizations of the community, historical background of vegetation cover, agroforestry systems and practices, multipurpose tree planting, tree growing and management practices, climate change and agroforestry and perception of farmers to climate change were summarized. Finally, in this study, the existing agroforestry systems, practices and tree management practices were identified and analyzed in the order of importance.

Materials and methods

Descriptions of the study area

The Hadiya zone is geographically located between 7°07'-7°92'N Latitude and 37°29'-38° 13'E Longitude (Fig. 1). The topography of the Hadiya zone is rugged high land and hilly areas with a range of slope angles of about 2-35 percent. Generally, the terrain is a mountainous, undulating and broken type that is very much prone to soil erosion. The distribution of soil units in the Hadiya zone is eutric nitosols 61 percent, chromic luvisols 23 percent, cambisols 11 percent and eutric regosols 5 percent (Hurni *et al.*, 2010) The zone is found in three traditional agro-climatic zones namely "Dega", "Woina Dega" and "Kolla" with an altitudinal range of 500-3200 meters above sea level with the variability of climate elements.

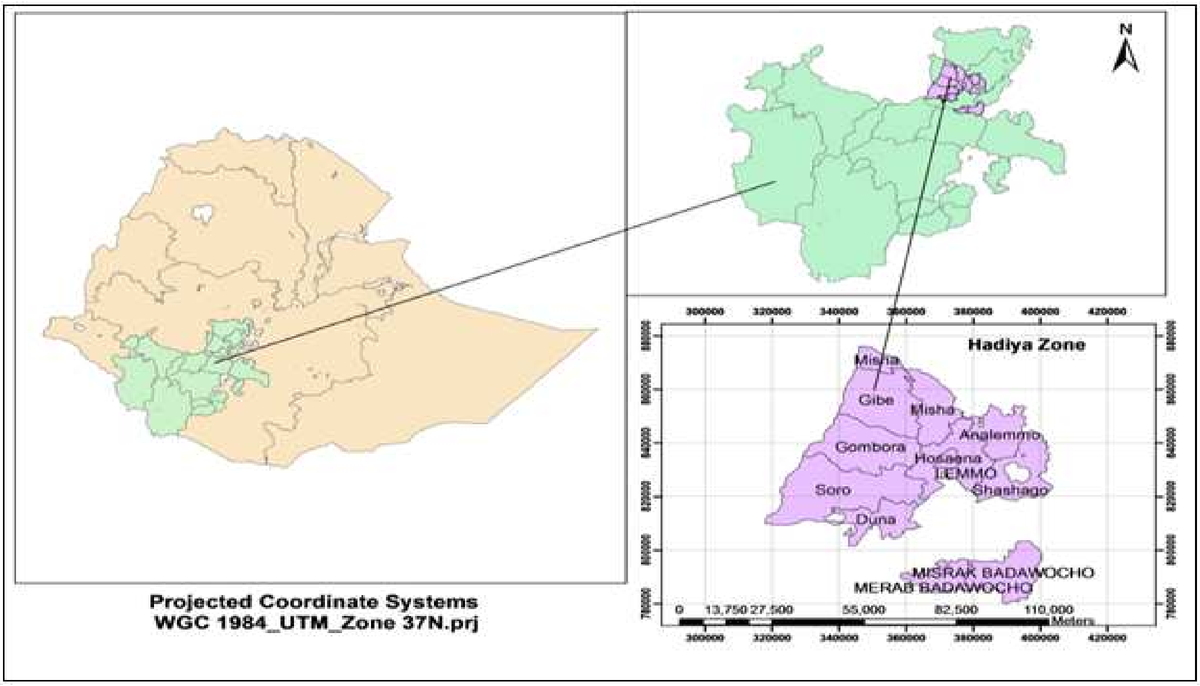

Fig. 1. Map of the Hadiya zone concerning Ethiopia and SNNPRS.
(Source: Survey of this study).

In the Hadiya zone, all-natural vegetation and grazing lands have been converted into cultivated land. What remains in the area are the retained scattered trees in all land-use types. Farmers are already acquainted with plant tree species to replace the former natural vegetation to meet wood, construction, and fuel demands. These trees are predominantly made up of the exotic *Eucalyptus* species. The zone practices mixed farming, with complete integration of trees, crop and animal components (DAaNRD, 2016).

Sample size determination

Study areas that were purposively selected made up the target population indicated below. The sample size was calculated using the statistical application. The techniques for calculating the sample size and precision considerations were considered. Heads of households were listed based on wealth category. Proportional respondents were sampled randomly from each wealth category.

According to Daniel (1999), the following formula was used:

$$n = \frac{N}{1+N(e)^2}$$

Where, n= sample size, N = population size, e = the desired level of accuracy, where e equals 1– accuracy (0.05 level of tolerable error) point of accuracy = 95% (0.091 = a theoretical or statistical constant). n = 86,902/1+ 86,902 (0.091*0.091), n= 86,902 /719.635462 = 121. As shown above, the sample size calculated was 121 households. Though considering this fact, the researcher tried to take 292 households from purposively selected 4 Woredas and 12 kebeles/PAs (peasant associations) proportionally. The researcher aimed to achieve the statistical principle, which asserts that the more the population sizes, the more the precision is and to arrive at the level of idea saturation. The proportionately calculated sample size based on kebeles/PAs performance and wealth status.

Methods and tools of data collection

The choice of a study depends on the type, objective and scope of the research (Daniel, 1999). Comprehensive RRA and PLA/PRA were used for primary data collection. Primary data were collected by using checklists and structured questionnaires, and key informant interviews. The questionnaires were pre-tested in the field.

Generally, the methods included a collection of secondary data at three levels (Zone, district and local levels), wealth ranking (poor, medium and better off) based on the category of sample households implementing agroforestry practices and not implementing agroforestry practices. This helped to have homogenous and proportional samples. Finally, a formal survey of sample households was carried out using wealth stratified random sampling within wealth status and agroforestry practitioners.

Data collection approach with comprehensive RRA and PLA/PRA were used for primary data collection. The primary data collections were carried out by employing a checklist and structured questionnaires, interviewing focus groups, and sample households. Twelve focus groups (consisting of six to eight members) of community strata (male, women and youth) from four locals were interviewed. The sample size of 292 households was proportionately from each wealth status (the poorest and poor, medium and better off) based on agroforestry systems and practices practitioners' categories were interviewed. Moreover, transect walks that are the actual field observations by dividing the catchment into upper, middle and lower areas were used in data collection.

Data were analysed using the PRA technique,Key informants (people who are knowledgeable about the Hadiya zone or their locality and have a good knowledge of the issues concerned) were selected with the help of development agents and peasant association administrators. As mentioned above, these informants mainly included elderly men and women, religious and opinion leaders in the selected community.

Interviews were conducted with selected key informants selected with the help of development agents and peasant association administrators. Twelve key informants groups (consisting of six to eight members per group) of community strata (male, female and youths) from four areas were interviewed.

A checklist containing important topics was used to lead the discussions on farm characterization, past good and bad years, future risks, and opportunities. This agrees with Sayer (1992) who states that for a tiny number of households, perhaps fewer than ten; examine each one exhaustively in terms of its history and context, namely, the specific experiences of the respondents regarding study variables.

Transect walk

A transect walk across the purposively selected representative lines used to collect biophysical data through the Hadiya zone enabled understanding of ecological problems and their socio-economic linkages. This field observation was used for both qualitative and quantitative data collection. It was done by dividing the Hadiya zones into three parts that is upper, middle and lower.

The transect walk captured land use-land cover and other features. It enabled the researcher to observe and collect biophysical data in a relatively short time. It was done by dividing the participants into three groups. Each group observed and discussed problems and opportunities while walking. Enumerators facilitated discussions on possible indicators of adaptation measures.

Data analysis

Qualitative data were analysed using PRA (Participatory Rural Appraisal) technique through pair-wise ranking analysis and comparisons, the focus group discussions using prioritizing techniques to identify critical issues, intervention points and implications on adaptation to climate change.

Ethics statement

The studies involving human participants were reviewed and approved by College of Agriculture and Environmental Science Ethics Review Committee, University of South Africa. The participants provided their written informed consent to participate in this study.

Results and discussion

Wealth Characterization of the Community

The focus groups selected in the Hadiya zone at different localities were categorised into wealth groups in terms of food security or safety-net programme based on government and donor categories. The key informants identified similar wealth groups or categories. These are rich (better off), medium and poor. Since discussions were guided, the researcher and enumerators (data collectors) tried to remind informants that the two extremes (very poor and very rich) should be considered. However, the focus groups or key informants indicated that the two extremes did not exist in their locality or the rest of the Hadiya zone. They indicated that wealth status can influence the adaptation to climate change strategy in the Hadiya zone; (it could be reflected on the five livelihood assets which are natural, financial, human, physical and social) as capital impacts adaptive capacity.

Table 1. Wealt group carateristics in the Hadiya zone.

Attribute/Criteria of classification	Wealth category		
	Poor and Poorest	Medium /Intermediates	Rich/Better off
Land size (ha)	0.25-0.5	0.5-1.5	>1.5
Number of cows	1	2	>2
Number of oxen	0	2	>2
Number of shoats	2	4	>4
Equines in number	0	1	2
House	1 “Tukul” house	2 “Tukul” house	3“Tukul” house corrugated Iron
“*Enset” in number	20-70	70-100	>100
Coffee in number	<10	20-50	>50
“*Chat” in number	<10	50-100	>100
Trees in number	<50	50-100	>100
Agricultural production	Cannot feed his family	feed his family	"Surplus"
Summary	20%	60%	20%

(Source: Survey results) *”Chat” (*Catha edulis*) * “Enset” (*Enset ventricosum*).

(Table 1) indicates similarities among the specific communities in their wealth category classification, with few exceptions. The rich had large landholdings, cows, oxen, shoats and equines. Moreover, the rich had a large number of “enset” plants, trees, “chat”, and coffee. The medium category had fewer of all types, and the poor and poorest of the poor had very few of each type. Based on the information or criteria given in (Table 1). The results of wealth ranking (Table 1) indicated that 20% of households are rich (better off), 60% of households are medium, and 20% of households are poor. The wealth status classification was quite essential and specific to that particular community. The classification criteria, units and quantities are the same for this specific community. This shows that wealth classification seems to be relative (specific community based) and depends on the actual situation of the community. This indicates that a farmer in a medium group in a study area may be poor in the other community and vice versa.

Vegetation cover change

To establish vegetation cover as an indicator of environmental degradations and how agroforestry and tree planting began, focus group interviews were carried out. During the interviews, there was recognition by farmers that the vegetation cover has changed over time. Previously, the vegetation cover of the Hadiya zone was dense except for some areas like grasslands. However, over time, the dense vegetation has changed to only a few scattered trees on farmlands that are in harmony (Kidane *et al.,* 2012; Betru *et al.,* 2019). Edible fruit trees like *Syzygium guineense*, *Carissa edulis*, *Ficus sur*, *Rosa abyssinica* were commonly found in the forest and were good sources of food (Ayele *et al.,* 2014).

Farmers nostalgically recalled that the forest was a source of food, implying that there were enough fruits in the forest to fill bellies. Focus groups also mentioned that it was difficult to herd domestic animals in the Hadiya zone because wild animals like lions (*Panthera leo)*, leopards (*Panthera paradus)* and hyenas (*Crocuta crocuta)* were common in the zone. Other wild animals that were commonly found in the forest are Menelik bushbuck (*Tragelaphus scriptus meneliki)*, Speke's gazelle (*Gazella spekei*), dikdik (*Scriptus minocqua),* mantle guereza (*Colobus guereza* LR/lc), wild pigs (*Sus scrofa*), porcupines (*Erethizon dorsatum*), warthogs *(Phacochoerus africanus),* apes (*Galago gallarum* LR/nt) and baboons or monkeys (*Papio hamadryas)*. Almost all the major types of these wild animals have disappeared except for a few like apes (*Galago gallarum* LR/nt), baboons or monkeys (*Papio hamadryas)* and the boreholes type hyenas (*Crocuta crocuta)* and porcupines (*Erethizon dorsatum*).

Table 2. Agroforestry systems identified in the Hadiya zone.

No.	Types Systems	No. 1*	No. 2*	No. 3*	Weight	Rank
1*	Silvopastoral	-	2	3	0	3
2*	Agrisilvicultural	-	-	3	1	2
3*	Agrisilvopastoral	-	-	-	2	1

(Source: Survey results; * = pair-wise ranking of columns versus rows).

The unique feature of grazing land or grasslands, as explained by a 76 year old interviewee (a member of a focus group) whose views were supported by others in the area is that there was grazing land or grassland with patches of dense native vegetation which forced the people in the area to be pastoralists with hundreds of livestock. Contrary to other areas with dense forest cover in the past, the population pressure of these areas forced the forest to encroach; this is similar to the findings of Sun *et al.* (2020). At the same time, the problem they faced urged the people to plant trees and the grassland areas were also integrated in the farming system. This indicates that there were complete practical changes in land use and land cover that is in agreement with Smith *et al.* (2012).

Table 3. Common agroforestry practices in the Hadiya zone.

No.	Common Agroforestry Practices	1*	2*	3*	4*	5*	Weight	Rank
1*	Home-garden (Hg)	-	Hg	Hg	Hg	Hg	4	1
2*	Parkland (Pl)	-	-	Lf	Pl	Pl	2	3
3*	Hedgerow /Live fence (Lf)	-	-	-	Lf	Lf	3	2
4*	Woodlot (Wl)	-	-	-	-	Wl	1	4
5*	Area closure (Ac)	-	-	-	-	-	0	5

(Source: Survey results; * = pair-wise ranking of columns versus rows).

The continuous land use land cover change and loss of vegetation (biodiversity) are attributed to population growth and pressure. Farmers regrettably mentioned that forest destruction or deforestation was caused mainly by population pressure and unwise use. The population pressure forced the community to look for more farmland (development of extensive farming) that caused deforestation.

Moreover, the reasons mentioned for the forest decline include tree cutting for charcoal and fuel-wood, and for farming and household tools.

Generally, the focus group discussions mentioned that the vegetation cover has evolved through time from a dense and highly diversified forest cover to few scattered trees on farmlands, as stated by Alebachew (2012). Thus the selective retention of trees by farmers has led to the existing local tree species like *Acacia abyssinica, Croton macrostachyus, Cordia africana, Olea europaea, Olea welwitschii, Haygenia abyssinica, Juniperus procera, Erythrina abyssinica, Ficus sur, Calpurnia aurea, Bersama abyssinica, Millettia ferruginea, Podocarpus falcatus, Albizzia gumiffera, Prunus africana, Ekbergia capensis, Vernonia amygdalina,* which are in agreement with Negash's (2010) tree lists.

Table 4. Common multipurpose tree species in the Hadiya zone.

No.	Tree Species	1*	2*	3*	4*	5*	6*	7*	8*	9*	10*	11*	12*	13*	14*	*Wt	Rank
1*	*Eucalyptus sp* (Eu)	-	Er	Co	Gr	Cr	Eu	Eu	Oe	Po	Eu	As	Ad	Se	Eu	4	7
2*	*Erythrina* sp (Er)	-	-	Co	Gr	Cr	Er	Er	Er	Er	Er	Er	Er	Se	Er	9	4
3*	*Cordia africana* (Co)	-	-	-	Gr	Co	Co	Co	Co	Co	Co	Co	Co	Co	Co	12	2
4*	*Grevillea robusta* (Gr)	-	-	-	-	Gr	Gr	Gr	Gr	Gr	Gr	Gr	Gr	Gr	Gr	13	1
5*	*Croton macrostachyus* (Cr)	-	-	-	-	-	Cr	Cr	Cr	Po	Cr	Cr	Cr	Se	Cr	9	4
6*	*Juniperus excelsa* (Je)	-	-	-	-	-	-	Je	Oe	Po	Ca	As	Ad	Se	Je	2	8
7*	*Cupressus lusitanica* (Cu)	-	-	-	-	-	-	-	Oe	Po	Ca	As	Ad	Se	Cu	1	9
8*	*Olea europaea* (Oe)	-	-	-	-	-	-	-	-	Po	Ca	As	Ad	Se	Oe	4	7
9*	*Podocarpus falcatus* (Po)	-	-	-	-	-	-	-	-	-	Po	As	Ad	Se	Po	7	6
10*	*Casuarina sp* (Ca)	-	-	-	-	-	-	-	-	-	-	As	Ad	Se	Ca	4	7
11*	*Acacia saligna* (As)	-	-	-	-	-	-	-	-	-	-	-	As	Se	As	8	5
12*	*Acacia decurrens* (Ad)	-	-	-	-	-	-	-	-	-	-	-	-	Ad	Se	7	6
13*	*Sesbania sp* (Se)	-	-	-	-	-	-	-	-	-	-	-	-	-	Se	11	3
14*	*Mellia azedarach* (Me)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	10

(Source: Survey results of *pair-wise ranking of columns versus rows) * For listed tree species, vertical numbers are the same for horizontal numbers (Pair-wise ranking).

Identification of agroforestry systems

The identification and ranking of agroforestry systems was done to establish the existing agroforestry systems and their level of importance in the study area. Adaptation to climate change is unquestionable for sustainable development of the agricultural sector in the world in general and in the country of Ethiopia and to the study area in particular. The focus groups believed that this is possible only based on the performance of the farming system. The farming system effectiveness and efficiency is the collective effect of the primary agricultural components (trees, crop and animals) which are wisely integrated. This is in harmony with the finding that states that agroforestry practices are a combination of trees, annual crop growing and livestock production. It boosts farm efficiency when the various components occupy the corresponding position, and their relations are supervised successfully (Chaturvedi *et al.,* 2011; Lasco *et al.,* 2014). During this study, essential components integration-based agroforestry systems and practices were discussed, identified and analyzed.

The results in this study (Table 2) are in agreement with Rigueiro-Rodríguez *et al.* (2008) who pointed out the importance of agroforestry systems that were revealed in this study. The agrisilvopastoral system ranked first (the order of importance and more weight given by focus group discussions), the second was agrisilvicultural system, and the third was a silvopastoral system.

Table 5. Tree population versus niches in the Hadiya zone.

No.	Trees Niches	1*	2*	3*	4*	5*	6*	7*	8*	9*	Weight	Rank
1*	Home-garden (Ho)	-	Ho	Ho	Ho	Ho	Ho	Ho	Ho	Ho	8	1
2*	Farm boundary (Fb)	-	-	Fb	Fb	Fb	Fb	Lf	Wl	Fb	5	4
3*	Parkland (Pl)	-	-	-	Pl	Pl	Pl	Lf	Pl	Wl	4	5
4*	Road side (Rs)	-	-	-	-	Rs	Rs	Lf	Wl	Rs	3	6
5*	Gully side (Gs)	-	-	-	-	-	Ss	Lf	Wl	Ac	0	9
6*	Stream side (Ss)	-	-	-	-	-	-	Lf	Wl	Ac	1	8
7*	Live fence (Lf)	-	-	-	-	-	-	-	Lf	Lf	7	2
8*	Wood lot (Wl)	-	-	-	-	-	-	-	-	Wl	6	3
9*	Area closure (Ac)	-	-	-	-	-	-	-	-	-	2	7

(Source: Survey results of *pair-wise ranking of columns versus rows)* For listed tree species, Vertical numbers are the same for horizontal numbers (Pair-wise ranking).

As indicated in the discussion and (Table 2) the agroforestry systems identified, analyzed and recorded in the Hadiya zone are illustrated in (Fig. 2).

The focus group participants' recognized that integration, intensification and diversification of farming are possible only through agroforestry systems and practices. Environmental and economic benefits are quite remarkable and significant in agroforestry systems these agree with the Rao *et al.* (2007) findings, which indicated that agroforestry interventions, because of their capability to offer economic and ecological benefits, are regarded as the best no regrets actions in making communities adapt and become flexible to the impacts of climate changes. The central elements of agroforestry systems that can play a significant role in the adaptation to climate change include changes in the microclimate, shield through the provision of everlasting cover, chances for diversification of the farming systems, improving efficiency to use of soil, water and climatic capital which is similar to Jiru (2019) and Ayele *et al.* (2014).

Smallholder farmers in the past have reacted to ecological changes by regularly altering their farming practices, and selecting adapted cultivars, using their native knowledge and skill (Lasco *et al.,* 2011). In this way, the natural elasticity of smallholder farmers to present and future climate unpredictability will likely get better (Verchot, *et al.,* 2007). The other findings by Rao *et al.* (2007) showed that while the people long ago have shown elasticity and ability to adapt to variations in climate through keen watching, testing and performance, adaptation to the fast changes, that is the winning position in worldwide climate and other sectors are further than that of a usual nature-correcting course. In the same way, a wide variety of agroforestry systems and practices currently exist with the potential to recover productivity, positively control microclimate, check soil degradation and reinstate soil fertility and broaden the horizons of income-generating chances. These findings agree with the existing potential and practical activities and facts in the Hadiya zone observed during the focus group discussions and transect walk.

Identification of agroforestry practices

According to focus group discussions, the order of importance for all standard agroforestry practices (CAP) existing in the Hadiya zone are similar. That is home-garden> (higher or greater than) live fence> parkland> woodlot> closure area and that all of them were well-planned agroforestry practices, this is similar to the findings of Alao and Shuaibu (2013). In an actual sense, area closure (a land degraded too much and closed to be rehabilitated) is common in areas where land degradation is standard and high. In the Hadiya zone, the closure area agroforestry practice is almost different from others. This is because the closure area is familiar to a specific locality. This implies that farmers' adoptions of this agroforestry practice are quite different based on the local situation, mainly of informal land use land cover systems. The most important of all agroforestry practices that are intensified, diversified, productive almost throughout the year, and more valuable is home-garden agroforestry practice. It is regarded as "gowaro yeset sira", meaning home-garden agroforestry practice is the duty of women which is similar to Alemu (2016). Like boundary planting of trees and live fences, home-gardens are sufficient in acting as windbreaks since the area is practicing smallholder farming. Alley cropping is not yet practiced, but it is at its trial phase in the Forestry Research Centre (FRC). The findings in the Hadiya zone were identified, analyzed, recorded and summarized in (Table 3) and illustrated in (Fig. 3).

Table 6. Comparison of past and present, risks and opportunities, good and bad years.

Situations in the past (before 1991)	Current situations (after 1991)
Extensive forest cover	No forest cover rather trees cover
Consistency of rainfall and temperature	Inconsistency of rainfall and temperature
Predictable production	Unpredictable production
Healthy environment	Polluted environment
Low-cost input	High-cost input
Low population pressure	High population pressure
Low famine	High famine
Availability of springs	Remarkable decreasing of springs
Unavailability of agricultural inputs	Availability of agricultural inputs
Unavailability and access to technology	Availability and access to technology
No physical soil and water conservation structures	Having physical soil and water conservation structures
Low awareness and chronic poverty	Better awareness and relative poverty
Possible risks	Opportunities
Pathological and livestock disease outbreak	Development of technologies and access to it
Erratic rainfall and varying temperatures	Intensive and integrated farm fields
Low productivity	Developing agroforestry/ biodiversity
Famine and flood	Increased market potential
High cost of inputs	Agricultural inputs availability
Environmental pollution	Tree conscious farmers
Good years	Bad years
Evenness of rainfall and temperatures	Varying rainfall and temperatures
Increased production and productivity	Famine because of food shortage
Free of disease and pests	Pest and disease outbreak
Absence of drought	Incidence of drought

(Source: Survey results).

As perceived by focus group participants in the Hadiya zone, agroforestry systems and practices do not only mean planting trees. Trees are considered as the distinctive and pillar component of agroforestry systems and practices but the trees are integrated with crops and livestock. According to a focus group discussion agroforestry systems and practices were ranked not only based on production but also with different considerations and factors like the productivity of the system, integration of the components, adaptation to climate change or environmental soundness and socio-economic feasibility in the Hadiya zone.

Findings from focus group discussions agree with different scholars' assertions. According to Mbow *et al.* (2014) home-gardens agroforestry practice is the entire crop-tree-animal element administered by family labour. Bishaw *et al.* (2013) state that home-gardens are the combination of tree-crop-animal invention methods recognized on small plots of land productivity near home. Furthermore, Rao *et al.* (2007) argue that home-garden agroforestry practice encourages gender impartiality. According to Bishaw *et al.* (2013) home-gardens consist of many woody species in a close, multi-storied organization with aromatic plants, yearly and perennial crops and livestock all administered on the same portion of land. Likewise, growing and maintenance of parkland agroforestry practice may be rooted on protection and management of chosen developed trees previously on the site (Rocheleau *et al.,* 2012). Trees scattered on farmlands serve as or provide production and service (Nzuma *et al.,* 2010). Live fencing, hedges, and boundary markers can serve as productive and ecologically valuable components of agroforestry systems and practices (Bishaw *et al.,* 2013).

The hedges are pruned periodically in the crops' growth to offer biomass and improve soil nutrient status (Rigueiro-Rodríguez *et al.,* 2008). Many woodlots occur as a division of an arable farm or as a shock absorber and on unproductive land (Bishaw *et al.,* 2013).

Fig. 2. Agroforestry Systems in the Hadiya zone.

According to Eshete and Mamo (2016). closure areas or natural vegetation rehabilitation is also essential to develop biodiversity and microclimate of the areas, Oldeman *et al.* (2017) stated that establishing maintenance areas and regenerating degraded lands are also advantageous to promote agricultural development because they care for catchments and stabilize local and regional climate and hydrological systems. Conservation of rural environments also ensures the sustainable provision of crucial forest products and environmental services (Adimassu *et al.,* 2012).

Windbreaks are rows of trees and shrubs planted and maintained to change wind flow and get better microclimate, thereby shielding a definite area (Bishaw *et al.,* 2013), and such tree plantings can also ultimately influence the crop-livestock production scheme by acting as windbreaks and shelterbelts (Rigueiro-Rodríguez *et al.,* 2008).

Common agroforestry trees or multipurpose tree species

Concerning preferences for growing trees and shrub species, a discussion was held with the focus group. In this study, the findings revealed that the majority of the trees and shrub species retained and planted in the Hadiya zone were used for multipurpose (construction, fuel-wood, farm tools, food, animal feed and dry and live fence), that is grown for more than one use (production and protection or service role) which is in harmony with Duguma and Hager's study (2010). These results agree with the statement that the introduction of new germplasm for agroforestry (with a focus on improvement of the genetic material for agroforestry expansion in typical agro-ecological zones of Ethiopia and Kenya) is significantly crucial to climate change adaptation and impact alleviation measures (Temesgen *et al.*, 2014). Furthermore, trees on parklands serve as food, fuel-wood, construction wood, feed for animals, mulch, and raw materials for making agricultural equipment, house utensils and revenue for the farmers (Nzuma *et al.,* 2010; Duguma and Hager, 2010).

It is also true to say no farmers are against tree planting in the Hadiya zone; instead, they are very much encouraged to get and or raise tree seedlings to be planted at appropriate niches, which is similar to the study of Abiyu *et al.* (2016). This is also in agreement with the focus group discussions result obtained during risks and opportunities analysis, which asserts that tree conscious farmers are one of the opportunities in the Hadiya zone (Table 6).

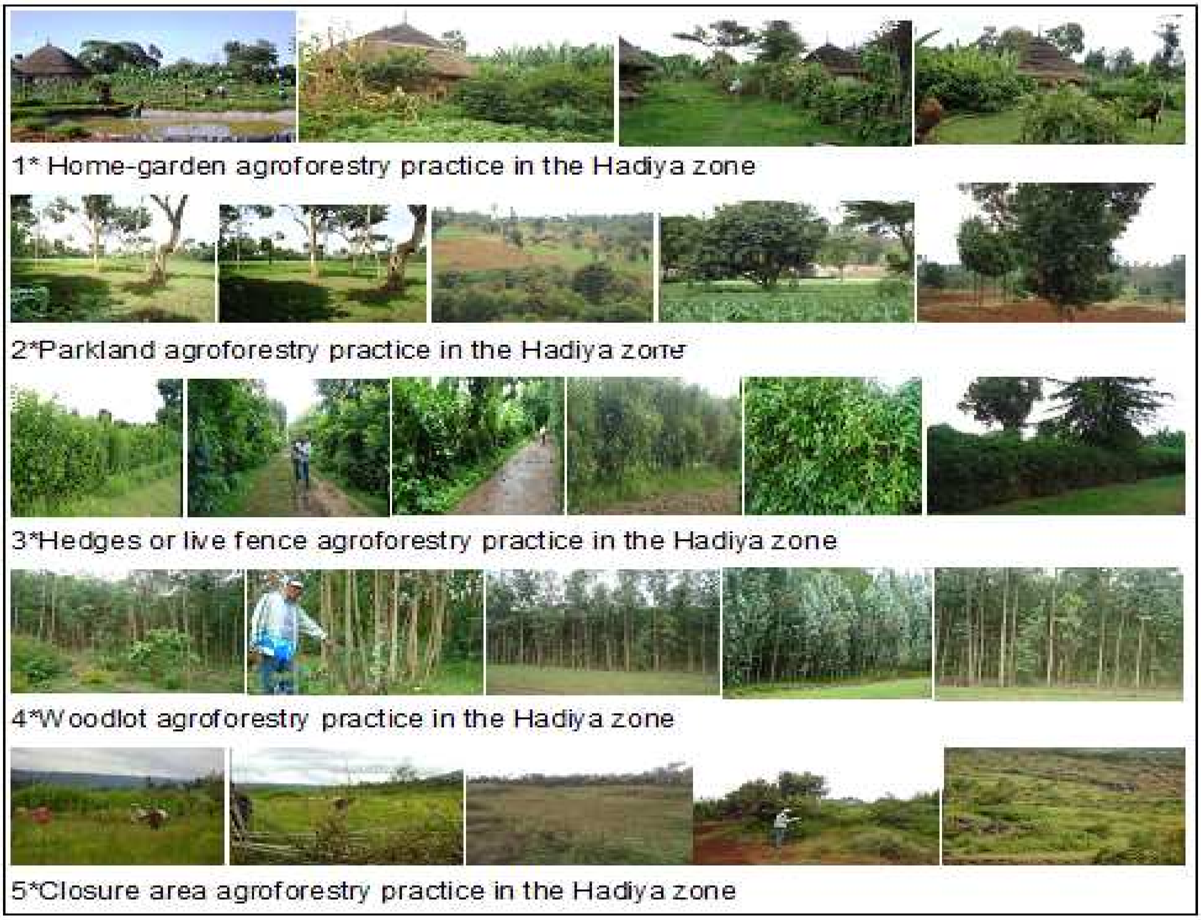

Fig 3. Common agroforestry practices in the Hadiya zone.

The results obtained in this heading are shown in (Table 4). Also, for more detailed information on multipurpose and/or agroforestry tree species, associated food crops, spices and fodder grasses identified.

The type of trees with their abbreviation, the weight or point given by focus group discussions and level of importance are analyzed and illustrated in (Table 4).

In the Hadiya zone, it is evident that *Grevillea robusta* and *Cordia africana* were the first and the second most preferred tree species (Table 4). The focus group said that they are using these and other tree species as fuel-wood income sources to improve local or microclimate (directly and indirectly) and satisfy their existing and increasing demands for wood, food, and fodder needs. This is similar to previous findings that state that trees improve microclimate (Verchot *et al.,* 2007). Besides, the occurrence of trees on farmlands serves as windbreaks and shelterbelts and is utilized to rebuild property damaged by the wind (Waha *et al.,* 2013). A study conducted in Western Kenya shows that trees on farmlands offer a more easily accessible, secure and stable source of fuel-wood for energy and income (Thorlakson and Neufeldt, 2012).

It is also significant that farmers preferred *Grevillea robusta* as the best agroforestry or multi-purpose tree species compared to other important existing indigenous and introduced multi-purpose tree species. In contrast, *Mellia azedarach* and *Cupressus lusitanica* are the least preferred tree species.

This may be because of the low benefit that they are obtaining from the tree *Mellia azedarach,* and they are also aware of *Cupressus lusitanica* that homestead or home-garden is not an appropriate niche for planting this species.

Tree propagation and sources of planting material

According to the results from focus group discussions, farmland trees propagation techniques, including species selection, seed treatment, sowing, and nursery management by farmers, were apparent. Farmers typically propagate and raise seedlings of *Eucalyptus spp and Ensete ventricosum* on their own. *Rhamnus prinoides* is propagated both sexually and in vegetative methods. Its seeds are sown by rubbing them with ash. This is done to stimulate and increase initiation of germination and seed protection from drying, which is similar to standard pre-treatment of seeds before sowing on seedbed prepared in the nursery. In the vegetative method, *Rhamnus prinoides* is propagated by layering the branches. *Ensete ventricosum, Arundo donax and Arudinaria alpina* are also propagated in vegetative methods by farmers themselves. These facts prove that planting materials and planting practices are prevalent in the study location (the Hadiya zone). These are similar to the study by Alebachew (2012).

Fig. 4. Tree management practices in the Hadiya zone.

Additionally, in seedling production in the nursery, farmers traditionally use wildlings from natural regeneration to grow tree species like *Olea europaea, Olea welwitschii, Cordia africana, Acacia abyssinica, Croton macrostachyus, Podocarpus falcatus, Ekbergia capensis* and *Rhamnus prinoides*. Farmers are also aware of their knowledge limitation in tree propagation, as indicated in the study of Lu *et al.* (2016). It was pointed out that raising seedlings of valuable indigenous tree species is difficult mainly due to the longer nursery life and lack of practice. For example, *Podocarpus falcatus* and *Olea europaea* seeds are very difficult to germinate, and *Olea europaea* does not easily become wet when put into water.

The pair-wise ranking result indicated that the sources of planting materials vary with the greatest share of seedlings or planting materials coming from the Ministry of Agriculture (MoA)> (higher or greater than) farmers themselves (self-preparations)> followed by obtaining from different sources (buying from sellers, a gift from others, wildlings or natural regenerations)> NGOs (Non-Governmental Organizations). Even though the government is playing a significant role, the contribution of farmers themselves to planting materials production is substantial. Remarkably, they are not worrying about trees propagation and sources of planting materials which is the base for trees growth, as indicated by Yirgu *et al.,* (2019). This implies that the people in the

Hadiya zone are aware of and knowledgeable about trees propagation and growing. This may be the reason why they are developing agroforestry systems and practices in the Hadiya zone.

Trends in tree growing practices

The tree cover change at the farm level is associated with both decreasing and increasing trends over time. The most preferred niches where the number of trees increased over time are identified, analyzed and summarized. Respondent farmers in the Hadiya zone valued the vital role of trees on different land use and land cover and showed this by planting trees for different purposes. In this regard, all of the focus group respondents reported that farm-level trees cover increase has been observed on nine niches with the highest increase being designated in home-gardens and the least is in gully side. The details are shown in (Table 5).

Eucalyptus spp particularly *(Eucalyptus camaldulensis, and Eucalyptus globules)*, *Grevillea robusta*, and *Cupressus lusitanica* are among the most commonly planted tree species in woodlots agroforestry practice. The pair-wise ranking results on several stems per niche area; support the above assertion that trees growing at farm level are highest with home-gardens in the study location. The environmental significance of planting trees is also well understood by the farmers. They agree that agroforestry consisted of a wide variety of experiences that involve establishing and administering trees deliberately around or within parklands and grazing lands with the purpose of:

- Soil erosion control,
- Soil fertility improvement,
- Providing fuel-wood,
- Animal fodder and modify microclimate of the area,
- Developing sustainable agricultural production scheme,
- Improving wildlife habitat and rural landscape,
- Mitigating environmental pollution and
- Rising farm economy throughout yield of tree-based commodities (Kumar *et al.,* 2015; Duguma and Hager, 2010).

The focus group also characterized tree population versus niches-based trends concerning tree species on the farming system. All the details are in harmony with findings that state that agroforestry is the combination of trees with yearly crop cultivation and livestock production. Agroforestry increases farm productivity when the various elements occupy complementary niches, and their relations or interactions are administered successfully (Chaturvedi *et al.,* 2011). However, in the Hadiya zone, the highest numbers of trees or shrub species were in niches designated as shown in (Table 5), which is in harmony with the study of Gebru *et al.* (2019). The trend has this order: Home-garden> (higher or greater than) Live-fence> Woodlots> Farm boundary> Parkland> Roadside> Streamside> Gully-side for all study area exclusive of area closure (Table 5), but Home-garden> (higher or greater than) Live-fence> Woodlots> Farm boundary> Parkland> Roadside> Closure area> Streamside> Gully-side for all study area inclusive of area closure. On the other hand, farmers articulated limitations that inhibit tree combinations: shortage of particular trees (*Podocarpus falcatus and Olea europaea)* seedlings or planting materials, water and land scarcity, inadequate knowledge and slow maturity of the trees discourages more trees planting. This is quite the same as Nkonya (2004) who asserts that adequate seeds and germplasm supply are other constraints to agroforestry practices.

Moreover, bringing in new germplasm for agroforestry focusing on economically useful trees (upgrading the genetic material for agroforestry development for typical agro- ecological zones of Ethiopia and Kenya) became significantly crucial to climate changes adaptation (Temesgen *et al.,* 2014). The proportional pilling analysis result of the focus group indicated the income contribution of different tree niches: home-garden is 30%, live-fence is 20%, farm boundary is 15%, woodlots is 10%, parkland is 9%, the roadside is 6%, closure area is 5%, streamside is 3% and gully side is 2%.

Tree management practices

The knowledge of tree management practices revealed in the Hadiya zone community was remarkable. Coppicing, lopping, pollarding, pruning, and thinning are the common tree management practices identified, analyzed and indicated in (Fig. 4). The farmers did not only have profound knowledge of which tree species are capable of coppicing and pruning but also the timing of these activities. For example, *Eucalyptus spp* is mentioned as a highly coppicing tree species if cut at the appropriate time of the year. The suitable time for cutting coppice trees is the end of "Tikimit" (October) or soon after the rainy season. It was mentioned that the cutting of trees in April would cause decay of the stump by creating pests and also cutting in the rainy season can cause the stump to decay. It was preferred to cut trees above the ground level at the height of one "chama", meaning one-foot length, which is almost equivalent to the standard recommendation (30-50cm). This is primarily to keep newly developed shoots from splitting in the wind and to get additional shoots. It was noted that coppicing takes away the requirement of replanting trees after harvest. The yield from coppicing can be employed to make fuel-wood and charcoal, and add to tree harvests

Detailed knowledge of coppicing and pollarding was established: how, when, what to be cut for the purpose of coppicing. It was also noted that pollarding is very important to avoid the shade effect on companion crops. Pruning "ket bilo endiyadig yadergewal" meaning a straight stem, is a significant concern in the management of pruning. The other tree management practice mentioned was thinning that makes the trees "erajim ena wofram endihon yadergewal", meaning tall and more abundant in diameter. Farmers were very much accustomed to thinning of *Eucalyptus* species. The other tree management practice mentioned was lopping, which is very important to avoid shade effect on associated and companion crops. The most widespread tree management practice was coppicing. Coppicing was also practiced mainly on *Eucalyptus* species for poles and timber. Some of the tree species, like the *Eucalyptus species,* were coppiced (cut) in the dry period. Many farmers noted that trees coppiced (cut) during the wet period do not grow back and die-off from infestations. Pollarding was mainly influenced by trees usefulness, a niche where trees were found and desired for products (Lu *et al.,* 2016; Gebru *et al.,* 2019).

Fruit providing tree species were not at all pollarded since farmers noted from experience that pruning would decrease the capability of fruit production, productivity and, in turn, influence income level. Fruit trees are common in the home-garden agroforestry practice. This was observed during the transect walk. As stated previously, scattered trees planted and retained in the crop or farmland were largely lopped and pollarded in June before sowing crops to reduce shade and make leaves available for moisture conservation, temperature regulation, and lifeless boundary marker to defend livestock from browsing crops. Timber, fuel-wood and fodder trees for livestock feed were pollarded or cut (coppice) only as required. It is true; farmers are tree conscious, as stated by themselves.

Scattered trees found on farmland and cropland was not often pollarded, particularly trees in the home-garden, except for when the harvest was mandatory. Also, deliberately retained trees for shade purpose (human and livestock) specially located in the front yard, for example, *Podocarpus falcatus* is never pollarded and provide shade right through for cultural meetings and livestock. Given the type of land possession, individuals who had land on loan were not permitted to manage trees there, even if such trees might have a thick shadow which could affect the crop's capacity to access sunlight. These trees influence crop production and productivity. This is due to the advantage that the owner of the land gets better biomass from the trees. These findings are in harmony with enhanced tree management practice to boost growth rates, and the achievement of agroforestry practices on agricultural rangeland is quite essential (Chaturvedi *et al.,* 2011). The results for quantitative analysis indicated that tree management practices are among statistically significant influencing factors (M = 2.53, SD = .78). The trees management practices result obtained from observation and the focus group or key informants are indicated in (Fig 4).

Climate change and agroforestry practices

Farmers' awareness of agroforestry practices

The farmers who practiced agroforestry felt that the farmers who did not practice agroforestry looked at them with admiration. All key informants (100%) and almost all that is 265 (90.7%) households have an awareness of agroforestry systems and practices. The focus group discussions indicated that farmers with agroforestry practices are not only practicing it to adapt to climate change but also to secure food. The focus group felt that farmers who have agroforestry practices could fertilize their farm field by planting trees. Some individuals mistakenly perceived that agroforestry compacted arable land and required a long period to pay back. It can take years for the products of the trees to be realized and provide returns for the farmers. However, there was also positive thinking. For example, one of the focus group members said that farmers with agroforestry practices are the real farmers and farmers without agroforestry practices were seen as inferior to other farmers.

This was supported by other members of the focus group. Some farmers have agroforestry practices that help them protect their farm fields. In the Hadiya zone, farmers try to plant fodder trees near their farmstead to avoid burning their fields. Additional strategies applied in the Hadiya zone included encouraging neighbors' to participate and doing the same practices and organizing awareness meetings by developing agents working in the Hadiya zone.

According to the farmers, it is evident that agroforestry practices have a significant impact on the livelihoods of the farmers and their families concerning: improving soil fertility and yields, increasing income and savings, increasing knowledge and experience related to agroforestry practices, improving food security and nutritional status, increasing fuel-wood supply and mitigation of the impacts of climate changes. These findings agree with the findings that indicate that agroforestry offers the capacity to develop synergies between efforts to alleviate climate changes and efforts to help susceptible populations adapt to the adverse effects of climate changes (Verchot *et al*., 2005). This is also in harmony with Garrity *et al.* (2006) who state that agroforestry trees offer vital ecosystem services plus soil, springs, streams and catchment protection; animal and plant biodiversity maintenance; and carbon seizure and storage, which in the end influence food and dietary security. Farmers acknowledged that there are challenges like lack of adequate knowledge and finances, few partners, lack of awareness among stakeholders and farmers, the inadequacy of quality planting materials and drought in scaling up agroforestry systems and practices. This is more or less similar to Garrity (2012) who states that the technological barriers to the fast development of agroforestry are the lack of acquaintance regarding the design and management practices, assortment and domestication of multipurpose tree species administration guidelines and accessibility of resources.

Farmers' perceptions of climate change

Focus group discussions confirmed that climate change implies unpredictable situations related to rainfall, or temperature that causes failure of production or farming systems. All key informants (100%) and all households 292 (100%) have an awareness of climate change threatening agriculture. They perceived that climate change is "segat legibrina", meaning a threat to agricultural activities (tree growing, crop and livestock production) and livelihood of farmers, which is contradictory to the majority of farmers who have not heard about climate change. However, some respondents have information about this global phenomenon (Bogale and Bikoko, 2017).

Focus group discussions showed that farmers are very concerned or worried about climate change as they are victims of erratic rainfall, fluctuating or increasing warmness or temperature which can cause their produce (trees, crops and livestock production) to fail. No focus group members perceived an increase in rainfall and a decrease in temperature. The focus group members witnessed irregularity in rainfall timing and distribution, which have severe cost implications for their production system, which agrees with Bogale and Bikoko (2017). Most of the Hadiya zone farmers have experienced climate change and variability. This means that they have experienced increasing temperatures and number of hot days, and fluctuations of rainfall amount, which is also in agreement with meteorological data in the Hadiya zone over the last 40 years.

Also, climatic conditions affect households' capacity to produce seasonally and grow diversified and continuous crops throughout the year, which is in agreement with the finding that indicated that climate change or variability imposed significant influences on the overall activities of human beings. This impact also influences the local peoples' day-to-day activities. Most of the respondents (81%) believed climate change or variability has had a significant impact on different aspects in the Hadiya zone (Bogale and Bikoko, 2017).

The focus group discussions indicated that the incidence of drought is at least every ten years and changes in winter and summer temperatures are common. This is in agreement with the study of McKee (2008) that states that in general, Ethiopian history is punctuated by drought and famine, which affected large parts of the country, covering hundreds of thousands of square kilometers and millions of households. According to a study by Ronneberg (2004) droughts have occurred in different parts of the country at different times since 1985. Also, a study by Rosenzweing *et al.* (2001) states that even though there is a long history of droughts in Ethiopia, studies show that the frequency of droughts has increased over the past few decades; and drought in Ethiopia can household production by up to 90% of a typical year output (Seo and Mendelsohn, 2007).

Moreover, the focus group discussions revealed that due to deforestation, if there had not been agroforestry systems and practices in general and multipurpose tree species planting practices in particular, it would not have been possible to continue agricultural production. This implies that it may be because of adaptation to weather and climate through agroforestry systems and practices that agricultural production and productivity has improved. This agrees with the argument that agroforestry systems, and practices can very likely contribute to escalating the resilience of tropical farming systems (Verchot *et al.,* 2005).

Improvement in productivity of the farming systems due to practices of agroforestry was confirmed by the focus groups and key informants. Tree planting practices generally contributed to the production and productivity of the farmers. Furthermore, environmental protection, soil fertility improvement and micro-climate amelioration are considerable. These are similar to the observation by Young (1997) that trees have a significant role in soil conservation and fertility management. This agrees with the findings obtained and summarized in (Tables 2, 3, 4 and 5), that identified agroforestry systems and agroforestry practices, multipurpose tree species planted and tree niche in the study location. These facts were also observed during the transect walk in the Hadiya zone.

It is evident from the facts discussed above that the climatic conditions are worsening in the Hadiya zone. Farmers are also conscious of the situation and are taking action as much as possible. Tree planting practices are becoming common among all farmers. They also easily compared the climatic conditions for the past six decades (Table 6). In an actual sense, the findings summarized in (Table 6) are similar to

Leakey (2012) that states that agroforestry has mutually environmental and economic importance to boost the productivity of land and sustainability of the environment in developing countries. In its recently released fourth evaluation report, the intergovernmental panel on climate change (IPCC), commenting on the role of human activity concluded there is more than 90 percent probability that human activities over the past 250 years have warmed our planet (IPCC, 2015).

The economic, service and social roles or benefits of agroforestry systems and practices have been recognized by farmers in the Hadiya zone which is similar to social acceptability is a much more meaningful measure of success for agroforestry technologies than for commercially-oriented, high-input agricultural and forestry technologies (Chaturvedi *et al.,* 2011); and also Chaturvedi *et al.* (2011) confirmed that the rural poor are commonly considered as the primary beneficiaries of agroforestry; consequently, agroforestry technologies are expected to be especially relevant and applicable to small-scale land users with low capital. These facts agree with the findings of quantitative data analysis results of this study. For example, data analysis results indicated that the livelihood assets are decisive in adaptation to climate changes. Comparison of past and present, risks and opportunities and good and bad years before 1991 and after 1991 by focus group discussions were analyzed, and results are summarized in (Table 6).

Generally, the comparison analysis indicated in (Table 6) is in agreement with findings that indicated that some confirmations of the fast climate changes are (i) unpredictable climate, (ii) reduced precipitation quantity, (iii) reduced rate of native plants and crops, (iv) decline in livestock production, (v) reduced river discharge amount, (vi) fall in the groundwater table, (vii) worldwide rise in hotness, and (viii) severe events (Huq *et al.,* 2004). The findings of this study are contrary to those of Huq *et al.* (2004). The findings are in harmony with the study results of Tschakert and Dietrich (2010) that states the background of high and chronic poverty coupled with a low awareness for complex drivers of change. These two challenges require particularly urgent attention and creative solutions. Also, adaptation is still developing as a science, the role of agroforestry systems and practices in reducing the susceptibility of farming systems (and the rural populations that rely on them for their living) to climate changes or climate variability should be highlighted more (Verchot *et al.,* 2005).

Agroforestry systems and practices are essential habitats that can provide farmers, communities and society at large with a broad array of forest-related goods and services and it can also be identified as a combination of land use that can directly improve plant variety and production while reducing habitat loss and disintegration (Leakey, 2012 and Ong *et al.,* 2015).

Conclusions

Environmental and economic benefits are quite remarkable and significant in agroforestry systems. The central elements of agroforestry systems that can play a significant role in the adaptation to climate change include changes in the microclimate, shield through the provision of everlasting cover, chances for diversification of the farming systems, improving efficiency in the use of soil, water and climatic capital. According to focus group discussions, the order of importance for all common agroforestry practices (CAP) existing in the Hadiya zone are similar. The most important of all agroforestry practices that are intensified, diversified, productive almost throughout the year, and more valuable is home-garden agroforestry practice.

However, in the Hadiya zone, the highest numbers of trees or shrub species were in designated niches. The results shown is that the sources of planting materials vary with the share of seedling or planting materials coming from different organizations. The knowledge of tree management practices found in the community was remarkable. Farmers have profound knowledge of which tree species are capable of coppicing and pruning and the timing of these activities.

Generally, the comparison analysis indicated some confirmation that the fast climate changes are leading to unpredictable climate, reduced precipitation quantity, reduced rate of native plants and crops, decline in livestock production, reduced river discharge amount; fall in the groundwater table, worldwide rise in temperatures and severe events.

Therefore, in the region, zone, woreda, development agents and farmers working in line with the focus on trees planting have to share their ideas and experience in developing agroforestry systems and practices (agro-biodiversity). Promoting women involvement equally with men or full participation as guarantors of rural livelihood is essential.

This is because the intensified, diversified, almost productive throughout the year and more valuable food and fodder and income-generating home-garden agroforestry practice (the most important of all agroforestry practices) are said to be "gowaro yeset sira" meaning home-garden agroforestry practice is the duty of women. Subsequently, rural women and men play a complementary role in adaptation to climate change. Stakeholders' active participation and cooperation (for extension and training) need to be ensured in the process of transferring trees planting, associated or companion crop and livestock-related technologies. This research could be regarded as an initial or entry point. However, further and detailed research on specific topics instead of general research in the Hadiya zone to demonstrate the fundamental role of independent agroforestry components to climate changes, are very much recommendable.

Data availability statement

The datasets presented in this article are not readily available because Ethical clearance given may not permit sharing of datasets with a third party. Requests to access the datasets may be directed to yohannesh2005@gmail.com or john@wcu.edu.et

Author contributions

Yohannes Horamo (YH) (Ph.D.) and Munyaradzi Chitakira (MC) (Professor): project conception. YH, MC and Kowiyou Yessoufou (KY) (Associate professor): draft and final manuscript. MC and KY: manuscript quality control and supervision. YH: data collection and analysis. All authors contributed to the article and approved the submitted version.

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Conflict of interest

We all authors assure that our research manuscript has not been submitted elsewhere for publication and it is our original work. So that, we all authors would like to confirm that no conflict of interest.

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