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Full-Length Research Article

Enhancing Environmental Sustainability and Income Diversification through Agroforestry Practices in the Dollo Watershed, Kamba Zuria District, Southern Ethiopia

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ABSTRACT

This study evaluated the contributions of agroforestry to community welfare and environmental health in targeted regions. Data were collected from 231 farm households across five villages using close-ended and open-ended questionnaires, complemented by focus group discussions with community leaders, male and female heads of households, and farmers with various experience levels. A relative scoring method was employed to rank preferred woody species, with results indicating that 90% of participating farmers integrated agroforestry with monocropping, while only 9% practiced non-agroforestry agricultural activities. Among the 32 most preferred tree species identified for agroforestry, 79% were native and 21% were exotic. The findings revealed that 91% of respondents viewed agroforestry as their primary source of income while the 9% relied on non-agroforestry agricultural activities. Furthermore, 51% of households believed that agroforestry enhances biodiversity compared to monoculture, and 66.67% recognized increased crop output as its main advantage. However, as data collection was confined to a specific timeframe, seasonal variations in agroforestry systems and income generation were not fully captured. This underscores the necessity for innovative extension services and proactive engagement from governmental and non-governmental organizations to enhance the role of agroforestry in improving rural livelihoods and the environment.

Keyword: Community; carbon sequestration; environmental sustainably; income; soil improvement

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1. INTRODUCTION

Agriculture is well-thought as backbone and the single largest sector of Ethiopian economy in terms of employment opportunities for 85% of the total population, accounts for about 90% of exports materials and supplies over 90% of the raw materials for the agro industries (Zenebe *et al*., 2011) and total 33.88% of its GDP (Plecher, 2020). However, ensuring food security for the Ethiopians is becoming a big challenge, as a result of the rapid population growth, rapid urbanization, negative consequences of climate change, increasing demand for agriculture and forest products and civil conflict (Yigezu, 2021). The Ethiopian population will be projected to be 171.8 million at 2050 by increasing at a rate of 2.5% annually (Bekele and Lakew, 2014). This will increase the demand for agricultural and livestock products (Hemathilake and Gunathilake, 2022). To mitigate these, adoption of the agroforestry practices is important. Agroforestry is a traditional land use system that may contribute to the solution of many present and future environmental problems (pantera *et al*., 2021). Agroforestry is a sustainable land management practice that includes the deliberate integration of a woody component with an agricultural production in the lower story (Damianidis *et al*., 2021).

In recent years, agroforestry has gained recognition as a crucial practice for promoting environmental sustainability and enhancing community livelihoods, particularly in regions such as Ethiopia. Empirical evidence confirms that agroforestry adoption supports to the farming income by generating an assured income for the local community (Rosati *et al*., 2020; Tesfay, 2024). Study carried out by Mulugeta and Mabrate (2017) Gedeo's indigenous agroforestry practices provided 40% of Ethiopia's premium grade coffee. Current studies of Bussa and Feleke, (2020) result revealed that increased income source and food security values of agroforestry practices for farmers had positive impression on their living standard.

The novelty of this special issue is the contribution for the understanding of how agroforestry practices will become a pathway for sustainable agricultural land management, environmental benefit, and as such help link science to practice. Agroforestry a solution to overcome the biodiversity challenges in the world, while fulfilling the European and Global Biodiversity Targets (Mosquera-Losada *et al*., 2020). The effort by Mantzanas *et al.* (2021) contributes to our knowledge on intercropping perennial trees with cereal crops species, is a very promising practice for Mediterranean areas with traditional olive agroforestry systems. Agroforestry could reverse the climate change impacts in many different ways and restore and promote soil health (Bateni *et al*., 2021). Healthy soil is arguably one of the most critical resources for the health of natural and agro ecosystems so that they can sustain food production as well as provision of ecosystem services.

Agroforestry provides numerous provisioning, regulating, cultural and supporting ecosystem services and environmental benefits while promoting eco-intensification based on a more efficient use of the land resources. Nevertheless, there is only little published recent information on the contribution of agroforestry to the environment in general and on climate change, carbon sequestration and forest fires in particular. In this special issue a number of articles are included that provide a multidimensional environmental benefits that agroforestry provides to the environment. The novelty of this special issue is the contribution for the understanding of how agroforestry practices will become a way for sustainable agricultural land management, and provide multidimensional benefits that agroforestry provides to the community and environment in the study area. While agroforestry is increasingly recognized for its potential benefits in various regions, there is a lack of comprehensive study focusing specifically on the Dollo Watershed and its unique environmental and socio-economic context.

2. MATERIALS AND METHODS

2.1. Study Site

The study was conducted in Dollo watershed in Kamba zuria district Southern Ethiopia. The study watershed lies within 39° 37" E and 9° 41 " N. Situated 607 km south west of the capital city, Addis Ababa. The watershed forms parts of Gamo highlands of Ethiopia which is the part of Omo basin. The watershed is characterized by diverse topographic and elevation ranges from 1647 to 2180m.a.s.l. The annual average temperature of the area is 19.7 °C; annual average rainfall is 1470 mm. The farming system is a rain fed system.

2.2 Sample size determination and sampling technique

A household sample size was determined based on Yamane developed method (Yemane, 1967).

$n = \frac{N}{1+N(e^2)}$ =547/6.47 =**231**

Where, N is total household, n is number of sample size and 'e' is precision level for this case 5 %. Systematic random sampling was used for selecting the participants from the total households as the total list of households was available.

2.3. Data Collections

Data were collected from January 2022 to April 2023. Primary data for the study were collected using close-ended and open-ended questionnaire. The watershed had a total population of 547 household farmers of which 231 were selected systematically from household. Household socio-economic characteristics, farmers' species preferences, and agroforestry contribution to income diversification and environmental benefit were collected through questionnaire, focus group discussion and key informant interviews.

2.3.1 Key informant interviews

The purpose of the key informant interviews was to collect their views on the role of agroforestry to household income diversification. The key informants include kebele administration leader, model farmers, elders and young farmers and agriculture development agents. From five villages 40 key informants were selected for interviews.

2.3.2 Focus group discussions

Two focus group discussions were conducted using randomly selected kebele administrations members. Separation of the gender groups provided equal opportunity for women and men to elicit and check perceptions and opinions on the role of agroforestry on household income diversification. All interviewees were informed about the purpose, subjects, and reasons of the research. Their participation was voluntary. The presence of kebele managers and local agricultural development agents facilitated the discussions and communication between researchers and respondents. Each focus group discussion lasted 1hours.

2.3.3 Questionnaire

The data were collected using a standard close-ended and open-ended questionnaire administered through face-to-face interviews. This questionnaire was filled for the same rural respondents who adopted agroforestry activities.

2.4. Data Analysis

The data collected from the survey were first checked for completeness. The quantitative data was analyzed through descriptive statistical analysis such as frequency, mean and percentage. The qualitative data were summarized by using narrative analyses. Simple majority/Relative score was used to calculate species preference in the study area.

3. RESULTS AND DISCUSSION

3.1 Socio-economic characteristics of the household

During household surveys, data on age, family size, land holding size, and educational status were collected. The mean age of the respondents was between 25 and 35 years. Most respondents were males (84.5%), and the majority of the respondents (77.38%) were married. Most of the respondents (62%) had undergone formal education, with the majority (23.81%) having completed primary education, few (21.43%) had attended secondary education. Majority of the respondents (66.67%) had land size between 0 and 0.5 hector (Table 1).

Table 1: Socio-demographic characteristics of the households

Households data	Variables	Frequency	Percentage
Sex	Male	195	84.5
	Female	36	15.5
Family size	4	44	19.04
	5	50	21.43
	6	41	17.85
	7	36	15.47
	8	22	9.52
	9	25	10.71

Households data	Variables	Frequency	Percentage
	10	14	5.95
Age	Below 25	52	22.62
	Between 25-35	83	35.73
	Between 35-45	55	23.80
	Above 45	41	17.85
Marital status	Single	25	11.92
	Married	179	77.38
	Divorce	11	4.76
	Widowed	17	7.14
Land holding size (hector)	Below 0.5	154	66.67
	Between 0.5-0.1	52	22.62
	Between 1-1.5	17	7.14
	Above 1.5	8	3.57
Educational status	Not read and write	88	38.09
	Read and write	39	16.67
	1-8th grade	55	23.81
	8-12th grade	50	21.43

3.2 Agroforestry practice

According to the survey on agroforestry practices, the majority (95.2%) of the population engaged in home gardens, , followed by parkland (64.3%), woodlots (60.7%), and grazing systems (36.9%), respectively (Figure 1).These findings are consistent with Berihanu et al. (2020), who found that in northern Ethiopia, parkland agroforestry (90%) was practiced alongside woodlots (7%), home gardens (3%), and other land uses. The majority of the crops integrated with multipurpose trees, included *Zea mays* (maize) and *Eragrostis teff* (teff). Key informants explained that home garden agroforestry practices are the most dominant in the study area since they are simple to manage. Similarly, key informants raised that parkland agroforestry is next highly adopted practice because of providing extra yield and services to human and animals.

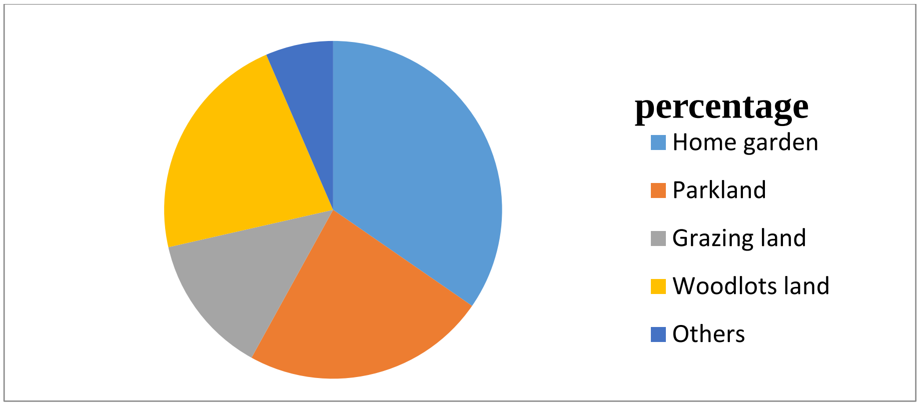

Figure 1 the dominant agroforestry practices in the study area

3.3 Species preference among farmers

A total of 32 different tree species were identified as suitable candidates for agroforestry, with 21% categorized as exotic species and 79% classified as native species. From highest to lowest, these were the top 10 that a significant percentage of farmers preferred: *Persea americana* (93%), *Coffee arabica* (87%), *Cordia africana* (83%), *Croton macrostachyus* (73%), *Combretum molle* (57%), *Casuarina equisetifolia* (45%), *Olea africana* (43%), *Terminalia brownii* (39%), *Eucalyptus globulus* (38%) and *Eucalyptus grandis* (38%) from highest to lowest (Figure 2). This study is consistent with studies of Alao and Shuaibu, (2013) and Adewusi, (2006), which showed that fruit trees both native and exotic are the most preferred. This suggests that food is considered the most important resource, and the fire wood species are also the second critical resources for human existence.

Furthermore, the study's findings are consistent with those of Nkurikiye *et al.* (2024), who found that farmers had a favorable preference for planting trees that boost maize yields through agroforestry. In addition to contributing to crop production, *Calliandra calothyrsus*, *Gliricidia sepium*, and *Senna spectabilis* are studied for their ability to conserve natural resources, safeguard the environment, and produce exceptional fuel wood (Kuyah *et al*., 2020). These results also coincided with those of Tazebew and Asfaw (2018), who found that the choice of farmers to cultivate native multipurpose trees on their properties is a factor in the ecological and financial utility of the species when it comes to agroforestry practices centered on coffee.

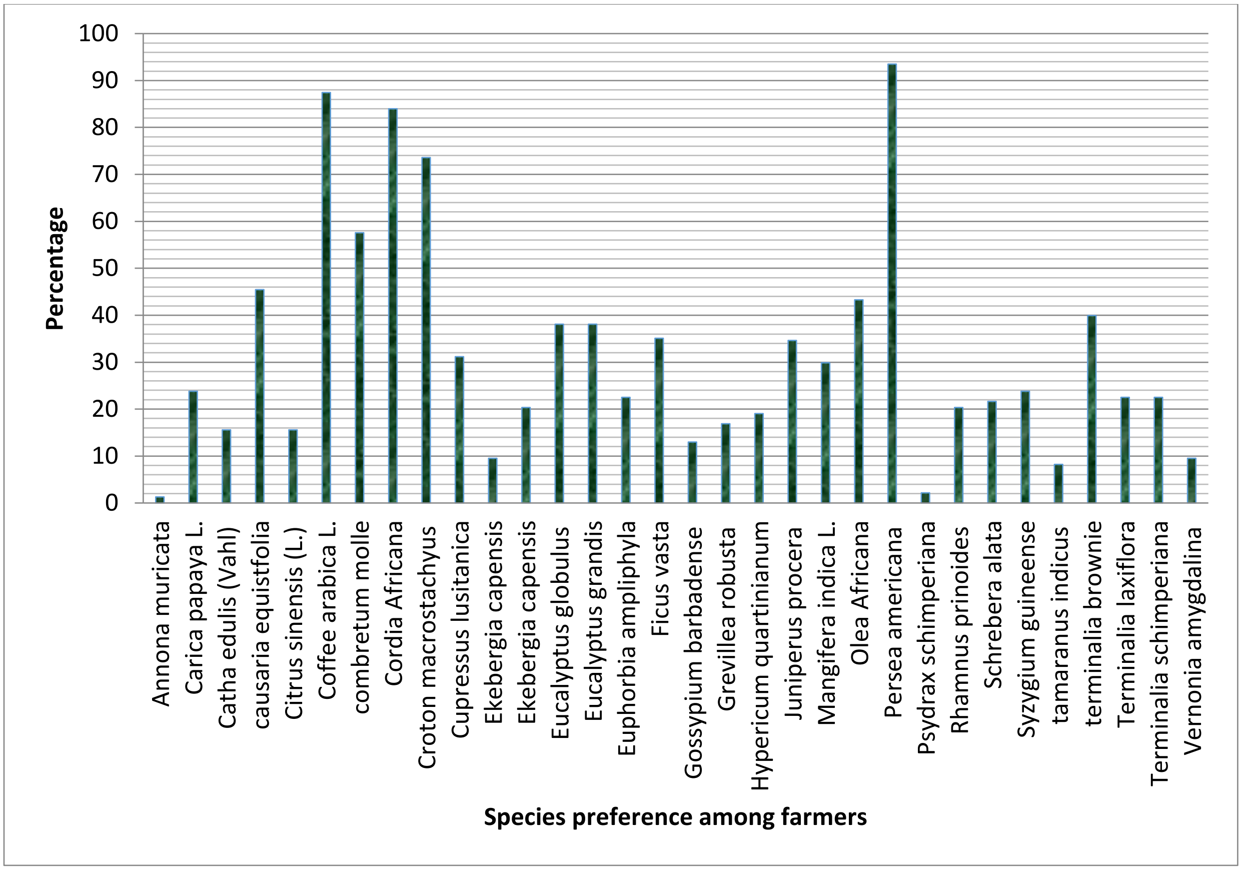

Figure 2 Species preference among farmers in the study area

The preference rating for woody species was calculated using a relative score. Respondents were asked to rank the top nine woody species from most prefered to list prefered among the species they plant and keep.., The following woody species were preferred in order of significance: *Persea americana* (93%), *Coffee arabica* (87%), *Cordia africana* (83%), *Croton macrostachyus* (73%), *Combretum molle* (57%). Their preference was were ordered based the species ability to serve multiple purposes, such as providing food, generating income, providing firewood, being used as building materials, serving to shed from sunlight, providing fodder, and enhancing soil fertility (Table 2). Woody plants, both native and alien, are valuable assets on farms because of their significance to farmers' daily life. In the study area, *Cordia africana* and *Terminalia brownii* were the first and second species to integrate with crops. For example, species of trees that benefit agricultural crops, such as *Cordia africana* and *Terminalia brownii*, are planted widely throughout agriculture fields, but species of trees that compete with crops are planted individually to lessen their impact. Farmers set a variety of requirements for integrating trees on farmlands, such as the trees' ability to decompose quickly, their compatibility with crops, their multipurpose use value, their ability to promote soil fertility, and their low branch volume. In the Lemo district of Southern Ethiopia, similar results were observed in crop livestock tree mixed systems (Kuria *et al*., 2014).

Table 2: Respondents' species preference ranking in the study area (n=231)

Species Scientific name	Respondents					Relative score					Total score	Rank	Reason of preference
	1st	2nd	3rd	4th	5th	1st	2nd	3rd	4th	5th			
Persea americana	143	55	30	25	-	88.5	13.1	3.9	2.7	-	108.2	1st	2, 1 and 5
Coffee arabica	55	55	25	74	14	13.1	13.1	2.7	23.7	0.85	53.65	2nd	2,5 and 7
Cordia fricana	-	83	22	14	-	-	29.8	2.1	0.85	-	32.75	3rd	2, 3 and 4
Croton macrostachyus	-	8	17	25	80	-	0.28	1.25	2.71	27.71	31.95	4th	2, 3, 4 and 7
Combretum molle	11	-	83	14	3	0.52	-	29.8	0.85	0.04	31.21	5th	2, 4, 5 and 7
Casuarina equisetifolia	-	8	28	22	28	-	0.28	3.39	2.09	3.39	9.15	6th	3, 4, 6 and 7
Olea africana	22	14	11	11	-	2.1	0.85	0.52	0.52	-	3.99	7th	7, 2 and 1
Terminalia brownii	-	-	-	22	3	-	-	-	2.09	0.04	2.13	8th	5 and 7
Eucalyptus globulus	-	-	6	8	-	-	-	0.16	0.28	-	0.44	9th	3 and 4
Total	231	223	222	215	128								

Footnote: relative score was calculated by multiplying the number of respondents in each ranks by its proportion (e.g. 143*143/231=88.52). Reason of preference, 1= food, 2=income generation, 3= fire wood, 4= construction materials, 5= shade benefit, 6= animal fodder 7= soil fertility improvement

3.4 Preferred tree species for agroforestry practices

According to key informants and household members, preference to tree species depended on the type of agroforestry and the function of trees. The best tree species for home gardens, based on household results, are multipurpose trees that provide cash crops, firewood, fodder, soil fertility, and a diversity of income streams. Common tree species in this study area include *Cordia africana, Persea americana, Citrus sinensis, Coffee arabica, Mangifera indica, Carica papaya, and Rhamnus prinoides*. In addition, Table 3 lists the tree species that are found in home gardens along with an order based on respondents' ratings. Key informants claim that plantation activities and the preservation of spontaneously regenerating native tree species are the sources of the tree species seen in their parkland. Their knowledge indicates that fuel wood, building materials, fruit, traditional medicine, farm implements, shade, beekeeping, soil fertility, and timber are only a few of the uses and services offered by agroforestry practices. *Persea americana*, *Mangifera indica*, *Croton macrostachyus*, *Cordia africana*, *Casuarina equisetifolia*, and *Terminalia* brownii are common tree species found in parkland agroforestry.

The tree species found on grazing forms of agroforestry are incredibly large and dispersed, according to information from key informants. Based on information from key informants, field observations, and household interviews, the common tree species found in grazing land are *Terminalia schimperiana*, *Cordia Africana*, *Terminalia brownii*, *Ficus vasta*, *Croton macrostachyus*, and *Terminalia laxiflora*. According to data acquired from interviews with households, the types of trees recognized in agroforestry woodlots are large and densely populated. According to field observation and home interviews, the common tree species in woodlot agroforestry types are *Cupressus lusitanica*, *Eucalyptus grandis*, *Eucalyptus globulus*, *Combretum molle*, *Terminalia brownii*, and *Croton macrostachyus*. Agroforestry tree species that are found in woodlots are also listed.

The results of FGD, key informant interviews, and household surveys indicate that farmers' choices for particular species rely on the significance of those species within each type of agroforestry practice and how those components interact with one another. This conclusion is consistent with that of López-Sampson and Andrade (2024), who found that farmers placed a high value on animal temperature regulation and that providing environmental services can make agroforestry species more appealing. Furthermore, the findings of Hailu *et al*. (2024) investigation showed that farmers' choices for woody species differed across the nation and that they planted various woody species according to their respective advantages.

Table 3: Preferred tree species for different types of agroforestry in the Dollo watershed

Species scientific name	Home garden	Parkland	Grazing land	Woodlots	Percentage
Annona muricata	2	-	-	-	0.21645
Carica papaya	70	-	-	-	30.303
Catha edulis	12	-	-	-	5.19481
Casuarina equisetifolia	-	50	-	-	21.645
Citrus sinensis	13	-	-	-	5.62771
Coffee arabica	110	-	-	-	47.619
Combretum molle	-	-	11	21	6.92641
Cordia africana	0	0	36	23	6.38528
Croton macrostachyus	20	41	43	46	16.2338
Cupressus lusitanica	-	-	-	16	6.92641
Ekebergia capensis	-	12	-	-	5.19481
Eucalyptus globulus	-	-	-	34	14.7186
Eucalyptus grandis	-	-	-	31	13.4199
Euphorbia ampliphyla	-	-	-	19	8.22511
Ficus vasta	-	-	70	-	30.303
Gossypium barbadense	8	-	-	-	3.4632
Grevillea robusta	30	-	-	-	12.987
Hypericum quartinianum	-	-	-	14	6.06061
Juniperus procera	20	-	-	13	7.14286
Mangifera indica	60	23	-	-	17.9654
Olea africana	-	32	7	-	8.44156
Persea americana	120	98	-	-	47.1861
Psydrax schimperiana	-	-	-	18	7.79221
Rhamnus prinoides	60	-	-	-	25.974
Schrebera alata	-	-	9	-	3.8961
Syzygium guineense	-	-	-	19	8.22511
Tamaranus indicus	-	8	-	-	3.4632
Terminalia brownie	10	102	30	43	20.0216
Terminalia laxiflora	-	-	17	-	7.35931
Terminalia schimperiana	-	-	12	-	5.19481
Vernonia amygdalina	-	9	-	15	5.19481

3.5 Role of agroforestry to livelihoods diversification

The farmers in the study area generate household income from both agroforestry and monoculture farms. Out of the farmers surveyed, 90% practice both agroforestry and monocropping.

Meanwhile, 9% of the farmers engage in non-agroforestry farming activities, and the remaining 1% is involved in non-agricultural pursuits. Additionally, 91% of households reported that their primary source of income comes from agroforestry operations, while 9% indicated that their main source of income stems from non-agroforestry farming activities. These indicate that the agroforestry significantly increases farm income compared to non-agroforestry farm activities.

Agroforestry can diversify Farmers' income in a number of ways. These include fruits, coffee, fodder crops, fire wood and dairy products. More than 93% of respondents use fruits from home garden agroforestry, such as banana, *Carica papaya, Persea americana,* and *Mangifera indica; 90% use crops from parkland, such as Zea mays (Maize), Eragrostis teff (teff), haricot bean*, and groundnuts; and 88% use woodlots, parkland, and home garden agroforestry for fuel and other wood products for construction. 83 % of the respondents declared that their primary source of income comes from coffee plantations, which are a significant cash crop in the region. 67% of all respodents employed home gardens, parklands, and agroforestry to produce fodder for animals (Figure 3). Fruit was the most popular product harvested from agroforestry trees, demonstrating how dependent farmers were on these items for their primary source of revenue. This outcome was consistent with findings from related studies which looked into the roles of agroforestry in increasing farmers' income (Mabel *et al.*, 2017; Tharlakson, 2012; Quinon *et al.*, 2010). This outcome was consistent with reports from other academics (Kalaba, 2010; Maroyi, 2009) that said that agroforestry's various productions have enabled people to build sustainable lives.

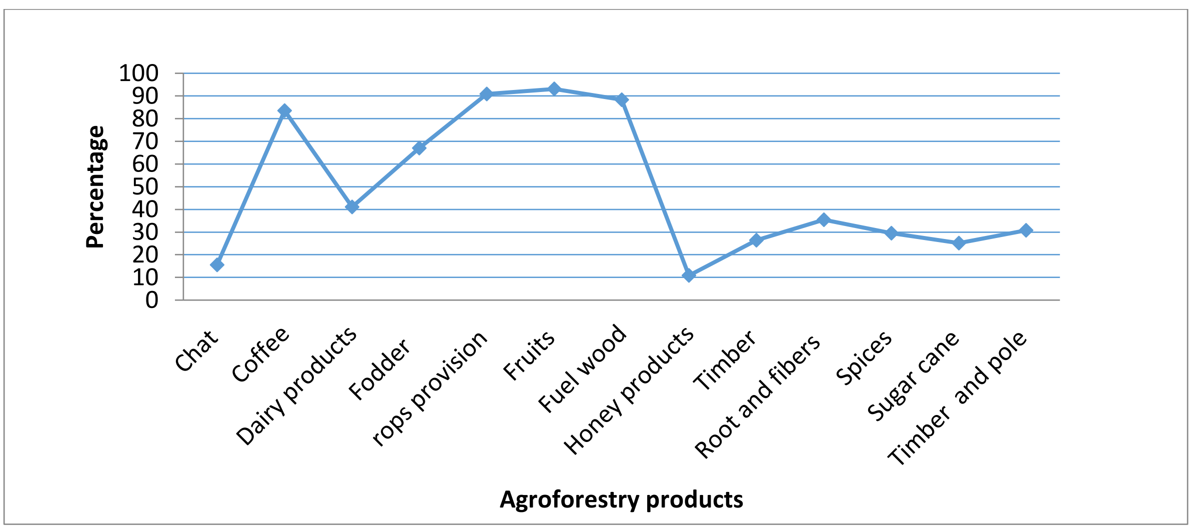

Figure 3 List of products to livelihoods diversification from agroforestry practices

3.6 Role of agroforestry to Environmental Sustainability

Based on the results of the poll, farmers concur that agroforestry contributes to environmental sustainability by making more nutrients available to the soil, which helps to preserve and restore soil fertility. Out of all the households surveyed, 51% thought that agroforestry offered superior woody biodiversity than mono cropping farming, while 66.67% thought that the main advantage of agroforestry techniques was an increase in crop yield. Out of all the respondents, 46% claimed that agroforestry could improve soil nutrient availability and decrease soil erosion, while 36% claimed that it could provide shade for cattle and control the microclimate (Figure 4). Additionally, by increasing soil organic matter through leaf litter, agroforestry practices improve soil fertility. Traditional land use practices like agroforestry could help find a solution of environmental problems in agriculture (Pantera *et al*., 2021).

One acknowledged effect of agroforestry practices was increased crop yield. This results from enhanced soil characteristics, microclimate, and nutrient levels (Fahad et al., 2022). The current findings in lined with (Akinnifesi *et al*., 2006; Castle, 2021), who found that agroforestry techniques can raise crop yields in many regions of the world. Agroforestry in the Umbria area of Italy improved soil health and counteracted the negative impacts of soil erosion in a variety of ways (Bateni *et al*., 2021; Pantera *et al*., 2021). This result is consistent with that of Ndalama *et al*. (2015), who found that the primary ecosystem services received from agroforestry were soil improvement, water and nutrient retention and conservation, and biodiversity conservation. Increased agroforestry adoption, according to Khanal (2011), lessens the strain on forests and protected conservation areas. Furthermore, the present findings are consistent with the reviews conducted by Rolo *et al.* (2021) and Rosati *et al.* (2021), which suggested that implementing agroforestry techniques might enhance the sustainability of organic farming and augment soil fertility. Additionally, Tsegaye's (2023) study result shows that agroforestry practices provide protective services such soil improvement, climate regulation, biological conservation, and recreational value in addition to their productive role.

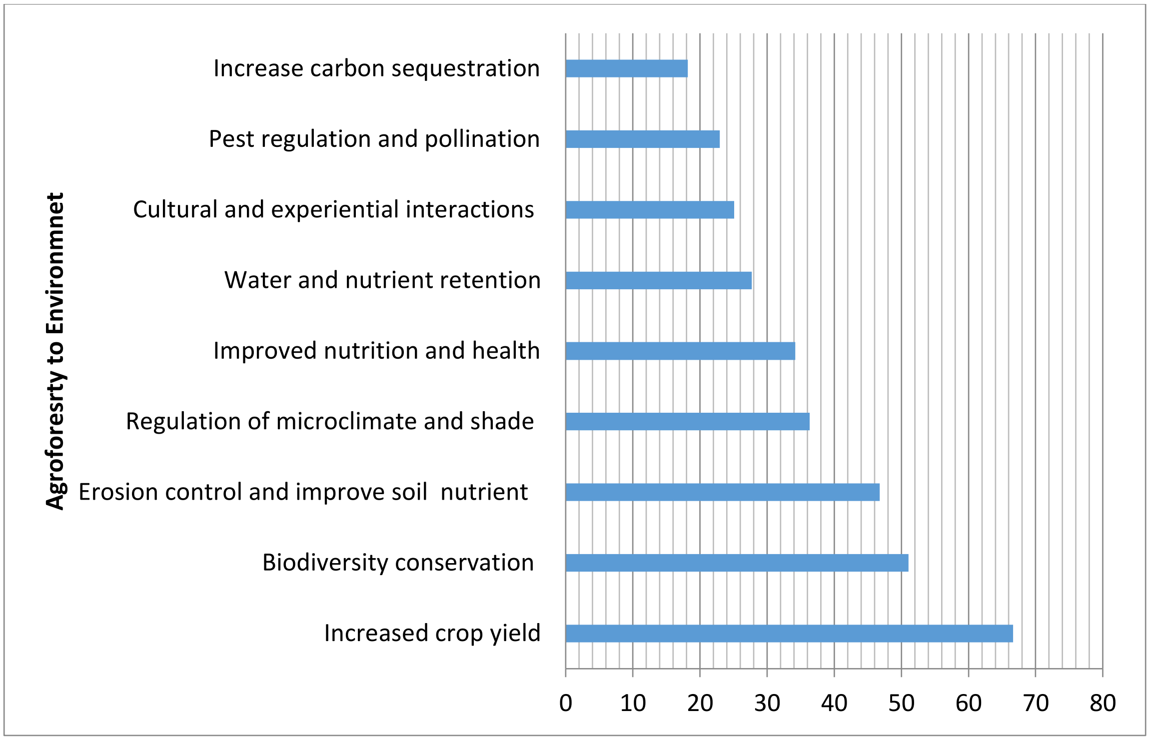

Figure 4 Contribution of agroforestry practices to environmental sustainability

4. CONCLUSIONS

The study demonstrates that agroforestry significantly enhances the livelihoods and environmental sustainability of farmers. Practices such as home gardens, parklands, woodlots, and grazing systems are common, with a preference for multipurpose tree species like *Persea americana*, *Coffee arabica*, and *Cordia africana*. Agroforestry contributes to household income through products like fruits, coffee, and firewood, and improves soil quality, crop yields, and reduces soil erosion, aligning with previous research on its benefits for economic stability, biodiversity, and environmental resilience.

To maximize agroforestry benefits, further research on species selection, management practices, and innovations is encouraged. Knowledge sharing platforms should be established to disseminate best practices. Integrating agroforestry into national and local agricultural policies can promote food security and income generation, especially in rural areas, through technical support, subsidies, and incentives.

Agroforestry is vital for sustainable land management, enhancing soil fertility, and reducing soil erosion. It supports biodiversity conservation by promoting native, multipurpose species, contributing to ecosystem resilience. By providing diverse income sources, agroforestry reduces dependency on single crops and enhances resilience to market fluctuations and climate change, mitigating its impacts through improved soil health and carbon sequestration. Policymakers should consider agroforestry in climate adaptation and mitigation strategies, particularly in vulnerable regions.

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Conflict of Interest

The authors declare no conflict of interest

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