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Homegarden improved avocado cultivation, income diversification, and food security for rural households in Central Ethiopia

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ABSTRACT

Homegarden avocado cultivation offers a viable option for smallholder farmers to diversify their sources of income and food. This study examined the contribution of avocado cultivars to household income diversification and food security in the Jewe and Upper Gana kebeles of Central Ethiopia. Data were collected from 164 households using a semi-structured questionnaire and supplemented with focus group discussions. The results of this study indicated that Nabal, Hass, and Ettinger were the most commonly cultivated avocado cultivars. On average, the households owned four improved avocado trees. This study revealed that households had highly diversified income sources, with an average SID value of 0.63. The average fruit yields for the Nabal, Hass, and Ettinger cultivars ranged from 45 to 60 kg per household. These cultivars contributed approximately 14% and 10% of the household income sources and food consumption scores, respectively. This study found that, on average, households consumed 40 kg of Hass and 25 kg of Ettinger fruits, and sold 55 kg of Nabal and 25 kg of Ettinger fruits per harvest season. Improved avocado cultivation was positively associated with household income and food consumption. Local governments should encourage cultivation of these cultivars to enhance income and food security for farmers.

IMPACT STATEMENT

The cultivation of improved avocado cultivars has sparked significant interest among Ethiopian smallholder farmers owing to the potential benefits offered by the different cultivars. This study examines how avocado cultivars contribute to household income diversification and food consumption among smallholder farmers in Central Ethiopia. The findings indicated that Nabal, Hass, and Ettinger were the most commonly grown avocado cultivars, which significantly contributed to household income sources and food consumption. Furthermore, 64% of the total avocado harvest was used to generate household income, while 36% was used for food consumption. Expanding these three avocado cultivars has the potential to maximise economic profits, enhance food and nutrition security, and support demand-driven avocado farming practices, both within the country and beyond. Consequently, these findings provide valuable information to local government agricultural extension experts, fruit tree development partners, avocado seedling production enterprises, and smallholder avocado farmers. The results can also guide policymakers in developing local-specific enabling policy frameworks that encourage the cultivation of these avocado cultivars on a wider scale, thereby enhancing food security and household income generation.

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1. Introduction

Homegarden agroforestry on smallholder farms encompasses a variety of woody plants and herbaceous species that support sustainable agricultural practices and improve living standards (Nair et al., 2021). It is a mixed cropping system that offers additional food and income sources at the household level (Galhena et al., 2013). Homegarden is an important strategy for achieving the Sustainable Development Goal of zero hunger (Sharma et al., 2022). Crop and income diversification strategies employed by smallholder farmers substantially improved the livelihoods of poor rural communities in Malawi, Zambia, and Niger (Asfaw et al., 2019). Homegarden agroforestry in Ethiopia integrates multiple types of fruit and cash crops including mango (*Mangifera indica*), avocado (*Persia americana*), papaya (*Carica papaya*), banana (*Musa paradisiaca*), enset (*Ensetee ventricosum),* coffee (*Coffee arabica*), gesho (*Rhamnus prinoides*), khat (*Catha edulis),* vegetables, and spices (Admasu et al., 2022). The improved avocado cultivars are commonly integrated with coffee, spices, vegetables, and cereals in homegarden (Biazin et al., 2018).

Homegarden fruit tree cultivation contributes significantly to the food and nutrition security and dietary diversity of rural households and communities (Jemal and Callo-Concha, 2017; Romeo et al., 2016). Homegarden provides 25–85% of the food needs for rural households in South Ethiopia (Wolka et al., 2021). Fruit trees grown in homegardens have significant potential to enhance food security for rural communities, particularly during times of crisis (Rahaman et al., 2015). Diversifying crop production and income can enhance household food security by increasing food spending among wealthier households relative to poorer ones (Matsuura-Kannari et al., 2023). Farmers who engaged in homegarden cultivation exhibited significant and positive improvements in food security, with a 4.6% increase in the food consumption score of their households compared to non-participating farmers (Issahaku et al., 2023). Smallholder farmers who cultivate macadamia nuts and avocados, alongside staple crops exhibit an enhanced capacity to maintain a steady income and consistent access to food throughout the year, in contrast to those who focus solely on annual crop production (Ngcaba & Maroyi, 2021; Modika & Oluwatayo, 2022). This is due to the distinct fruiting and maturation patterns of fruit trees and annual crops, which complement the household's food and nutrition security at different times of the year. Improved avocado cultivation can reduce reliance on cereal crops and can be used for home consumption during the dry and lean seasons, which can enhance household food security (Mokria et al., 2022; Gebru et al., 2022). For instance, according to Sora (2023), Ettinger (29 ton/ha), Hass (23 ton/ha), and Fuerte (22 ton/ha) are known for their high fruit yields, demonstrating their potential to increase household income and food security in Southwest Ethiopia.

Homegarden fruit and vegetable cultivation also provides an important contribution to household total income generation (Mathewos et al., 2018). It significantly enhances the financial well-being of households by providing a source of income through the sale of fruits, vegetables, and other tree products harvested from the homegarden (Amenu, 2017). Fruit trees can thus significantly contribute to socioeconomic stability, employment opportunities, and income generation (Tola, 2023). The cultivation of improved avocado cultivars can enable farmers to increase their income (Hakizimana & May, 2018), diversification, and resilience to economic disruption (Alobo Loison, 2015). In addition, smallholder farmers who participated in avocado export markets generated more income for their households (Amare et al., 2019).

The cultivation of improved avocado cultivars has gained considerable interest among farmers motivated because of the potential benefits offered by the different cultivars (Desta & Lemage, 2019; Mokria et al., 2022). These benefits include increased yield, superior fruit quality, and shorter maturation periods, enabling farmers to sell their produce sooner and earn greater profits (Ramírez-Gil et al., 2019). The extended fruit-setting seasons of certain avocado cultivars, such as Fuerte and Shepard, provide a consistent supply of avocado fruits to consumers, thereby sustaining farmers' profits over a longer period (Ferreyra et al., 2016).

Despite the potential for fruit tree cultivation, approximately 50% of Ethiopia's population lives below the poverty line and more than 11% of the people in rural areas are food insecure and unable to meet their basic needs even after a year of normal rainfall (FAO, 2020). Based on the Central Statistics Agency, fruit crop production in Ethiopia comprises an estimated 150,900 ha of cropland. Among these, 27,400 ha has been allocated to the cultivation of avocados. The country produced a total of 1780

million kilograms of fruit in smallholder farmer homegarden agroforestry farms in 2022, of which avocados accounted for approximately 190 million kilograms (CSA, 2022), representing 10% of the total fruit production. According to Sina et al. (2023), Ethiopia's agroecological conditions are conducive to smallholder avocado cultivation. However, the current avocado cultivation in smallholder farms does not fully utilize the countrýs potential (Abdela & Brahmbhatt, 2023). This is because smallholder avocado growers have faced various implementation challenges, including limited access to high-quality avocado seedlings, insufficient supplementary irrigation, issues with fruit degeneration, disease concerns, and inadequate technical skills in the propagation of grafted seedlings and tree management practices (Garedew & Tsegaye, 2011; Faris, 2016; Seid et al., 2024). Additionally, there is a shortage of high-quality scion material for avocado propagation (Banjaw et al., 2023), and there are practical difficulties in obtaining access to superior avocado cultivar mother trees as sources of this scion material. Furthermore, the limited cultivation efficiency of these avocado cultivars has resulted in a yield gap compared to the global average avocado fruit yield (Jalata, 2021).

In the study area, a few previous studies have assessed the growth, fruit production potential, and market value chain of improved avocado cultivars (Mokria et al., 2022; Gebru et al., 2022; Eyuel, 2020). However, these studies did not examine the impact of improved avocado cultivars on the diversification of household income and food security. Furthermore, there may be differences in the level of food consumption, income generation, and benefits obtained from planting avocado trees in rural communities for each production year. Therefore, this study aimed to explore the contribution of avocado cultivation to household income diversification and food consumption in Central Ethiopia. This study provides a comprehensive analysis of the income and home consumption contributions of three avocado cultivars in the study area, which enables stakeholders to expand their farm products based on consumer demand, maximize economic profits, promote the nutritional value of these avocado cultivars, and support sustainable avocado farming practices in smallholder avocado producers.

2. Materials and methods

2.1. Description of the study area

The study site was located in Lemo District in the central regional state of Ethiopia. The area is situated between the coordinates 7°22′00″–7°39′59 North and 37°40′00″–38°00′00″ East. It experiences an annual rainfall of 900–1400 mm. The minimum and maximum temperatures in the area are 12 °C and 26 °C, respectively, and the altitude ranges from 1990 to 2720 m above sea level (Degefa, 2019). The study area falls within the midland agroecological zone, which is favorable for fruit and vegetable crop production. Most households derive earnings for subsistence and commercial purposes from cultivated cereals, fruits, and vegetable crops (CSA, 2022).

In the study area, both seeded and grafted avocado trees were grown as key components of homegarden agroforestry. In 2014, the Africa RISING (Africa Research In Sustainable Intensification for the Next Generation) project introduced five improved avocado cultivars (Hass, Ettinger, Fuerte Nabal, and Reed) at the study site. The main distinction between the local and improved types of avocado trees is that local (seeded) avocado trees take between seven and nine years to bear fruit, with small fruit size but large tree size. In contrast, the improved (grafted) avocado trees mature early and can produce fruit within two to three years of establishment, with larger and sweeter fruits, and dwarf tree height, making them easier to harvest than seeded avocado trees.

2.2. Data sources and method of data collection

2.2.1. Research design

This study used a mixed research design method that incorporated both quantitative and qualitative data collection approaches. Primary data were gathered through a household survey and supplemented with focus group discussions to gain more detailed and in-depth qualitative insights from the participants.

2.2.2. Sampling procedure and data collection

The household survey was conducted in Upper Gana and Jewe Kebeles. This study was a complementary study to the previous Africa RISING Project research intervention. A total of 164 households engaged in improved avocado cultivation on their farms at both sites were purposively selected and interviewed. These included all farm households that planted avocado cultivars introduced by the Africa RISING project in 2014 and that still lived at the study site. This enabled the investigation of improved avocado trees with comparable age, cultivar type, and management practices. A semi-structured questionnaire was used to collect data. Household income diversification was determined using the Simpson Index of Diversity (SID), as described in Equation 1 (Agyeman et al., 2014). This index was chosen because it presents a range of values between 0 and 1 and also considers the number and distribution of income sources evenly (Alemu, 2023). A value near to 0 indicates a high level of specialization in a single income source, whereas a value close to 1 indicates highly diversified income sources. Household income diversification was classified as low (0–0.30), moderate (0.31–0.60), or high (0.61–1), as described by Dev et al. (2016).

$$SID = 1 - \sum_{i=1}^{n} P^2 \tag{1}$$

Where SID is the Simpson index of diversity, n is the number of active income sources, and P is the proportion of income from the sources.

SID in this study was denoted as:

$$\mathrm{SID} = 1 - \sum((\mathrm{CI}/\mathrm{THI})^2 + (\mathrm{VI}/\mathrm{THI})^2 + (\mathrm{LI}/\mathrm{THI})^2 + (\mathrm{IAI}/\mathrm{THI})^2 + (\mathrm{MTI}/\mathrm{THI})^2 + (\mathrm{REI}/\mathrm{THI})^2 + (\mathrm{OFI}/\mathrm{THI})^{2)}.$$

CI: Cereal crop production income (wheat, maize, teff, faba bean, peas, lentils); VI: Vegetable crop income (local cabbage, chilly, potato & carrot); LI: Livestock income (sheep, ox, caw, by-product such as chees); IAI: Improved avocado tree income (Hass, Ettinger, Nabal); MTI: Multipurpose & cash tree income (lumber, fuelwood, khat);REI: Remittance income (migrant family members cash support); OFI: Off-farm income (income from security guard, farm work, carpentry); THI: Total income.

The harvested avocado fruits per tree were recorded as the number of filled sacks per tree, which was then converted into kilograms using a conversion factor derived from weighing a sack of Ettinger, Hass, and Nabal fruit (Juma et al., 2019). Then the total avocado fruit yield per household per year was subsequently calculated as a sum of the fruit harvest weights of the three cultivars collected per household in the production years of 2022 and 2023.

The avocado contribution to household income was calculated based on the gross income generated from the avocado cultivars. The gross income was determined by multiplying the total avocado fruit harvest per household by the local market price per kilogram per production year (Teshome et al., 2015).

The food consumption score (FCS) calculation involved determining the food items consumed and the frequency of food item consumption in the studied households, multiplied by their corresponding weight factors. The sum of the weighted scores for each food item provides the food consumption score.

The household food consumption score was categorized as follows: 0–21: Poor; 21–35: Borderline; >35, acceptable, Equation 2, as outlined by the World Food Program (WFP, 2008)

$$\mathrm{FCSi} = \sum(\mathrm{wXj})(f\mathrm{Xji}) \ldots\ldots\ldots \tag{2}$$

Where FCSi = Food consumption score for household i, wXj denotes the weight of food item j consumed by individual i (value of j: main staple food =2; pulses = 3; vegetables = 1; fruit = 1; meat, egg, fish = 4; milk = 4; sugar =0.5; oil = 0.5). fxji refers to the frequency of consumption of food item j by individual i, ranging from one day to seven days.

Food items (j) included: the main staples (enset (kocho), teff (injera), wheat/maize (bread), and tubers/potato); main pulses (faba beans, peas, lentils); meat, fish, eggs, milk, oil, vegetables, and main fruits (avocado, banana).

Two focus group discussions were conducted (one with each kebele). Each focus group consisted of male, female, youth, and elder members of the community, with a total membership of 10–12 participants, aiming to promote active and equitable engagement and foster meaningful discussions.

2.2.3. Statistical analysis

Data collected from the household survey were analyzed using IBM SPSS version 23. Descriptive statistics such as means, frequency, and percentages, were used to identify the variability and pattern of trends in fruit yield, household income diversity, and food contribution across different avocado cultivars. One-way analysis of variance (ANOVA) was conducted to test the statistical significance differences in fruit yield and income contribution among avocado cultivars. The Games-Howell post-hoc test was used to identify significant differences between the means ($p < 0.05$). A multiple regression analysis was employed to examine the relationship between avocado production, income generation, household income diversity, and food consumption contribution. This analysis determined the most important contribution aspect of avocado cultivars to rural household subsistence improvement. The independent variables included revenue from the sale of avocado fruit, household source of income, and food consumption group (main staples, pulses, meat, fish, eggs, milk, oil, vegetables, and fruits). The avocado fruit yield per household was considered as a dependent variable, hereafter referred to as avocado cultivation. The model fit was evaluated using Beta Coefficients and *p*-values. The data gathered from the focus group discussions were statistically analyzed using frequency and mean, then summarized qualitatively through text narratives and tabular presentations using Excel.

3. Results

3.1. Demographic characteristics of respondents

The study findings revealed that the participating households were predominantly male-headed (86%), with low female participants in improved avocado cultivation across the study sites (Table 1). The majority of the participants had attained basic education up to secondary school, while 11% and 18% were identified as illiterate in Jewe and Upper Gana, respectively. In terms of age distribution, the majority of participants were between the ages of 30 and 60, and most of them were married (Table 1). Furthermore, the respondents had medium-sized families comprising six to ten family members. The majority of the respondents operated on land holdings of less than one hectare at both study sites, implying that avocado farming practices are predominantly under small-scale farming.

3.2. Avocado cultivar types and distribution

The survey results indicated that Ettinger, Hass, Nabal, Reed, and Fuerte were avocado cultivars grown by farmers, with Nabal, Hass, and Ettinger being the most frequent while Fuerte the least common (Figure 1a). On average, farmers owned three cultivars and four trees per household. However, some

Table 1. Demographic characteristics of respondents.

Description		Jewe Kebele (%)	Upper Gana Kebele (%)	Total ($n = 164$) (%)
Sex	Female	15	13	14
	Male	85	87	86
Marital status	Married	94	91	93
	Unmarried	6	9	7
Education	Illiterate	11	18	15
	Literate	89	82	85
Age (years)	< 30	6	11	9
	31–60	89	78	84
	>60	5	11	8
Family size (No)	1–5	19	28	24
	6–10	71	68	70
	10– - 15	10	4	7
Land holding (ha)	0–1	26	34	30
	1.1–2	60	50	55
	>2	14	16	15

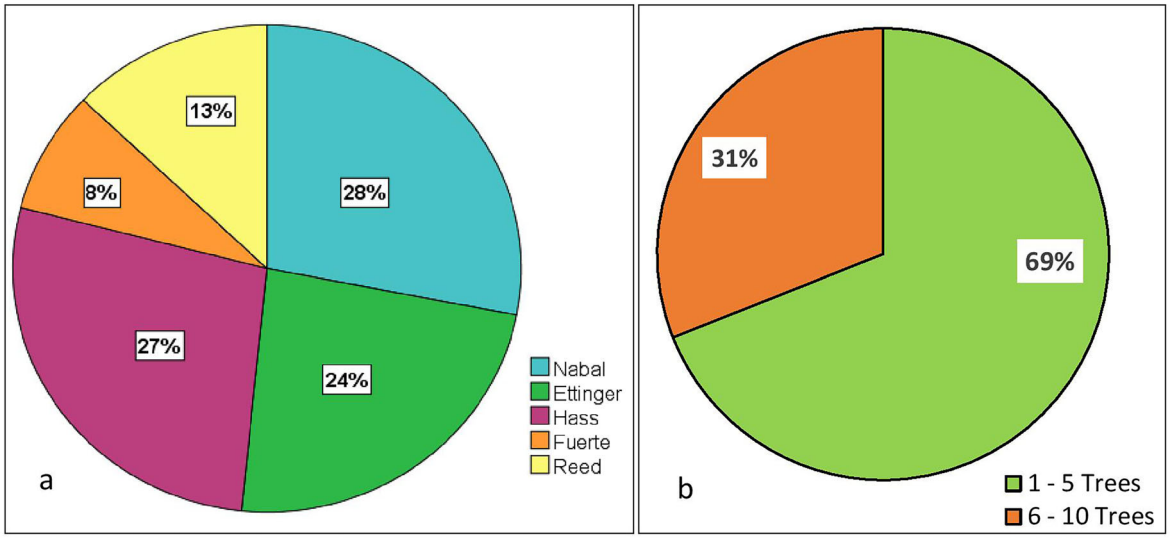

Figure 1. Distribution of avocado cultivars (a); No. of avocado trees at household level (b).

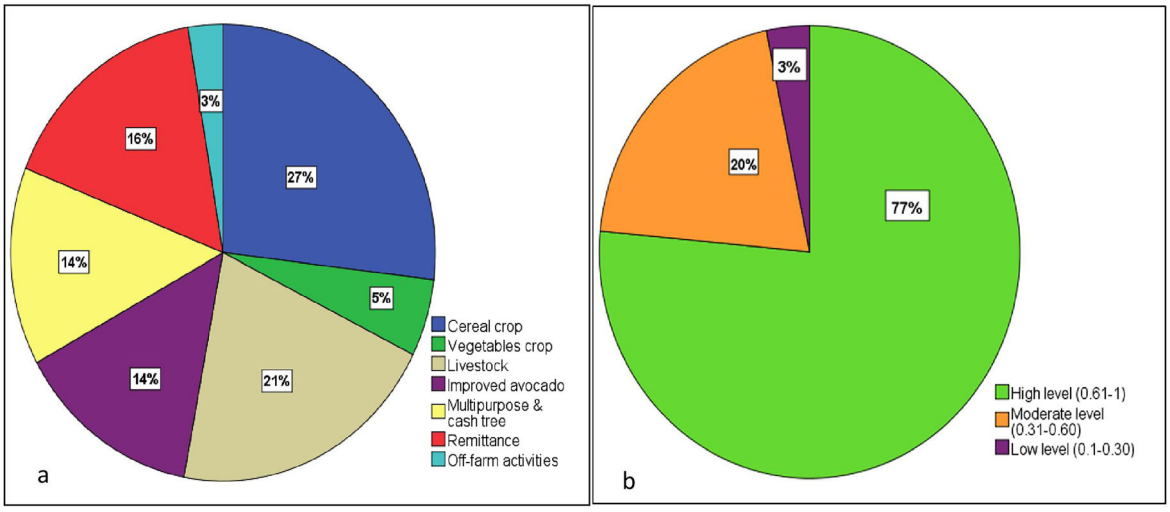

Figure 2. Percentage of income sources (a) and income diversification levels (b).

Table 2. Main staple crop and fruit tree harvest calendar in the study site for 2023.

	Months											
Crop & fruit tree type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wheat												
Barley												
Maize												
Teff												
Enset												
Hass												
Ettinger												
Nabal												
Local avocado												
Banana												
Note						Planting						
						Mid-season (Flowering)						
						Harvesting						

farmers grew up to ten trees per household (Figure 1b). In light of their uneven distribution, this study concentrated on the three most widely cultivated avocado cultivars, Hass, Ettinger, and Nabal, and assessed their contributions to household income diversification and food consumption.

Table 3. Avocado yield and its contribution to household income and consumption.

	In year 2022				In year 2023			
Cultivar	Total yield (kg/tree) Contribution (%)	Consumed (kg/tree) Contribution (%)	Sold (kg/tree) Contribution (%)	Total income (ETB/tree) Contribution (%)	Total yield (kg/tree) Contribution (%)	Consumed (kg/tree) Contribution (%)	Sold (kg/tree) Contribution (%)	Total income (ETB/tree) Contribution (%)
Ettinger	39 (31)	26 (38)	17 (22)	509 (22)	57 (30)	25 (32)	33 (31)	1665 (31)
Hass	38 (30)	36 (53)	2 (4)	93 (4)	56 (30)	50 (64)	5 (5)	244 (5)
Nabal	49 (39)	6 (9)	43 (74)	1729 (74)	72 (39)	3 (4)	69 (64)	3434 (64)
Total	126 (100)	68 (100)	57 (100)	2331 (100)	185(100)	78 (100)	107 (100)	5343 (100)
N	492	492	492	492	492	492	492	492

Note: The value outside the parenthesis is the mean value and value inside the parenthesis is its contribution percentage score per household.

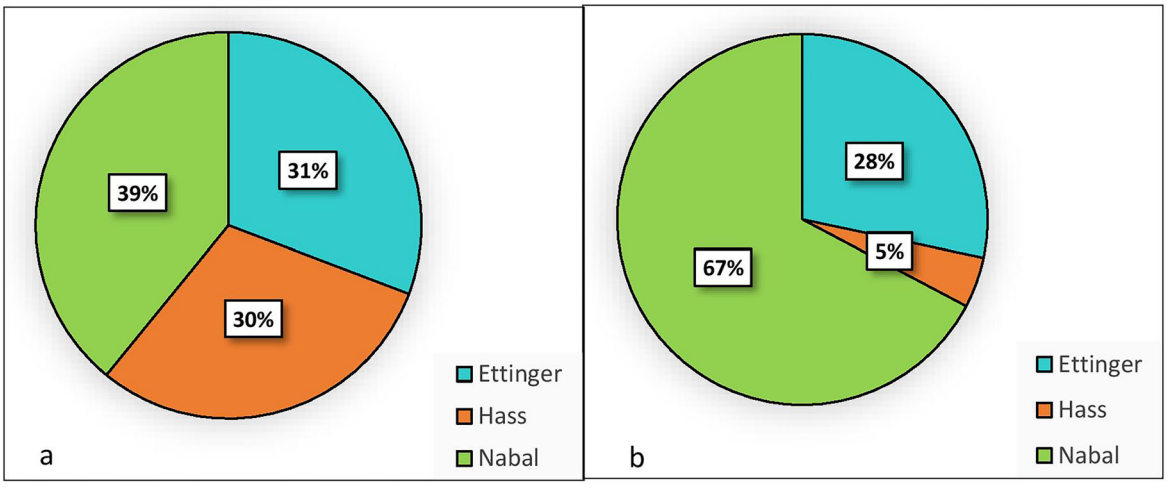

Figure 3. Average fruit yield contribution percentage of each avocado cultivar per household per both years (a) and average income contribution of each avocado cultivar per household per both years (b).

3.3. Households' income diversification

The respondents mentioned that their primary sources of revenue were crop production (27%), livestock production (21%), and remittances (16%) (Figure 2a). The findings revealed that improved avocado and multipurpose or cash tree products were ranked as the fourth household income source among the seven sources (Figure 2a).

The crop and tree harvest calendar indicated that the income generated from the improved avocado was a single harvest in one production season, whereas the income derived from the crop harvest was the lump sum received from various types of grains. The avocado fruit and cereal crops are harvested at different periods of the year, resulting in variations in income generation time (Table 2). Moreover, the Simpson index of diversity (SID) indicated that the majority of respondents had well-diversified income sources, with an average SID value of 0.63 (Figure 2b). Only 3% of households fell under a low-income source, with SID values less than 0.30.

3.4. Avocado fruit yield and contribution to household income

The overall average fruit yield across avocado cultivars demonstrated a statistically significant variation in fruit production (supplementary table ST 1). The average fruit yields were 125 kilograms and 180 kilograms per household in 2022 and 2023, respectively (Table 3). The highest and lowest mean total fruit yields were recorded for the Nabal and Hass cultivars, respectively (Figure 3a). Of the total avocado fruit production, approximately 112 kilograms of Nabal fruit per household was sold for revenue generation in both years (Table 3).

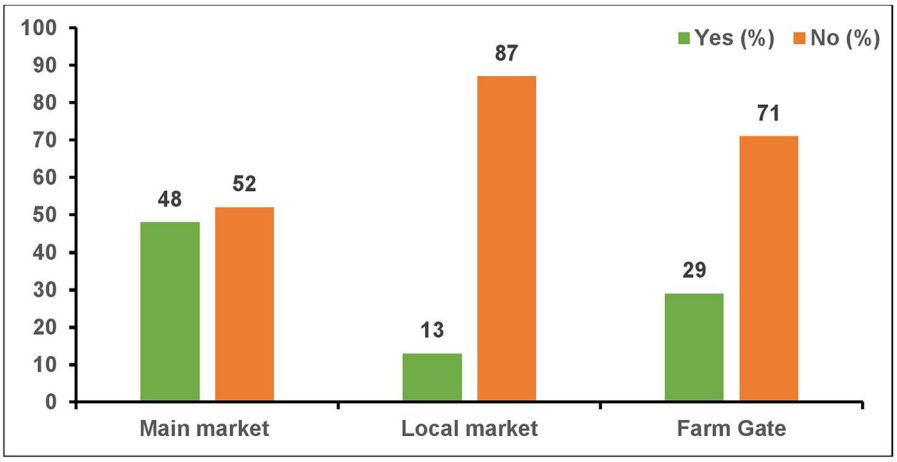

Figure 4. Market options for selling avocado fruit in the study area.

Table 4. Mean value of food consumption categories per household and its food consumption percentage score.

No	Food Item	Mean food intake frequency in 7 days (Days)	Weight factor	FCS contribution (%)
1	Enset (kocho)	2.2	2	7
2	Teff (injera)	3.6	2	12
3	Wheat (bread)	3.3	2	11
4	Tubers / potato	2.0	2	6
5	Pulses (bean, pea, lentil)	4	3	11
6	Meat	0.2	4	1
7	Oil, butter	4.0	4	13
8	Eggs	0.8	4	3
9	Milk and dairy	2.3	4	7
10	Vegetables	4.0	1	13
11	Improved avocado	3.4	1	11
12	Local avocado	1.3	1	4
13	Banana	0.5	1	2
	Total	30.9		100

Thus, the average income generated between avocado cultivars differed significantly (ST 2). The average gross annual income derived from the sale of the assessed avocado cultivars amounted to 3830 Ethiopian Birr (ETB) (68 USD) per household per year, with Nabal being the most sold cultivar, followed by Ettinger, whereas Hass made the least contribution to income generation (Figure 3b).

The respondents also reported that approximately 64% of the total avocado production was used for household income at both study sites. According to the focus group discussions, the primary purpose of Nabal was immediate sale because of its relatively short shelf life and high production. The study revealed that the majority of participants sold avocado fruits in the central market, whereas only a few choses to sell them in local markets and farm gates (Figure 4).

Earnings from selling avocado fruits have been allocated for various purposes. Approximately 37% was utilized to cover school fees and purchase exercise books, clothes, and shoes for children; 34% was used for the acquisition of consumable food items (coffee, salt, cooking oil), soap, and kerosene. About 12% was designated for government farmland tax payment, 10% was allocated to purchase inorganic fertilizer while the remaining 7% contributed towards social activities such as 'Iddire' and 'Equb'. Iddir is an indigenous social insurance association primarily established to provide support for burial matters. Equb is a traditional savings and credit scheme in which a group of people agrees to contribute a fixed amount of money to a common pool regularly, and the accumulated funds are then distributed to members in rotation, usually on a weekly or monthly basis.

3.5. Food consumption score (FCS)

The study results showed that the avocado cultivars accounted for 10% of the food consumption score of the household (Table 4). Approximately 36% of the total avocado production was used for home

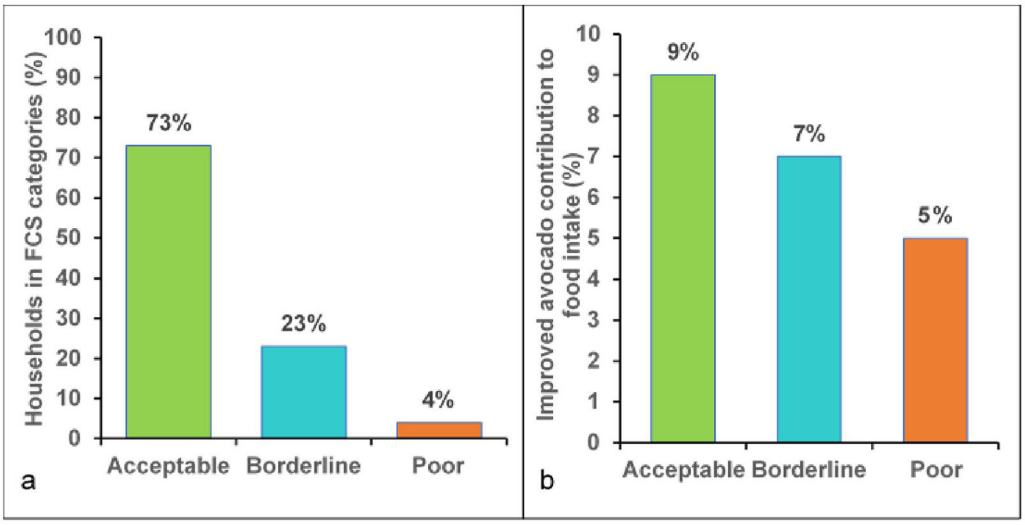

Figure 5. Percentage of households in food consumption categories (a) Percentage contribution of the studied improved avocado cultivars to the household food consumption score (b); The Food Consumption Score (FCS) level specified as 0–21 as poor, 21.5–35 as borderline, and >35 as acceptable (WFP, 2008).

Table 5. Correlations between avocado cultivation and the rural household income and food consumption.

Variables	Standardized Coefficients Beta	t value	*p* value	Collinearity Statistics (VIF)
(Constant)		2.387	0.018	
Farm income diversification	0.041	0.572	0.568	1.187
Avocado income generation	**0.479**	**6.794**	**<0.001***	**1.156**
Food consumption score	0.063	0.459	0.647	1.369
Kocho (Enset)	0.075	1.073	0.285	1.13
Injera	**−0.24**	**−2.29**	**0.023***	**2.553**
Bread	−0.017	−0.187	0.852	2.006
Tubers /Potato,	−0.004	−0.045	0.964	1.487
Pulses	**0.165**	**2.034**	**0.044***	**1.536**
Meat	0.088	1.223	0.223	1.207
Food oil, butter	0.078	0.832	0.407	2.069
Eggs	0.103	1.493	0.138	1.103
Milk and dairy	0.102	1.507	0.134	1.075
Vegetables	0.068	0.849	0.397	1.499
Improved avocado	***0.042***	***0.318***	***0.751***	***1.415***
Local avocado	−0.075	−0.975	0.331	1.378
Banana	0.002	0.034	0.973	1.139
Adjusted R^2	0.30			
F statistics	5.37		<0.001*	

Dependent Variables: avocado production per household per both years.

consumption at both sites. Among cultivars, Hass avocado is predominantly used for household consumption due to its nutritional benefits and year-round fruit production. Approximately 35 kg and 50 kg of Hass fruit per household were consumed in 2022 and 2023, respectively (Table 3). Moreover, the results of the focus group discussions indicated that the Hass avocado was mainly used for consumption because of its delicious taste, continuous yield, and relatively longer shelf life compared with other cultivars.

A significant difference in food consumption scores was found between households (Figure 5a and ST 3). Similarly, avocado cultivars significantly contributed to the household frequency of avocado intake (ST 4). The study found that the average FCS values for the households under investigation were 48, 32, and 20, corresponding to the acceptable, marginal, and low categories, respectively. Approximately 73% of the respondents had a food consumption score within an acceptable range, 23% had a borderline consumption score, and the remaining 4% fell into the poor category (Figure 5), implying that 27% of the households were food insecure. Furthermore, participants reported that their avocado consumption was higher in 2023 than in 2022. This observation was linked to the high local availability and affordability of avocado fruit in 2023.

3.5. Correlation between avocado production and household income and food consumption score

Regression analysis revealed a strong positive correlation between avocado cultivation and income generation ($p < 0.001$) (Table 5). The results also indicated that avocado cultivation tended to be positively associated with household food consumption scores (Figure 5b) and the diversification of farm income sources, but these relationships were not statistically significant. Furthermore, the study showed that avocado cultivation had a significant positive correlation with households that consumed pulses ($p = 0.044$), whereas it was negatively associated with households that consumed injera ($p = 0.023$) (Table 5). Which showed avocado cultivation mainly contributed to household income generation and stimulated pulse consumption more than other food groups.

4. Discussion

The survey results indicated that the most commonly cultivated improved avocado cultivars in the study area are Hass, Nabal, and Ettinger. These findings are consistent with those of a study by Sina et al. (2023) who reported that Hass is the most commonly cultivated and distributed avocado cultivar in southern Ethiopia. However, Fuerte cultivars are commonly grown in Rwanda, followed by Hass and Ettinger, this is because of the availability of local and global avocado markets (Gaspard et al., 2021). Differences in avocado cultivars grown in different countries can be attributed to factors such as climate suitability, farming practices, and market demand (Juma et al., 2019).

Owing to a shortage of grafted seedling access, the majority of participants had approximately three to four avocado trees per household. The number of trees per household is consistent with a study by Jalata (2021), who found that farmers owned an average of eight avocado trees in the Oromia region, Ethiopia, somewhat higher number of avocado trees grown per household in the Oromia region was linked to the relatively larger farms in the Oromia region than in our study area. The lack of grafted seedlings from known sources has been identified as a major obstacle to avocado production in Ethiopia (Megerssa and Alemu, 2013). This is because avocado trees are commonly grown from seeds rather than grafted seedlings (Biazin et al., 2018), leading to difficulties in obtaining adequate scion materials for sufficient propagation of grafted seedlings. The findings of this study suggest that the expansion of grafted avocado cultivation could be an area for future intervention by local governmental and non-government organizations focused on fruit tree development.

The survey results showed that households depend mainly on income from annual crop farming and livestock rearing. This result agrees with the findings of Berhanu and Guye (2022), who found that both crop production and livestock contributed substantially to household earnings. Moreover, this study found an SID value of 0.63, indicating that households derived income from a variety of sources. Similar studies conducted by Gecho (2017) and W/kidan and Tafesse (2023), reported slightly lower SID values of 0.59 and 0.56, respectively, among smallholder farmers in southern Ethiopia. Homegarden agroforestry enables farmers to diversify their income sources and improve their financial stability and resilience under unforeseen conditions by providing additional sources of income (Bojnec and Knific, 2021). This finding suggests that smallholder farmers may benefit from the cultivation of various avocado cultivars through increased fruit yield and diversified crop harvests, thereby supplementing their diet.

Most respondents observed differences in fruit yields and financial returns among the three avocado cultivars. Nabal accounted for approximately 39% of the total fruit production, whereas Ettinger and Hass accounted for 31% and 30%, respectively. The yield difference between Nabal and Hass could be attributed to fruit drop issues in the Hass cultivar, which can exhibit a high flowering rate followed by fruitlet abscission (Garner et al., 2008). In addition, Nabal exhibited a higher yield with large fruit size and longer harvest period than Hass, which enabled avocado farmers to prolong their harvest time and increase their income.

In terms of income generation, Nabal generated approximately 67% of the total household avocado income, followed by Ettinger at 26%, and Hass at only 5% in both years. The participants observed a trend of increasing avocado prices, leading to new marketing opportunities for avocado growers. On average, rural households earn approximately 3830 ETB (68 USD) per year from selling the fruits of the

three cultivars. This finding aligns with prior research by Adane et al. (2019), who found that a household can earn an additional income of 2750 ETB (49 USD) per year through fruit sales in a fruit tree-based agroforestry system. This suggests that agricultural extension services should focus on enhancing farmers' understanding of the potential yields of various avocado cultivars and effective cultivation methods.

Furthermore, avocado cultivation was strongly and positively correlated with household avocado income. A 1% increase in avocado production by farm households corresponds to a 0.48% increase in income derived from avocados. This positive association can be attributed to the fact that avocado cultivars provide a higher income contribution to households than to their food consumption. A similar result was reported by Mulyatno and Titik (2021), indicating that an increase in avocado production leads to increased income for rural households. Mwambi et al. (2016) reported that the income of smallholder avocado growers in Kenya was greatly improved by contract avocado farming and market linkage. Additionally, farmers who owned bigger farms with a greater number of Hass avocado trees and participated in the export market obtained higher income and revenue compared to farmers who did not participate in the export market (Amare et al., 2019).

The income generated from avocado marketing was used to cover the cost of children's school fees, clothes, and shoes, as well as purchasing consumable food items (coffee, salt, cooking oil), agricultural supplies, government taxes, and social contributions. This finding suggests that selling avocado fruit can support children's education and cover household costs but may decrease dietary benefits. Therefore, local government officials and development experts must balance the economic benefits of avocado cultivation with the potential impact on health.

Furthermore, the survey results showed that avocado cultivation contributes to household food consumption, with approximately 36% of the total avocado harvested being used in homes. This finding is consistent with earlier studies by Garedew and Tsegaye (2011), which indicated that households consumed approximately 20% of avocado production and regarded it as an essential commodity. Avocado fruit consumption by local farmers has also increased in the Wondo Genet area of, Southern Ethiopia (Banjaw et al., 2023). Across cultivars, Hass played a greater role in supporting domestic food consumption, owing to its delicious taste and year-round production. The cultivation of avocados substantially enhanced dietary diversity among households that grew this fruit, especially during the avocado production season from May to December (Uosukainen, 2018). Fruit trees growing in homegardens can reduce dependence on grain crops, increase food availability during times of scarcity, and improve family nutrition (Oladele et al., 2020). It has the capacity to contribute to household livelihood improvement (Mathewos et al., 2018), which is consistent with (Gebru et al., 2022; Mokria et al., 2022).

According to the food consumption score (FCS) finding of the study, over 70% of participants had satisfactory levels of food intake. On average the studied avocado cultivars accounted for 10% of the total food consumption score but contributed only 6% to households with borderline or inadequate levels of food consumption. The study findings also indicate a positive relationship between the income diversification of farm households and their food consumption scores. Households with high food consumption scores also have a high value for income diversification. Similar results were obtained by Mango et al. (2018), who found that households practiced high levels of crop diversification and tended to maintain diverse food consumption. The regression results showed that avocado cultivation had a positive relationship with food consumption, but this was not significant, suggesting that even though farmers had grown avocado trees, their actual consumption of avocados was inadequate. This implies that more efforts are required to increase household fruit intake and promote nutritive dietary habits because avocados have a positive influence on smallholder farmers' food security and health (Hakizimana and May, 2018).

A significant positive correlation was observed between the avocado cultivation and pulse consumption. A 1% increase in avocado production led to a 0.16% increase in the likelihood of pulse consumption. Conversely, avocado production was significantly and negatively associated with injera consumption. A 1% increase in avocado production may result in a 0.24% decrease in the probability of consuming injera, and households involved in avocado cultivation are more likely to consume pulses and less inclined to consume injera, which suggests that avocado cultivation can stimulate healthier and

nutritious diets. This is attributed to households that cultivate avocado cultivars having the opportunity to consume more avocado fruits, which reduces their reliance on injera. Injera is a traditional Ethiopian staple food, which is produced from teff grain, that requires lengthy fermentation and cooking processes. In contrast, freshly harvested pulses can be rapidly prepared by boiling or roasting, facilitating more immediate consumption in the study area. In addition, teff has a higher price than pulses, farmers view it as a valuable crop. As a result, more than half of the teff harvest in the study area is sold commercially rather than retained for household consumption. Teff is consumed in higher amounts by urban wealthy households compared to rural poor households, as it is often priced at double the cost of the cheapest cereal, maize (Tadele & Hibistu, 2021). This shift in food consumption patterns promotes dietary diversity and improved nutritional outcomes in rural communities. Pulses are recognized for their protein content and essential minerals, aligning with healthy food consumption and enhancing food security (Lal, 2017). Incorporating pulses into people's diets can improve their dietary quality and provide essential nutrition (Marinangeli et al., 2017). These findings indicate that promoting avocado cultivation could potentially lead to a shift towards nutritious food intake. Further investigation on the impacts of specific avocado cultivars on the food and dietary diversity of rural households could be a valuable research area.

In general, the results of this study demonstrated that the expansion of homegardens to improve avocado cultivation is highly beneficial. This can increase income, stimulate diverse food options for smallholder farmers, support food and nutrition security efforts, and contribute to the national economic development of smallholder fruit growers.

5. Conclusions

This study focused on the contribution of improved avocado cultivation to household income and food security. The study found that Nabal, Hass, and Ettinger were the most commonly cultivated cultivars, with Nabal and Hass producing the highest and lowest fruit yield, respectively. It was also evident that avocado cultivation played a crucial role in both the income generation and food consumption of the households involved in the study. Household income was highly diversified, as indicated by the average SID value of 0.63. This study also revealed that, on average, the three cultivars made up 14% and 10% of household income sources and food consumption scores, respectively. Most of the respondents achieved an adequate food consumption score, but approximately 30% of the farmers still experienced food insecurity.

Overall, cultivating these three avocado cultivars has the potential to enhance the economic situation of rural farmers and support food security and dietary diversity. However, avocado producers are more interested in using avocado cultivation as an income-generating option, rather than for home consumption. Policymakers and development partners should support the integration of these cultivars into rural farming systems to, expand income sources for farmers. Moreover, to ensure food security in rural households, raising farmers' awareness of the nutritional benefits of consuming avocados through agricultural extension services is recommended.

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Ethical approval

This study was approved by the Ethics Committee of Sokoine University of Agriculture, (reference number SUA/FSC/D/2020/0018/14), on 04 March 2022.

Authors' contributions

Hadia Seid: conceptualized the study, designed the methodology, curated and analyzed the data, drafted the original manuscript, and reviewed and edited the manuscript. John Kessy provided supervision the study, contributed to the study design, and reviewed and edited the manuscript. A. Sigrun Dahlin offered supervision, contributed to the study design, and reviewed and edited the manuscript. Zebene Asfaw provided supervision, participated in the design process, and reviewed and edited the manuscript.

Study participation informed consent

We obtained verbal consent from the study participants prior to conducting the household survey and the focus group discussions. At the time of data collection, we introduced the study's purpose and asked participants whether they wished to participate, using the following question: 'Do you wish to participate in this study?' Those who indicated 'Yes' were included, and the information they provided was treated with utmost confidentiality, while those who selected 'No' were excluded, and we proceeded to the next participant.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

Data supporting the findings of this study are available upon reasonable request from the corresponding author.

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