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Assessing the Demand and Current Status of Agricultural Mechanization in Major Coffee-Production Areas of Ethiopia

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Abstract

Ethiopia, the primary coffee producer in Africa and the fifth in the world is facing challenges in agricultural mechanization. The research aims to assess the status, constraints, preferences, and demand of mechanization in Ethiopia, focusing on strategies to improve smallholder access to capital-intensive inputs and bridge the gap between mechanization and farmers' needs. A household survey and focus group discussions were conducted on 136 random samples using a multi-stage procedure, with semi-structured questionnaires used to interview 81 households of small-scale and 19 households of large-scale coffee farmers. The study found that preferences for each operation during coffee production are based on difficulties in work drudgery, with 42.45% believing that the first energy-consuming operation is hole digging for coffee plantation and cultivation. Coffee harvesting is a highly time-sensitive operation for 49.4% of smallholder farmers, with hand tools being the main implement dominantly used for weeding. Poor harvesting practices reduce the quality of coffee during processing, and some unions have two or more wet mills using old machinery. The main challenges for low mechanization in Ethiopia include difficult topography, fragmented land, a lack of manpower, lack of awareness of technology, weak linkages of coffee mechanization channels, high technology costs, a shortage of running budgets, and a weak support system of cooperatives and unions. Experts suggest that capacity building on extension systems is the best way to facilitate the extension system of coffee mechanization technology. Assessments of technology manufacturers, machine assemblers, maintenance service providers, and importers were conducted in Harar, Hawassa, Jimma, Bonga, and Addis Ababa cities. Challenges include a lack of enabling laws and incentives to facilitate business start-ups. Importation of small-scale engine-driven equipment is an additional means to meet demand in some cooperatives and may provide farmers with an alternative source of cheaper machinery. Ethiopian academics and higher education institutions are essential players in exploring mechanization options, and public and private sectors, including cooperatives and farmer organizations, need to have a clear understanding of their respective responsibilities and areas for collaboration.

Keywords: Farmers, cooperatives, importers, technology, drudgery, time-sensitive, challenges

INTRODUCTION

Ethiopia is the primary coffee producer in Africa and the fifth globally (ICO, 2015), with one-fourth of the country's population relying on this sector. Almost all production and type of coffee is Arabica coffee, which has been identified by several studies (Tefera *et al.,* 2019). The country's coffee production contributes to 65% of Ethiopia's forex income and accounts for 25% of its GDP specifically Arabica coffee (Beshah *et al.,* 2013; World Bank, 2009). In 2014/15, Ethiopia exported around 180,000 metric tons of clean coffee, accounting for 4.2% of the global Arabica coffee market (FDRE, 2009). Coffee farming alone provides a livelihood income for around 15 million Ethiopians (16% of the population), with four million smallholder farmers dependent on it (Tefera & Tefera, 2014; Minten *et al.,* 2014). Ethiopia has a good production environment for growing coffee, including suitable altitude, temperature, rainfall, and soil type. However, productivity is low in input and output, leading to crop productivity levels that are significantly below regional and international standards. Lack of advanced cultivars, unavailability of advanced production technology, and physiological issues like loss of life over and over again are critical factors for low coffee yield. Strong transport of agricultural inputs, and planting of advanced sorts, fertilizers, and pesticides at low prices, is advocated, but the use of herbal and mineral fertilizers is limited in some production structures (Muhie, 2022).

Smallholder coffee farmers in Ethiopia have limited or no access to mechanized technologies, making it difficult to produce at a scale comparable to African and international averages. The primary variable that impacts drudgery and low productivity is the planting, weeding, harvesting, and processing methods, which are traditional hand digging, hand-choosing, and husbandry labor. The production of coffee is the capital-demanding function of coffee and hard work, extensive weed management (weeding and digging), and harvesting are pricey and tremendously huge capital. The minimum wage in coffee areas is very excessive as compared to other cereal crop-generating farming structures (Wolde *et al.,* 2017). Value-lowering mechanisms such as progressive machines related to exertion-intensive operations should be given due weight. Various constraints, such as lack of improved, early maturing, and disease-resistant varieties, lack of infrastructure, inadequate access to services, low-value addition, and inadequate improved production technology, are among the major challenges of coffee production in Ethiopia (Dida, 2022).

Encouraging the utilization of improved technologies to boost the gross return and cost minimization through the utilization of different creative and innovative agricultural engineering technologies like machines is crucial to increasing the gross margin of coffee in Ethiopia. Assessment of interventions concerning mechanization in farm power and farming systems needs to take into account and outline the most constraining bottlenecks across the coffee production scheme, and recommendations to arrive at the desired outcome are required (Fortune & Tawanda, 2013). Mechanization in coffee production may be a relatively new concept but can be critical to successful and efficient production. The productivity and profitability of coffee farms depend largely on the availability and efficient use of facilities related to production factors and infrastructure (Diro *et al.,* 2017). Developing countries like Brazil and developed countries like the USA (Hawaii) and Australia grow coffee in well-prepared flat and gently sloping lands under open conditions, which help them, implement advanced agricultural engineering technologies to reduce dependency on human labor with very high capital investment (Rudragouda, 2017).

Some studies examined the mechanization needs of coffee producers in the Gomma area of Ethiopia's Jimma Zone. Weeding was the most expensive management practice for coffee, with a single-cutting cost ranging from USD 14.67–29.34 per hectare of land (Diro *et al*., 2019). Further study is needed to identify the major constraints, tackle the problems in the future, and review coffee farming practices used to adopt appropriate technology for productivity improvement. This research aims to assess the demand for and current status of agricultural mechanization in the major Arabica coffee-producing areas of Ethiopia.

MATERIALS AND METHODS

Study Area

Ethiopia's coffee-growing areas are primarily located in the southwest and southeast regions, with Oromia and Southern Nations, Nationalities, and Peoples (SNNP) regions being the main areas. The north has modest production, with Oromia, 35% from SNNP, and the remaining 1% from other regional states. Most Ethiopian coffees are shade-grown, with 40-60% canopy cover. The country covers 19,000 km^2 and grows coffee in designated agroecological zones. Around 20% of Ethiopia's coffee is cultivated in small plots in partial shade or full sun, with at least 80% coming from farms with shade, forests, or settings resembling forests (Teferi *et al.,* 2018).

The majority of Ethiopia's coffee is grown between 650 and 2,600 meters above sea level in humid evergreen forests like Moist Afro-Montane Forest (MAF) and Transitional Rain Forest (TRF). Coffee growing is connected to the Dry Afromontane Forest in places like the Harar Zone. Forest and semi-forest coffee are the main types of coffee grown in Ethiopia. Forest coffee systems use wild coffee stands naturally within the forest with minimal farmer intervention, while semi-forest coffee is more intensive with increased farming interventions like tree thinning, understory clearance, weed cutting, and seed planting. Sun coffee farming systems are small, often found at higher altitudes near dwellings, providing coffee for household consumption, local consumption, or the wider market (Moat *et al.,* 2017).

Agroforestry systems are family-run and consist of a wide variety of crops in association with indigenous forest cover. In the Sidamo area, coffee is almost exclusively produced within an intensively managed agroforestry system, with forest coffee production relying on wild stands and semi-forest coffee accounting for 45% of national coffee production. Garden coffee production involves smallholder pots with seedlings taken from forest systems and relocated closer to farmers' dwellings, while plantation coffee production is on large estates owned by the state with intensive maintenance and agricultural practices (Moat *et al.,* 2017).

Data Collection

Data for this report was gathered from different sources using various techniques. The first approach of data collection was a focus group discussion about the general existing mechanization practices, type of farm operation used, number of farmers currently involved, perceptions, existing needs, and constraints with regional, zonal, and woreda coffee experts and development agents participated in the discussions about the survey. All the governmental office experts were encouraged to be actively involved and forward their opinions. Though it was targeted at qualitative information, useful quantitative data was also dealt with to complement the survey. This was the first approach to collecting primary

and secondary data on general and coffee mechanization information.

The study utilized a multi-stage sampling procedure to select sample households and stakeholders. The first stage involved identifying potential districts and zones in collaboration with regional coffee experts from the SNNP and Oromia regions. The western Hararge and Jimma zones in Oromia and the Sidama, Gedeo, Keffa, and Benchi Sheko zones in the SNNP regions were deliberately selected. The second stage involved selecting the two best coffee-producing *woredas* (the third level of the administrative divisions of Ethiopia) from the chosen districts or zones. The third stage involved selecting two *kebeles* (the smallest unit of local goverment) from each woreda based on production potential and the number of farmers involved. The fourth stage involved randomly selecting four smallholder farmers, two large-scale farmers or state farms, and a cooperative or union from each peasant association (PA). A household survey was conducted to gather primary data on coffee mechanization and needs in coffee production practices. The survey assessed individual farmers' practices, resources, skills, and support, which are used for population estimations. Woreda experts and development agents from respective PAs were also involved. Data was collected from sampled households using structured questionnaires. The instrument for the study was designed after reviewing secondary sources and assessing actual situations from regional, zonal, and district bureaus of agriculture and natural resource development offices. Secondary information on coffee production, processing, and marketing value chains was collected from published and unpublished sources from each zonal agriculture office. An assessment survey was conducted to identify gaps in the data. The instrument was created after a desk review of available secondary materials and improved through a preliminary analysis of real procedures.

Target Groups Selection

In-depth discussions were made with each selected zone and the wereda administration by the representative of the community complaints farmers. The target groups of the survey were divided into five groups, i.e. large-scale farmers (having a land size of more than 5 hectares), small-scale farmers (having a land size of fewer than 5 hectares), coffee co-operatives and unions, coffee machinery manufacturers, and importers, and Woreda coffee production development office representatives. Five separately prepared, semi-structured questionnaires were used to collect primary information from diverse stakeholders and institutes across the country. From the 136 samples, 81 households of small-scale coffee farmers, 19 households of large-scale coffee farmers, 12 officials of the Woreda agriculture office mainly extension experts, 7 machine manufacturers and dealers, and 17 unions and cooperatives were interviewed using semi-structured questionnaires. During the selection of the sample household for the household survey, farmers who were not involved in the growing of the coffee were left out. In proportion to the overall number of households in each kebele, a straightforward random selection of the households in each kebele was conducted.

Data Collection and Analysis

The data were gathered from sampled house-holds using a semi-structured questionnaire. Some socio-economic backgrounds and coffee mechanization issues related to the selected area were collected through the interviews of respondents. The instrument for the study was designed after a review of secondary sources and was well-refined through a preliminary assessment of

actual situations. It was also collected from regional and zonal and district bureaus of agriculture and natural resource development offices. The data collected were analyzed using descriptive statistics of IBM SPSS statistics 22 software packages. Frequency and mean were commonly used methods for the analysis. It comprised production and marketing attributes, existing constraints, coffee processing, technological awareness, mechanization needs, and extension services including farm mechanization was addressed from land preparation, post-harvest management, processing, and marketing stages.

RESULTS AND DISCUSSION

Household and Coffee Production Characteristics

The average age of the respondents was 42.8 years old. Out of the interviewed farmers, nearly 40%, 20%, and 11.1% had completed primary school, elementary school, and high school, respectively; however, 2.5% of the respondents had received a degree while almost 17% of the interviewed farmers had no education. On the other hand, education levels among the large-scale farmers (N = 19), which are male farmers with 15.8% are uneducated while diploma, high schools are 5.3% each but the remaining only can read and write or completed elementary school.

A household head's main occupation that showed the primary source of income of the respondent of large-scale farmers (N = 19) is coffee farming, while a total smallholder, generated from multiple responses, is generalized in percentage as shown in Table 1.

The survey results of smallholder farmers (N = 81) revealed that 9.9%, 56.7%, and 33.4% of the respondents have less than 1 hectare, 1–3 hectares, and 3–5 hectares respectively. Of this, 21.0%, 59.2%, and 19.8% of the respondent have 1 hectare, 1–3 hectares, and more than 3 hectares, respectively having a coffee farm. But 55.6%, 37%, and 7.4% of the respondents covered 1 hectare, 1–3 hectare, and more than 3 hectares respectively of the area of the farm covered by other crops as shown in Table 2. The household survey revealed that the average amount of land allocated for coffee production by the smallholder farmers was 2.19 ha, while in the same study, the analysis of the land for coffee production with a mean land area of 1.12 hectares (Diro *et al*., 2019) was significant at 1%, as shown in Table 2.

Regarding the number of coffee trees, 37% of the coffee farmers have less than 1000 coffee trees, and the remaining have more than 1000, but 11.1% of them don't know the number of coffee trees they have. However, 31.6% of the large-scale farmers have owned 5.5 ha of land and the remaining have owned greater than 6 hectares of land. The maximum land owned by large-scale farmers is around 31 ha. In the case of the number of coffee trees, the large-scale farmers managed a minimum and a maximum number of coffee trees of 5,000 and, 72,000 respectively. Ethiopian coffee production is characterized by manual farming, drying techniques, and limited modern mechanization.

Besides, the secondary data assessment using keyword searches, resource sorting in Google and Google Scholar databases, and analysis of publications as a part of this survey study revealed that from 2012 to 2016, Ethiopia experienced an increase in coffee output, mainly due to favorable weather, reduced disease and pest pressure, sufficient rainfall, and enhanced extension services. However, the total land area for coffee production increased by 15% between 2013 and 2020. In 2020, Ethiopia received 5,847,895 metric tonnes of coffee, with an average productivity of 0.683 metric tonnes per hectare (CSA, 2022). The graph

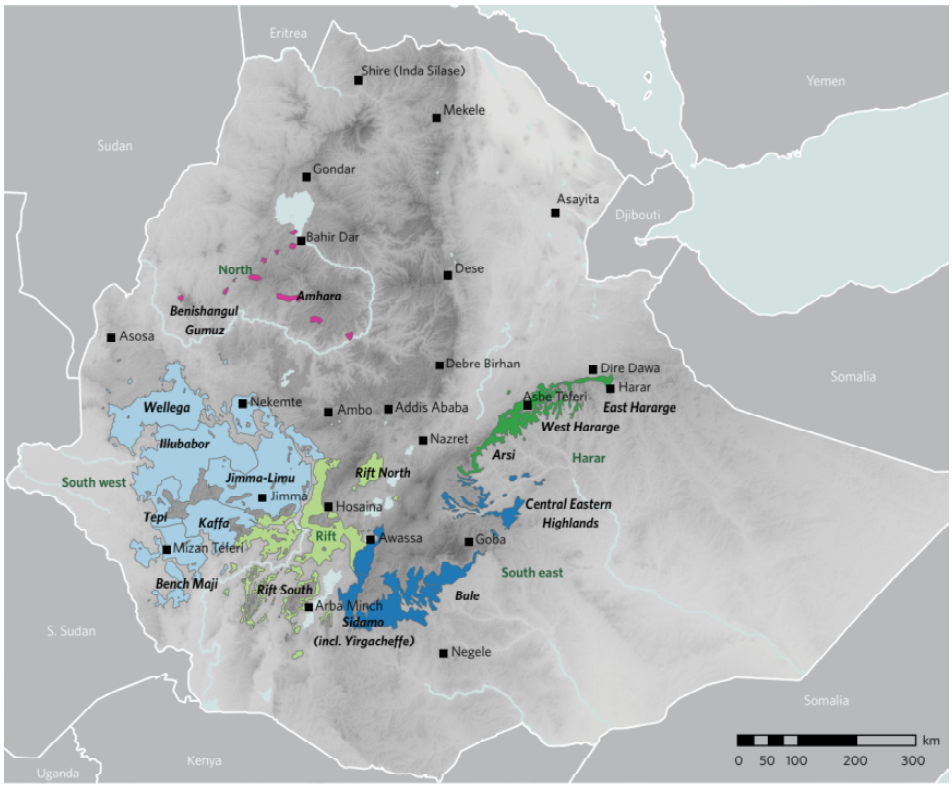

Figure 1. The main coffee growing zones of Ethiopia (Own computation from Moat *et al.,* 2017). The Oromia and SNNP areas were considered due to their potential for coffee production. The study was confined to the main coffee potential districts in western Hararge, eastern Hararge, and Jimma zones in Oromia, and Sidama, Gedeo, Keffa, and Benchi-Sheko zones in SNNP regions due to security constraints.

in Figure 2 shows that Ethiopia's coffee yield has varied over the past nine years.

This productivity is below the world average due to physical, biological, and man-made factors, such as the lack of high-yielding varieties. biological and institutional factors also play a significant role in coffee production. The average green coffee bean yield per hectare per year is 0.683 metric tonnes, lower than the world average and Brazil's average of 0.8 and 1.3 metric tonnes per hectare, respectively (Motebayenore, 2022). Table 3 shows the average agricultural land and coffee tree owned and managed by large-scale and smallholder farmers.

Similarly, 54.3% of the respondents used intercropping with bean (13.6%), maize (11.1%), *Enset* (9.9%), and both bean and maize (6.20%), and the remaining were taro, chat, and the combination of those crops for their coffee production. The other 45.7% have not used any intercropping practices and have produced forest coffee. The types of coffee farming systems account for 12.3% (forest) and 9.9% (semi-forest), and the rest (77.8%) are non-forest or garden coffee and

Table 1. The household's main source of income of smallholder farmers in (%)

	Smallholder farmers (%) (N = 81)	Large-scale farmers (%) (N = 19)
Annual-crops farming	9.90	0
Coffee farming	87.70	100
Livestock farming	1.20	0
Annual crops, coffee, and livestock farming	1.20	0
Total	100.00	100

Table 2. The one-sample test of land allocated for smallholder coffee farmers

	Test value = 1.12					
	t	df	Sig. (2-tailed)	Mean difference	95% confidence interval of the difference	
					Lower	Upper
Area in hectares of farm covered by coffee	3.853	80	.000	1.31	0.63	1.99

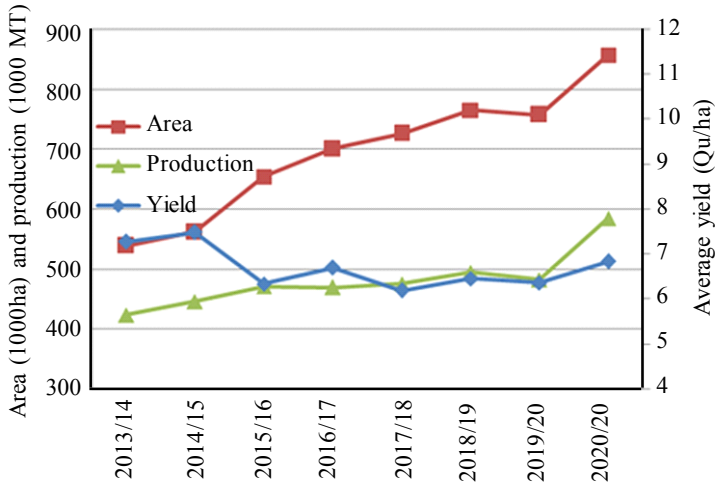

Figure 2. Ethiopian annual coffee production trends concerning the area (Source: Own computation from CSA, 2022 and Motebayenore, 2022)

plantation coffee. The types of coffee produced based on input uses are organic (82.7%), inorganic (12.3%), and both organic and inorganic (4.90%) coffee. On the other hand, 57.9% of the large-scale farmers do not use intercropping, but the remaining use bean, maize, e*nset,* and pepper for intercropping crops during their coffee planting. Similar studies in SNNP regions indicated that about 98.1% of the respondents produce coffee as a prime crop by way of intercropping with maize (75.2%) and *enset* (68.3%).

The assessment of the literature revealed that Ethiopia's coffee production systems are *Coffea arabica* primarily involve smallholder cultivation in rain-fed farming with minimal mechanization. Mixed subsistence farming involves raising crops and caring for animals. Smallholder farmers produce 95% of the world's coffee, while large-scale producers produce 5%. Although not officially certified, 95% of these coffees are organic (Alemayehu & Merga, 2017). The majority of garden coffee is found in the southwest, south, and east of the country, namely in the Sidamo, Gedeo,

Table 3. Agricultural land and coffee tree owned and managed according to farming scale

Agricultural land and coffee tree managed	Farm scale	
	Smallholder farmers (N = 81)	Large-scale farmers (N = 19)
Total agricultural land (ha)	3.215	9.216
Agricultural land for coffee (ha)	2.188	7.816
Agricultural land for other crops (ha)	1.085	1.4
Total number of coffee trees	4950	15069
Coffee trees planted last 4 years	2716	2316
Area of coffee at old stage (ha)	0.40	2.82

South and North Omo, Hararghe, Wollaga, and Gurage Zones. Forest coffee is grown in the regions of Bale, Jimma, Illubabor, and Qellam Wollaga in the western, southwest, and southeastern parts of Ethiopia. Human intervention is used to develop semi-forest coffee by decreasing tree growth, removing vegetation, and filling in vacant spots with naturally regenerated seedlings. Ethiopians only drink this sort of coffee, which is primarily grown in the south and southwest of the nation. After clearing the area and carefully preparing the soil and seedlings for planting, plantation coffee is grown. This approach calls for enhanced seedlings, better spacing, appropriate mulching, manuring, weeding, shade regulation, and pruning, among other agronomic practices. Seven different state farms in the Limmu, Tepi, and Bebeka regions are divided up into these farms. Illubabor, Kaffa, Jimma, Wollaga, and a portion of the Benchi Maji zone are the main coffee-producing areas in southwest Ethiopia. Lekemte and Jimma sun-dried coffee, as well as Limmu, Tepi, and Bebeka-washed coffee, are among the coffee varieties found in western and southwestern Ethiopia. Scholars have paid less attention to the evolution and continuity of Oromo coffee cultivation in Ethiopia, nevertheless (Duressa, 2018). Coffee was identified as the number one supply of cash in all assessed areas of the SNNP region, besides Gamo-Goffa, where bananas ranked first amongst coin vegetation (Tadesse *et al.,* 2020).

Coffee Marketing, Processing, and Socio-Economic Characteristics

The assessment report showed that 64.3% and 84.2% of the smallholder farmers and large-scale farmers are members of coffee corporate unions, respectively. At the time of this assessment study, the production stage of coffee for those study areas was summarized as shown in Table 4.

The production of coffee starting from 2009 to 2011 EC showed that the majority of the respondents were at the production stage with 80.2% in 2009 but gradually decrease to 14.8% and 4.9% in 2010 and 2011 respectively. The farming system for this coffee production stage (80.2%) in the year 2009 was also Forest, None forest, and both Forest and None forest with 18.5%, 79.0%, and 2.5% respectively. The type of coffee produced in 2009 was organic (70%), inorganic (9%), and organic and inorganic (2.5%), for both large and small-scale farmers. On the other hand, most of the large-scale farmers produced a non-forest type of coffee farming system with 73.7% of the total sample survey, while the remaining are forest and both forest and non-forest farming systems 5.35 and 21.1% respectively. The type of coffee produced based on the input used is organic and inorganic, which were 94.7% and 5.3% respectively. These findings inlined with other research reports where Ethiopia's forest coffee certification began in 2002, with 95% coming from smallholder farmers and the

Table 4. Coffee production stage according to farming scale

Stage	Farm scale	
	Smallholder farmers (N = 81), (%)	Large-scale farmers (N = 19), (%)
Growth stage	17.3	0
Production stage	55.6	73.7
Maturity stage	27.2	26.3

rest from large-scale producers. About 95% of organic production is unofficially certified, while less than 1% is certified as organic (Stellmacher & Grote, 2011; Motebayenore, 2022).

In terms of value addition for coffee processing and usage of processing technologies for sale on the market, about 88.9%, of small-scale farmers in the sample survey do not practice any value addition of their product through coffee processing and just sell cherry coffee and dried coffee without hulling, while the remaining 11.1% process using small-scale pulping machines through either private rent or cooperatives and unions. These farmers are getting pulping or processing services from privet rent and cooperatives/ unions with 1.2% and 2.5%, respectively. Although 26.3% of large-scale farmers do not practice any processing activity, the remaining use dry (natural) processing and wet (fermented and washed) processing activities at 57.9% and 15.8%, respectively.

The two basic coffee processing types used by large-scale farmers in the study areas are wet pulping of the cherry and then drying and hulling after drying of the cherry to remove the pericarp of the coffee bean. The type of wet processing type of pulping machine mostly used by 21.1% of the large-scale farmers was the disc pulping machine, which was a motorized drum pulpier. Hence, a hand pestle, and mechanical huller with 5.3% and 15.8%, respectively, were used for this purpose, and then the coffee husk was cleaned from the hulled coffee using a manual winnowing hand tool. Wash the coffee product after pulping or hulling using manual washing on a well-concrete tanker prepared in the ground, which is highly labor-intensive during coffee production.

This report is in step with studies in coffee production areas of the SNNP region, which showed that the majority of the farmers (47.5%) used to sell freshly harvested and dried coffee beans. But the best 2.5% of the farmers replied that they had been selling dried coffee beans. The other 50% of the farmers used to sell freshly harvested, dried, and pulped coffee depending on the urgency of the need for income. Harvesting become achieved through one-by-one hand-picking of ripped beans (57%), accompanied utilizing a mixture of hand-choosing, sweeping from branches, and accumulating from the ground (20%). As far as processing and storage had been concerned, approximately 77% of the respondents have been using raised beds lined with a polyethylene sheet for drying coffee beans and storing in jute sacks (62.5%) observed by bamboo baskets (20.8%) (Tadesse *et al.,* 2020). Perceptions of the farmers about the value addition based on market value revealed that the proportion of cheery coffee sales income versus another process stage in the past three years is presented in Table 5.

Besides this, most of the coffee farmers in the study area sold their products to retailers or traders, as shown in Table 6. Some of the large-scale farmers are also members of cooperative wet coffee pulping and cooperative dry coffee pulping associations with 10.5% of each, similarly, 30.9% of smallholder farmers also sold their coffee products to cooperative wet coffee pulping

Table 5. The proportion of cherry coffee sales versus other processes stages according to farming scale

	Farmers scale	
	Smallholder farmers (N = 81), (%)	Large scale farmers (N = 19), (%)
All production	9.9	5.3
3/4 of production	17.3	21.1
1/2 of production	3.7	5.3
1/4 of production	13.6	31.5
Less than 1/3 production	12.3	31.6
Do not recall/notice	35	5.3

Table 6. The proportion of coffee production sales (%) according to farming scale

	Farm scale	
	Smallholder farmers (N = 81), (%)	Large scale farmers (N = 19), (%)
Retailers/traders	46.9	47.4
Cooperative wet coffee pulping	30.9	10.5
Service cooperatives	3.7	5.3
Retailers/traders and cooperative wet coffee pulping	9.9	10.5
Exporter	1.2	5.3
Whole sellers	3.7	5.3
Cooperative dry coffee pulping	1.2	10.5

cooperatives, but 46.9% of them sold to retailers and traders which were the majority of the smallholder farmers. The farmers in each zone have recorded different trends of activity related to the wet coffee pulping corporative that the smallholder farmer usually sold to in Jimma (42.9%), West Hararge (31.3%), Bench Sheko (31.3%), Sidama (66.7%), and Keffa (42.1%) zones and used cooperatively to sell their coffee product. On the other hand, the entire sample from the Gedeo zone sells their coffee product to farmers' coffee corporative.

Trends of Agricultural Mechanization

Choices of mechanization

The assessment of the trend and status of agricultural engineering technologies in coffee production operations like pruning hand tools, hole digging equipment, weeding methods, harvesting techniques, and other processing technologies for smallholder producing farmers are conducted on their input efficiency, the productivity of labor and land, the cost of production, overall income and export capacity. The difficulties in terms of work drudgery of such activity are illustrated by the sample household of both large-scale and smallholder farmers. The preferences of each operation during coffee production are based on difficulties in terms of work drudgery, the choices of majority farmers in percentage revealed 42.45% believed that the first time and energy-consuming operation is hole digging for coffee plantation and cultivation than other activities as shown in Table 7.

Similarly, coffee production operations have varied numbers of labor requirements, called labor-intensive operations. According to the labor consumption the respondent farmers used, they have choices for their preference for mechanization rank by difficulty in terms of labor-intensive, which refers to an operation or activity that requires a large amount of labor to produce its coffee product or yield. Hence, the labor costs encompass all the costs necessary to secure the farmer's capital and the time necessary to complete work for each production activity. Based on the preference farmers for mechanization rank by difficulty in terms of labor intensiveness, the majority of choices are concluded in Table 8.

Table 7. Preference for mechanization rank by difficulty in terms of work drudgery according to farming scale

Type of farm operation	Smallholder farmers preference		Large-scale farmers preference		Total	
	Ranks	Estimated preference (%)	Ranks	Estimated preference (%)	Ranks	Estimated preference (%)
Holing/Digging	1	48.1	1	42.45	1	42.45
Weeding	2	43.2	2	45.3	2	45.3
Harvesting	3	44.4	3	45.9	3	45.9
Drying	4	27.2	4	24.15	4	24.15
Uprooting (Transplanting)	5	23.5	7	19.65	6	20.25
Stumping	6	24.7	5	20.25	5	19.65
Pruning	7	32.1	6	26.6	8	12.2
Nursery	8	19.8	10	17.8	10	26.6
Storage	9	19.8	9	20.45	9	20.45
Washing	10	8.6	4	12.2	7	17.8

Note: Household Survey Result (2019).

Table 8. Preference for mechanization ranks by difficulty in terms of labor-intensive work according to farming scale

Type of farm operation	Smallholder farmers preference		Large-scale farmers preference		Total	
	Ranks	Estimated preference (%)	Ranks	Estimated preference (%)	Ranks	Estimated preference (%)
Holing/Digging	3	37.0	3	36.8	3	37
Weeding	2	45.7	2	31.6	2	46
Harvesting	1	53.1	1	73.7	1	67
Drying	4	19.8	4	15.8	4	19.04
Uprooting (Transplanting)	10	24.6	6	26.3	8	24.92
Stumping	6	24.7	5	36.8	5	27
Pruning	5	21.0	8	26.3	6	22
Nursery	7	19.8	7	21.1	7	20.05
Storage	9	19.8	9	36.8	9	23.03
Washing	8	7.4	10	15.8	10	9.01

Note: Household Survey Result (2019).

On the other hand, wage levels were at the highest, and increasing demand for farm workforces increased in the coffee farming system. Labor costs are those costs associated with employing labor, including direct wages, food contributions, and transport included in labor costs in the coffee production system of the sample households. The farmers complain about the need for so many workforces for harvesting while the labor cost is getting increased and the time spent on the harvesting process is too long as shown in Table 9.

The household survey on coffee production trends related to mechanization technology demand depends on the exact time or operation required to practice what is called time-sensitive or timelines. Hence, it revealed that coffee harvesting is a highly time-sensitive operation with 49.4% and 47.4% of smallholder farmers and large-scale farmers' preferences, respectively, whereas storage and washing practices are the least time-sensitive activities for both smallholder farmers and large-scale farmers' choices, as shown in Table 10.

Agricultural Mechanization Status

Most of the Ethiopian coffee-grown areas are in hilly and undulating terrain under shade trees, and the operations are carried out mainly by human labor and remain primarily a labor-demanding crop with various constraints, especially for agricultural mechanization practices, which are not widely adopted by these farmers, of course, the practices are

Table 9. Preference for mechanization ranks by difficulty in terms of labor cost and wage according to farming scale

Type of farm operation	Smallholder farmers preference		Large-scale farmers preference		Total	
	Ranks	Estimated preference (%)	Ranks	Estimated preference (%)	Ranks	Estimated preference (%)
Holing/Digging	3	44.4	3	52.6	3	46
Weeding	2	46.9	2	52.6	2	47.9
Harvesting	1	42.0	1	57.9	1	45.02
Drying	4	22.2	4	22.2	4	22.2
Uprooting (transplanting)	5	24.7	5	26.3	5	25.0
Stumping	6	18.5	6	26.3	6	19.98
Pruning	7	19.8	8	26.3	8	21.04
Nursery	8	22.2	7	26.3	7	22.98
Storage	9	7.4	10	21.1	10	10.00
Washing	10	11.1	9	15.8	9	12

Note: Household Survey Result (2019).

Table 10. Preference for mechanization rank by difficulty in terms of time-sensitive operation

Type of farm operation	Smallholder farmers' preference (N = 81)		Large-scale farmers' preference (N = 19)		Total	
	Ranks	Estimated preference (%)	Ranks	Estimated preference (%)	Ranks	Estimated preference (%)
Holing/Digging	3	22.2	4	26.3	3	23.0
Weeding	2	33.3	2	21.1	2	31.0
Harvesting	1	49.4	1	47.4	1	49.0
Drying	8	19.8	7	21.1	8	20.1
Uprooting (Transplanting)	7	12.3	3	21.1	4	14.0
Stumping	6	19.8	5	26.3	7	21.0
Pruning	5	23.5	6	31.6	6	25.0
Nursery	4	13.6	3	21.1	4	15.0
Storage	10	14.8	9	15.8	10	15.0
Washing	9	13.6	10	15.8	9	14.0

important to improve the production of coffee that is lined with the finding of Diro *et al.,* (2019). Land preparation or hole digging is the first operation in coffee production before seedling/nursery establishment. Hand tools are the main material practiced by coffee farmers. The type of hand tools or machine ownership that is usually used in digging holes for plantations is shown in Table 11.

The size of holes usually prepared for coffee plantations by both small and large-scale farmers is also presented in Table 12. Most of the farmers used the recommended sizes of the hole of 60 cm by 60 cm, with 39.5% and 52.6% of the total observation in smallholder farmers and large-scale farmers' respectively, as shown in Table 11. A similar study in the Gomma district of Jimma Zone revealed that only 41% of respondents used the recommended hole size, while roughly 51% cited the job's high cost and labor-intensive nature as reasons for not using the recommended size of the hole, which was cited by 65% of respondents as a lack of finance and knowledge (Diro *et al.,* 2018).

Cultivation, or hoeing the coffee farm, is the other practice used by the coffee farmers next to the coffee replantation operation. About 92.6% of the smallholder farmers and all large-scale farmers' from the sample household dominantly used traditional hand hoes (*Degora or Domma*) for coffee cultivation. Very little of smallholder farmers used a modified hoe, and a semi-mechanized powered hoe was used with 3.7% of each sample household. The study inlined with the Gomma

district of Jimma Zone revealed that every day, a person digs 8–15 uniform coffee holes (60 cm × 60 cm), where a hole can cost anywhere between 0.027 and 0.63 USD and the average cost was 0.048 USD as a result, 95% of respondents said they needed a hole-punching machine, while the remaining 5% said it wasn't their top priority (Diro *et al.,* 2018). Weed control of the coffee farm is the challenged practice of coffee farmers similar to the other cereal commodities (Yared *et al.,* 2019) for both small-scale and large-scale farmers. Hand tools are the main implement dominantly used for weeding, with 94.7% and 98.8% of sample large-scale and small-scale farmers respectively. The remaining was weeding their coffee farm through manual hand weeding. It is commonly called *mencha* in East and West Harargie, but in other places called *machete* (*goradie* or *konchera*). Sometimes they also used sickles for weeding purposes in addition to coffee pruning. The number of weeds for one season is three times higher, with more than 49.4% and 52.6% for smallholder and large-scale farmers, respectively, as shown in Table 13.

Weed control is among the most expensive aspects of coffee management, and the best weed control method for coffee is slashing, while a coffee farmer slashes his coffee farm 2–4 times a year based on the intensity of rainfall which inlined with a study by (Diro *et al.,* 2018). The activity demands a significant amount of time and money because of how frequently it is performed each year. As shown in Table 12, the frequency of weeding for a season of coffee production is three times and four times with 49.4% and 42.0%, respectively, for small-scale farmers and three times and four times with 52.6% and 42.1%, respectively, for large-scale farmers.

Similarly, the frequency of cultivation for one production season of the household survey in coffee production indicated that about 3.70% and 5.30% of smallholder and large-scale farmers, respectively, do not cultivate their coffee farms and use forest coffee production. Most coffee farmers, both small and large-scale, cultivate three times per season, as shown in Table 14.

Table 11. Ownership of farm tools for hole digging according to farming scale

Type of machine or tool	The farming scale of farmers (%)	
	Smallholder farmers' preference (N = 81)	Large-scale farmers' preference (N = 19)
Spade	56.8	57.9
Shovel	13.6	10.4
Degora	1.2	5.3
Degora and spade	3.7	0
Spade and shovel	13.6	0
Geso	4.9	15.8
Shovel and *Geso*	1.2	5.3
Hand hoe	4.9	5.3

Table 12. Hole-digging practices by the household member according to farming scale

The size of the holes	The farming scale of farmers (%)	
	Smallholder farmers' preference (N = 81)	Large-scale farmers' preference (N = 19)
Not specified	3.7	0
60 cm by 60 cm	39.5	52.6
Above 60 cm by 60 cm	21.0	5.3
Below 60 cm by 60 cm	35.8	42.1

Table 13. The frequency of weeding for a season for coffee production according to farming scale

Frequency of weeding	The farming scale of farmers (%)	
	Smallholder farmers' preference (N = 81)	Large-scale farmers' preference (N = 19)
None	2.5	0
Once	1.2	0
Twice	4.9	5.3
Three times	49.4	52.6
Four times and more	42.0	42.1

Table 14. The frequency of soil cultivation for a season of coffee production according to farming scale

Frequency of soil cultivation	The farming scale of farmers (%)	
	Smallholder farmers' preference (N = 81)	Large-scale farmers' preference (N = 19)
None	3.7	5.3
Once	18.5	15.8
Twice	16.0	31.6
Three times	21.0	36.8
Four times and more	40.7	10.5

Pruning in coffee is a practice that lets the farmers produce a new plant from an old one. Hence, it was how old the coffee plant was after planting when the farmer started the first pruning practice. It is conducted during coffee production in the year after planting, which varies depending on the farmers' experiences. The household survey revealed that most of the farmers started the coffee pruning practice exactly three years later, with 31.6% and 37.0% of large-scale and small farmers, respectively. However, 15.80% and 7.40% of large-scale and small farmers, respectively, do not practice pruning or forest coffee farming, but the remaining have more than three years of plantation. The power source used in coffee pruning is usually human beings, with 97.55% and 94.70% of large-scale and small-scale farmers, respectively. The types of hand tools usually used in coffee pruning are also manual hand tools, as shown in Table 15.

Similarly, stumping is the practice of rejuvenating older coffee trees by cutting all their main stems, to encourage vigorous new growth. In Ethiopia, farmers stump trees after harvesting, one to two months before flowering. Stumping is known to increase coffee tree yields substantially when practiced along with other best agronomic practices. Most farmers used different hand tools for stumping practices in coffee production operations, as shown in Table 16.

The assessment of agricultural engineering technologies for pruning, stumping, hole digging, cultivating, and weeding practices for coffee-producing farmers to improve their input efficiency, increase the productivity of labor and land, reduce the cost of production, increase overall income, and immensely contribute to poverty alleviation is one essential component. The household survey indicated that 60.5% and 47.40% of small-scale farmers and large-scale farmers, respectively, do not have any background knowledge about modern mechanization technologies for those pre-harvest practices. Similarly, regarding post-harvest coffee mechanization technologies like pulping, dehulling, harvesting, and drying the household survey revealed that 21.1% and 28.4% have a knowledge gap on modern mechanization technologies for those post-harvest practices.

Table 15. Tools used in coffee pruning according to farming scale

Farm tools	The farming scale of farmers (%)	
	Smallholder farmers' preference (N = 81)	Large-scale farmers' preference (N = 19)
Pruning scissors	58.0	68.4
Knife	17.3	15.8
Mechete	1.2	0
Sickle	2.5	0
Mencha	3.7	0
No tool/bare hand	17.2	15.80

Table 16. Tools used in coffee stumping according to farming scale

Farm tools	The farming scale of farmers (%)	
	Smallholder farmers' preference (%)	Large-scale farmers' preference (%)
Axes	13.6	5.3
Hand saw	79.0	84.2
Engine driving machine	3.7	0
No practiced stumping	3.7	10.5

Mechanization Technologies Demand

The preferences of coffee farmers' mechanization demand regarding drudgery, labor cost, and time sensitivity, the household survey indicated that coffee processing practices, which was the way that a seed is removed from a coffee cherry, was the first choice by both smallholder and large scale sample household farmers as shown in Table 16. It is known, like any other pitted fruit, in four different ways to process coffee, all of which change the sweetness, body, and acidity of brewed coffee. These methods are called natural process, washed process, wet-hulled, and honey processed. Both the sample smallholder and large-scale farmers critically believed that they don't get the required cash from their coffee sales due to the lack of that coffee processing technology. Some coffee production places like Sidama, Benchi Sheko, Keffa, Jimma, and Gedeao zones are sold cherry coffee without any value addition to cooperatives and traders at cheap prices. Otherwise, in the west and east Harargie, the farmers dried the cherry coffee but without hulling and they get a relatively good sale.

Based on the choices of the sample household survey, the second mechanization technology demand concerning coffee production was drying methods. Coffee farmers used to dry the cherry coffee through the sunlight that depends on the natural weather condition of the area. Sometimes farmers restrict selling cherry coffee at a cheap price due to afraid of production loss in late drying that develops molds during drying. Similarly, coffee harvesting is the other labor-intensive and drudgery operation, through hand-picking of each single coffee bean on the coffee tree, which costs labor and drudgery. The same household survey revealed that production loss has existed during late harvesting that causes also shattering loss.

The sample household survey revealed that labor costs are the other challenges in coffee production that decrease farmers' productivity. Labor populations due to various factors are a serious problem that leads to increases in labor costs, higher production inputs, energy consumption, and less resource utilization. The labor cost for each production practice was presented in Table 17. The total labor cost by the farm operation and farm

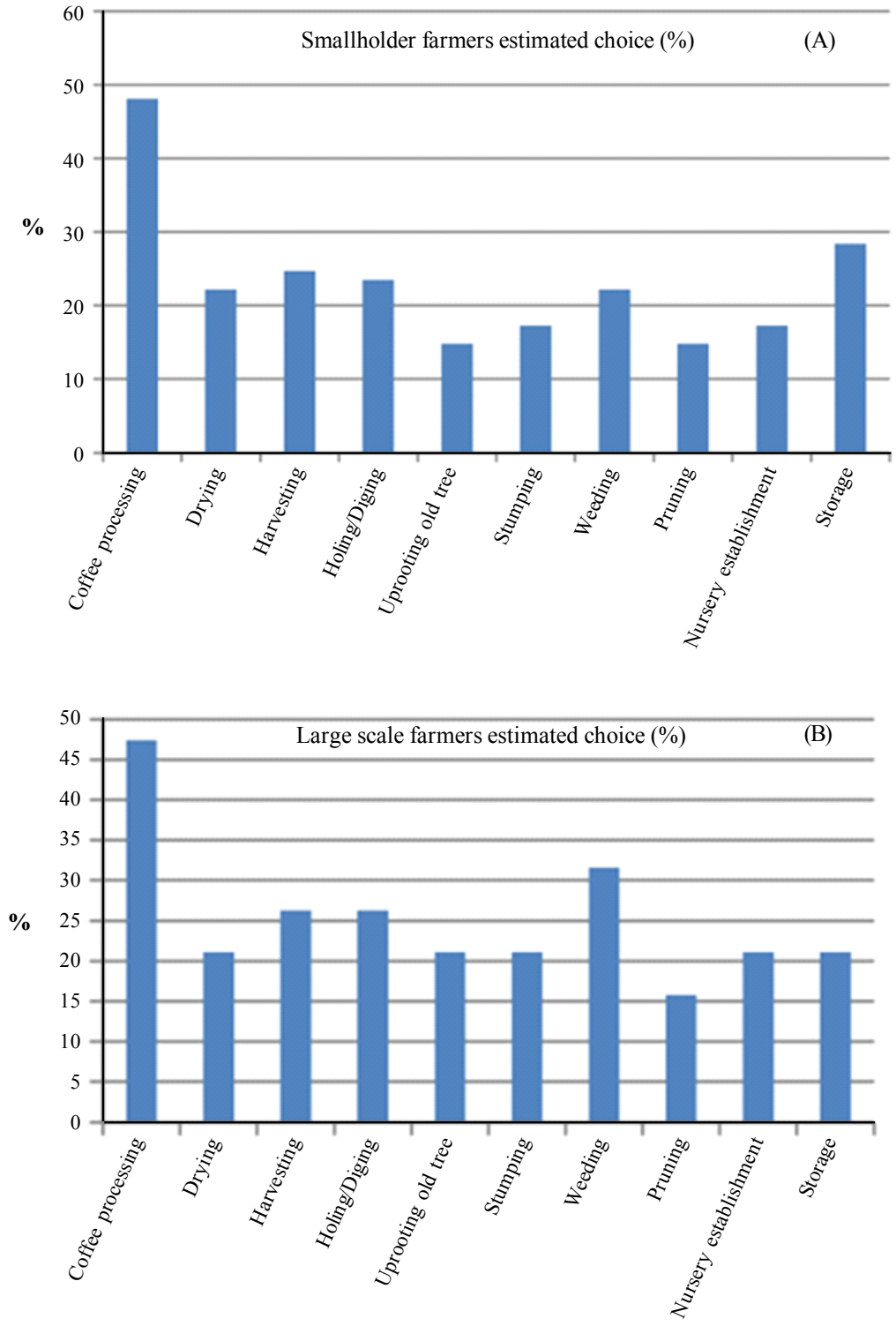

Figure 3. The overall choice for mechanization by the sample household for both small-scale (A) and large-scale farmers (B)

scales in birr per hectare showed that storage, drying, and harvesting practices have incurred higher labor costs per area in hectare respectively. The estimation of the storage and drying was by multiplying the average productivity per hectare and then the average costs in birr per hectare were estimated by the coffee farmers. Most of both small and large-scale farmers are members of coffee cooperatives and unions, but there are not any restrictions to supplying their coffee products to the cooperatives. Hence, farmers either sold the product to village traders or stored it in private storage houses for rent.

Studies revealed that per hectare of land, a single cutting or weeding operation costs an average of approximately USD 44.09 per season. In a day (8 hours), a person harvests 15 to 60 kg of red cherry coffee, which costs between USD 0.018-0.056 harvest (Diro *et al.,* 2018). Harvesting and digging have the highest value, with an overall variable price of USD 364.498 per season and a mean fee of USD 0.152 per kg (Diro *et al*., 2019). Coffee plants in Ethiopia are at least 20 years old, and some are even older than 40 years, while older coffee trees often lose productivity, resulting in lower yields over time (Laterite, 2022). Hence, the cost of coffee production is highly dependent on the stage of production, which is classified into stages based on tree age. The first stage is from the coffee establishment stage to the coffee age of one year, where huge establishment costs and zero yields are expected. The second stage covers children between the ages of two and three, which is the stage of intensive plant management. The third stage includes children between the ages of four and eight, which is a time of increased output and productivity. The fourth stage is nine to twelve years old, which is a stage of high production, cheap weed control, and expensive harvesting. The last stage is a big, ancient one, where the yield is anticipated to fall at this point and stamping and administration expenses are expected to rise to maintain the productivity of other production stages (Diro *et al*., 2019). The investigations in Jimma district revealed that the average cost of production in each stage of coffee in nursery establishment USD 134.475, hole digging USD 23.82, weeding USD 77.87, pruning USD 6.85, harvesting USD 47.30, drying USD 2.05, and storage USD 7.89 per season are estimated (Diro *et al.*, 2019).

The demand for mechanization technologies depends on the stages of coffee production, which include coffee growing, maturity, and production stages, as shown in Table 18. At the coffee maturity stage, the majority of sample households revealed maximum demand for mechanization, followed by the coffee growing and production stages, respectively.

Table 17. Total labor cost by the farm operation and farm scales

Type of farm operation	Smallholder farmers		Large scale farmers	
	Mean	SD	Mean	SD
Coffee processing/pulping (USD quintal^{-1})	16.2	7.5	40.2	0.9
Drying (USD quintal^{-1})	77.0	2.8	103.6	2.3
Harvesting (USD quintal^{-1})	88.6	2.9	362.6	11.5
Holing/digging (USD ha^{-1})	35.6	2.2	41.8	1.0
Uprooting old tree (USD ha^{-1})	24.0	1.0	33.6	0.6
Stumping (USD ha^{-1})	9.6	0.3	14.9	0.4
Weeding (USD ha^{-1})	37.6	0.8	272.2	9.2
Pruning (USD ha^{-1})	13.8	0.3	135.5	3.7
Nursery establishment (USD ha^{-1})	16.1	0.3	21.2	0.3
Storage (USD quintal^{-1})	38.6	1.1	28.1	0.3

Notes: Mean and SD of labor cost.

Table 18. The demand for mechanization of farm operation by two coffee farming scale

Type of farm operation	The demand for farming scale			
	Smallholder farmers		Large scale farmers	
	Demand (%)	N	Demand (%)	N
Maturity stage	44.4	36	47.4	9
Coffee growing	28.4	23	36.8	7
Production stage	23.5	19	15.8	3

Coffee Production Loss and Challenges

Regarding the coffee storage loss, about 71.6% and 78.9% of smallholder and large-scale farmers, respectively, have no storage technologies for coffee production. The household survey showed that pests like termites (17.3% and 15.8% of smallholder and large-scale farmers, respectively) and molds during drying (17.3% and 21.1% of smallholder and large-scale farmers, respectively) have caused the main production loss. The storage technologies that the coffee farmers used are illustrated in Table 19. The coffee farmers can keep it in the store without spoilage for six months to one year, with 41% and 36.8% for smallholder farmers and 26% and 40.7% for large-scale farmers, respectively as shown in Table 19.

The household survey indicated that coffee production losses both in quantity and quality at the farm level ranged from planting, weeding, harvesting, drying, storage, hulling, transporting, and marketing to bagging, storing, and grading practices. Reports suggested that coffee production losses in quantitative terms were noted during harvesting, with indiscriminate picking and mixing of ripe and unripe (green) cherries, as noted by the majority of the respondents. Similar reports by Tadesse *et al.* (2020) indicated that the maximum crucial constraints diagnosed in the coffee production system were two primary classes of biotic and abiotic factors that may be considered agronomic and environmental. Among the biotic elements, diseases, insect pests, weed species, and vertebrate animals were recognized as the most important ones. Recurrent drought, frost, fluctuating rainfall styles, excessive humidity, high temperature, low moisture, hail, hurricanes, wind, and reduced soil fertility were many of the abiotic factors affecting coffee manufacturing that could cause as much as 70% yield loss (Tadesse *et al.,* 2020). Also, coffee berry disorder nevertheless causes big crop losses on prone landraces, although the magnitudes vary from vicinity to region and on occasion. Other results showed that the unintended loss of cherries that are discarded during sorting and processing was approximately 5% of total coffee production (Feed the Future, 2021). The household surveys showed that the majority of quantitative losses that cause coffee production to lose money are presented in Table 20.

Farmers Coffee Cooperatives

The assessment involved focus group discussions and interview questions with 17 sample cooperatives, member farmers, members of the cooperative management, and cooperative leaders. Cooperatives were purchasing coffee from producers with and without collectors and selling their coffee to the union, which directly exported it to overseas markets. Some cooperative unions have also engaged in product processing and value addition, thereby economically benefiting their members. According to what was discovered by Tilahun (2007), practically all the cooperatives in the study area showed that their coffee markets were inefficient. Low operating capital and strict bureaucratic

Table 19. Demand of coffee storage technologies by small and large farmers

Storage techniques	The demand for farming scale			
	Smallholder farmers		Large scale farmers	
	Demand (%)	N	Demand (%)	N
Gunny bag	66.7	54	68.4	13
Sack	27.2	22	15.8	3
Traditional *Gotera*	2.5	2	5.3	1
A special place at home	1.2	1	10.5	2

Table 20. Several causes of coffee production loss (%)

Challenges of production	Coffee production loss	
	Cause of production loss (%)	N
Lack of storage facility	46.9	38
Insect infestation	51.9	42
Mold development	29.6	24
Rodent attack	28.4	23
Termites attack	34.6	28
Wild animals attack	58.0	47
Birds attack	58.0	47
Thefts during maturity	66.7	54
Bad weather condition	74.1	60
Lack of good harvesting method	46.9	38
Lack of good drying method	45.7	37
Challenges of cherry pulping machine	7.4	6
Lack of transportation	46.9	38
Drought	34.6	28
Lack of market	72.8	59
Shortage of land	45.7	37
Shortage of labor	58.0	47
Lack of high-yielding varieties	54.3	44
Low availability of quality seed	55.6	45
High cost of labor	69.1	56
The high price of good quality seed	51.9	42
Lack of good extension system	64.2	52
Poor soil fertility	24.7	20

Notes: Cause of production loss (%) and N (frequency of responses)

regulations limit cooperatives' ability to set the prices they give to farmers. Cooperatives often run washing stations where they purchase red cherries from local smallholder farmers. According to the evaluation, washed coffee generally has superior quality to sun-dried coffee and commands a higher border fee.

One of the challenges for the cooperatives was poor harvesting practices by member farmers that reduced the quality of coffee during processing. With overripe coffee, there is a possibility that the cherry will start fermenting, which causes a deterioration in flavor. The coffee cherries are dried immediately after harvest. This is usually done by sun drying on a clean, dry floor or mats, and the bed depth should be less than 40 mm. The most serious problem is dust and dirt blown onto the produce. Another problem is that rainstorms often appear (even in the dry season) with little warning and soak the product quickly.

The wet process involves pulping the fruit; the dry process involves drying the fruit in the sun or hot-air dryers. Washing removes all remaining traces of pulp from the coffee beans, which are then dried to a moisture content of about 12 percent. The fruits are mechanically hulled to free the seeds from their coverings and remove them from the pulp. Ethiopia exports 80 to 85 percent natural

or sun-dried coffee and 15 to 20 percent wet-processed coffee. Some areas prefer dry processed coffee for its "fuller" flavor, which is the simpler of the two methods used by coffee cooperatives. During drying, in addition to direct sun drying and artificial hot air dryer, the solar tunnel dryer has been recently introduced. Drum pulpers involve a rotating drum with a punched sheet surface and adjustable breastplate between, in which the pulp and beans are separated. Disc pulpers are the same concept, but a disc with a roughened surface is used. One of the coffee pulper machine models that were used recently in cooperatives and old machines was Aagaard pregrader, McKinnon, made in Brazil.

Most cooperatives that are members of the Sidama Coffee Farmers' Union have two or more wet mills; however, the mills use old machinery, which causes low efficiencies and high water consumption. An assessment of needs identified a range of equipment improvements and spare parts required at the wet mills of the various cooperatives participating in the assessment. It is expected that machinery upgrades will significantly improve product quality and the environmental sustainability of most cooperatives' wet mills. Less than 1% of coffee harvested in Ethiopia undergoes secondary processing carried out by cooperatives and local roasters that roast, grind, and package the coffee for sale either in the domestic market or for export. This may be because society has developed a negative attitude toward cooperatives in general. More active participation and coordination of members, managerial staff, and government bodies are required to make the cooperatives more incapacitated and efficient. Cooperatives in the coffee sector provide a variety of services, and there is a trade-off between them. In other words, coffee cooperatives appear to be poor at improving the performance of coffee markets but successful in providing increased inputs for the cultivation of food commodities. Our study demonstrated the value of looking beyond average effect comparisons since the cooperative membership effect is varied by member characteristics. This research demonstrates the significance of social impacts like women's empowerment and the indirect ripple impacts on food security to understand overall performance, whereas most empirical literature focuses on the direct economic effects of participation in a product market (Shumeta, 2017).

Development Office Representatives

Each zone's agriculture office was organized, and each zone had a coffee, tea, and spice office specifically representative of extension systems on those crops' productivity and quality experts, who were accountable to Ethiopia's coffee and tea authorities under the Ministry of Agriculture. Hence, the assessment was conducted on 12 randomly selected mechanization, coffee, and tea extension experts from each Wereda in the zone. The primary crop produced in the target survey area is coffee, but secondary crops are also available, including Enset, sorghum, maize, and beans. The coffee production type is mainly non-forest, which was encouraged by the experts, and organic. Most of the expertise revealed that the existing improved coffee mechanization practices in this survey area are coffee pulpier and de-huller machines. However, land preparation and cultivation are primarily done with primitive hand tools. It was stressed that the demands regarding improved mechanization technology in coffee production activities like land preparation, value addition, and post-harvest processing are land-forming cultivators, hole diggers, coffee processing, coffee storage technologies, and water pumps for coffee washing. It enables large-scale farmers to process and store coffee on their own, increasing their income from coffee sales, which is consistent with large-scale farmers' certification to export coffee to foreign markets.

In collaboration with some governmental and non-governmental organizations, the experience related to the coffee extension system was an adaptation of improved seed, poly bags, poly sheets, and plastic mats, as well as hand tools such as pruning scissors, hand pulping machines, stamping hacksaws, gloves, and animal carts. ECX, Feed the Future, U-Project, Ommo Microfinance, FOSEK (Food Security in Ethiopia and Kenya), Techno Service, Jimma Agricultural Research Center, and Ommo Microfinance were involved in the adoption of technologies for coffee production, however, experts regard mechanization as a significant gap. The assessment also showed that the main challenges for this low level of mechanization were difficult topography and fragmented land, a lack of manpower in agricultural mechanization, a lack of awareness of the technology, weak linkages of coffee mechanization channels, the high cost of technologies, a shortage of running budgets, and the weak support system of cooperatives and unions.

The experts revealed that the best way to facilitate the extension system of coffee mechanization technology was through capacity building of the extension experts, initiating mechanization experts at least in each zone, and continuing training and awareness creation for coffee producer farmers. A strong business linkage between farmers, coffee processors, industries, cooperatives, and unions is a big gap. It was also revealed that farmers are always ready to adopt agricultural mechanization if it is efficient and affordable. Individual and corporate farming were both land-holding characteristics in the coffee farming system. In the east and west Harergie, the average land ownership was lower than 2 ha and garden coffee production, whereas another location had relatively higher ownership, including forest coffee, difficult topography, and weak institutional coordination. On the other hand, coffee state farms are highly expanded in Gedeo, Benchi Sheko, Jimma, Keffa zones, and the Sidama region with relatively good coffee mechanization practices.

Technology Manufacturers and Importers

Assessments of technology manufacturers, machine assemblers, maintenance service providers, and importers were conducted in Harar, Hawassa, Jimma, Bonga, and Addis Ababa cities. Around seven machine manufacturers and importers or dealers were interviewed using informal discussions, target group meetings, and semi-structured questionnaires. During the assessment, it was discovered that coffee mechanization technology dealers and importers were restricted to Addis Ababa and did not only supply coffee-based mechanization technologies but also other mechanical implements primarily imported from China, Brazil, and India. Coffee mechanization is hampered by constraints faced by manufacturers, importers, and businesses that hire services. The assessment noted that challenges include a lack of enabling laws and incentives to facilitate business start-ups and enterprise operations, a lack of working places for manufacturers, discouraged import and export regulations, and foreign currency shortages. Small-scale private sector coffee processing machines like pulper and huller service providers are available in Hawassa, Jimma, and Addis Ababa, which are small-scale and limited to only pulper and huller machines. The markets for hire services are also in their infancy; there is usually very little demand due to the lack of awareness among smallholders of the need for mechanized services. Low demand is mainly a consequence of lack of development, but there are other constraints obtained from the assessment.

Importers and dealers supply coffee-based tools like sickles, pruning scissors, stumping hoes, weeding machetes, and pulping and hulling machines, which are available in Addis

Ababa, Hawassa, Jimma, and Bonga. Aside from dryers, importers and dealers of both artificial hot air dryers and solar tunnel dryers established themselves in Ethiopia. However, those are not specifically imported coffee-based machines that import and sell limited quantities of selected Chinese, Brazilian, and Indian brands. These companies are typically located in the country's capital city, but they may also have branches in other major cities and towns. Nevertheless, sales of major items of equipment (coffee grading, packaging, roasting, and harvesting machines) remain very low or almost non-existent. For this reason, it needs companies to diversify its activities, selling other kinds and brands of machines.

Donations of coffee processing machinery and other implements are often made to cooperative unions. However, almost all of these well-intentioned programs fail to produce the desired results. There is a lack of compatibility between products manufactured in donor countries and other machines already on the market, and, therefore, spare parts are unavailable. Donated machines quickly become "orphans": no services are available, and once the first breakdown occurs, the machines cannot be repaired. Importation of used equipment, particularly coffee processing and other specialized machinery, is an additional means to meet demand in some cooperatives and may provide farmers with an alternative source of cheaper machinery. However, in practice, this system is not necessarily beneficial to farmers, as the importer does not always provide additional services, such as repairs and the provision of spare parts. Used machinery is typically imported and sold in areas where technicians with relatively high levels of skill and knowledge are available, but labor costs are low. However, without specialized knowledge of agricultural machinery, failure is almost predictable.

The countries' manufacturing industries produce only the most basic hand tools, farm implements, and processing equipment, primarily for the artisan (blacksmith), small-scale workshop, and garage sectors. Maintenance and repair of those implements are generally straightforward and carried out at the local level by small workshops in the informal sector. On the other hand, training and refresher courses are not always available to other micro-enterprises in the private sector. Maintenance facilities are poor, and there is often a critical lack of spare parts, leading to long periods of downtime, underutilization of equipment, and, eventually, premature write-offs. A few decades ago, there was much emphasis on public sector programs and projects to develop agricultural mechanization maintenance and repair centers. However, these were not very successful, and most have since fallen into neglect.

CONCLUSIONS

As a primary coffee producer in Africa and the fifth globally, Ethiopia faces challenges in utilizing mechanization technology. This study analyzed coffee production trends and mechanization technology demand, and reveals that preferences for each operation during coffee production are based on work drudgery, with 42.45% believing that hole digging is the most time-consuming and energy-consuming operation. Coffee harvesting is a highly time-sensitive operation, with 49.4% and 47.4% of smallholder and large-scale farmers' preferences, respectively. Weed control on coffee farms is a significant challenge for both small-scale and large-scale farmers, with hand tools being the primary weeding implement. A household survey found that 3.70% and 5.30% of smallholder and large-scale farmers do not cultivate their coffee farms and use forest coffee production. A study of 17 Ethiopian cooperatives assessed their coffee purchasing practices, focusing on poor harvesting practices and outdated wet mills. The research highlighted

the importance of considering social impacts like women's empowerment and food security to understand overall performance. The study also highlighted the need for equipment improvements and spare parts at wet mills. Existing coffee mechanization practices include pulpier and de-huller machines, while land preparation and cultivation are primarily done with primitive hand tools. Improved mechanization technology is needed for land-forming cultivators, hole diggers, coffee processing, storage technologies, and water pumps for washing. Challenges include difficult topography, fragmented land, a lack of manpower and awareness, weak linkages, high technology costs, budget shortages, and weak cooperative and union support systems. The experts suggest capacity building for extension experts to facilitate the coffee mechanization technology extension system. Small-scale private-sector coffee processing machines are available in Hawassa, Jimma, and Addis Ababa, and importing used equipment, particularly coffee processing and specialized machinery, is an alternative source of cheaper machinery for cooperatives and farmers. It is essential to increase the availability of pre-harvest, harvest, and processing technologies with incentive structures for hiring service providers, support for producer groups, and specialist access to machine loans. Expanding mechanization in Ethiopian coffee production is crucial, necessitating the development of human resources at all levels. The supply chain approach to mechanization analysis offers a useful framework for defining mechanization processes in Ethiopia. Stakeholders should design strategies to improve relationships, technology, coffee quality, irrigation services, interest-free credit, market information, and experienced managers, and shorten distances between members and cooperative societies.

REFERENCES

Alemayehu, D. & W. Merga (2017). Current status of Arabica coffee (*Coffea arabica* L.) genetic resource: Conservations, constraints and mitigation strategies in Ethiopia. *International Journal Research Study Science Engineering Technology*, 4(10),1–11.

Beshah, B.; D. Kitaw & T. Dejene (2013). Quality and value chain analyses of Ethiopian coffee. *Journal of Agriculture and Social Research* , 13(2), 35–41.

Budd, O. (2022). Increasing coffee yield by stumping incentives. *Laterite.*

CSA (2022). Agricultural sample survey 2021/ 2022. Volume I. *Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Statistical Bulletin, 593*. Central Statistical Agency of Ethiopia. Addis Ababa, Ethiopia.

Dida, G. (2022). Coffee production: Opportunities, challenges and genetic diversity in Ethiopia. *International Journal of Research Studies in Agricultural Sciences*, 8(3), 1–9.

Diro, S.; B. Erko & D. Teferi (2018). Assessment of coffee farmers mechanization demand for resource use efficiency: Survey result of Gomma District of Jimma Zone. *World Journal of Agricultural Sciences*, 14(4), 136.

Diro, S.; B. Erko & M. Yami (2019). Cost of production of coffee in Jimma Zone, Southwest Ethiopia. *Ethiopian Journal of Agricultural Science*, 29(3), 13–28.

Duressa, E.L. (2018). The socio-cultural aspects of coffee production in southwestern Ethiopia: An overview. *British Journal of Multidisciplinary and Advanced Studies*, 2(2), 11–26.

FDRE (2009). *Country Program Evaluation of the Democratic Republic of Ethiopia.* Democratic Republic of Ethiopia.

Feed the Future. (2012). *Postharvest Loss Brief: Coffee, Feed the Future Ethiopia Value Chain Activity Partnering with*

the Agricultural Growth Program. Feed the Future. Addis Ababa, Ethiopia.

Fortune, C.F. & D. Tawanda (2013). An assessment of agricultural mechanization index and evaluation of agricultural productivity of some fast track resettlement farms in Bindura District of Mashonaland Central Province: Zimbabwe. *International Journal of Social Science and Interdisciplinary Research*, 2(7).

ICO (2015). *Historical Data on the Global Coffee Trade*. Statistics. International Coffee Organization.

Minten, B.; S. Tamru; T. Kuma & Y. Nyarko (2014). *Structure and Performance of Ethiopia's Coffee Export Sector. Working Paper 66. June 2014*. Ethiopian Development Research Institute (EDRI) and International Food Policy Research Institute (IFPRI). Addis Ababa.

Moat, J.; J. Williams; S. Baena; T. Wilkinson; S. Demissew; Z.K. Challa; T.W. Gole & A.P. Davis (2017). *Coffee Farming and Climate Change in Ethiopia: Impacts, Forecasts, Resilience, and Opportunities. – Summary*. The Strategic Climate Institutions Programme (SCIP). Royal Botanic Gardens, Kew, UK.

Motebayenore, E. (2022). Review on coffee production constraints and opportunities in Ethiopia. *Journal of Horticulture*, 9(1). No. 1000082.

Muhie, S.H. (2022). Strategies to improve the quantity and quality of export coffee in Ethiopia: A look at multiple opportunities. *Journal of Agriculture and Food Research*, 10(August), 100372.

Rudragouda, B.; C. Mukharib; D.S. Mote; K. Gokavi; N. Ramya; A.N. Manjunath & Y. Raghu-ramulu (2017). Mechanization in Indian coffee plantations: Evaluation of different types of machinery to improve labor use efficiency and to reduce drudgery. *International Journal of Current Microbiology and Applied Sciences*, 6(2), 744–751.

Shumeta, Z. (2017). *Impact of Cooperatives on Smallholder Coffee Producers in Southwest Ethiopia*. The Netherlands Organization for International Cooperation in Higher Education (NUFFIC), The Netherlands.

Stellmacher, T. & U. Grote (2011) : Forest coffee certification in Ethiopia: Economic boon or ecological bane?, *ZEF Working Paper Series, No. 76*, University of Bonn, Center for Development Research (ZEF), Bonn

Tadesse, T.; B. Tesfaye & G. Abera (2020). Coffee production constraints and opportunities at major growing districts of southern Ethiopia Coffee production constraints and opportunities at major growing districts of southern Ethiopia. *Cogent Food and Agriculture*, 6(1).

Tefera, A. & T. Tefera (2014). *Ethiopia. Coffee Annual Report. Report (Number ET1402–13/5/2014)*. Global Agriculture International Network (GAIN). USDA Foreign Agricultural Service.

Tefera, T.; B. Yaziz & T. Shimbir (2019). Response of coffee genotypes (*Coffea arabica*) for moisture stress condition at Tepi, South West of Ethiopia. *International Journal of Research Studies in Agricultural Sciences*, 5(1), 8–13.

Teferi, D.; A. Yilma & L. Beksisisa (2018). *Assessment Report on Effect of Dust on Coffee Production at Biftu Quarry Site*. Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center, Jimma, Ethiopia.

Tilahun, D. (2007). *Performance of Coffee Marketing Co-Operatives and Members' Satisfaction in Dale District: SNNPRS-Southern Ethiopia*. Haramaya University, Ethiopia.

Wolde, Z.; A. Tefera; S. Yared; T. Gezahagn & T. Tadesse (2017). A review on coffee farming, production potential and constraints in Gedeo Zone, Southern Ethiopia. *Journal of Natural Sciences Research*, 7(23), 1–9.

World Bank (2009). *World Development Report 2010: Agriculture for Development. Vol. 30*. World Bank. Washington, D.C.

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