Ethiop. J. Agric. Sci. 34(1) 60-79 (2024)

Investigating Soil Types, Crops and Use of Inorganic and Organic Fertilizer in Mixed Farming System of Ethiopia: A Baseline Survey

Temesgen Jembere[1*], Tadele Mamo[2], Musa Jarso[1], Ulfina Galmessa[1], Kebede Dinkecha[1], Gezahegn Mengistu[1], Takele Mebratu[1] and Fekede Feyissa[2]

[1] *Holeta Agricultural Research Center, Holeta, P O Box 31;*
[2] *Ethiopia Institute of Agricultural Research, P O Box 2003*
[*]*Corresponding author:* - tjbakara@yahoo.co.uk

Abstract

Due to high mineral fertilizer prices, use of available alternative organic fertilizers has got focuses now-a-days. Objectives of the current work were to investigate major soil types and means of soil fertility analysis by farmers, inventory crops grown, usage of improved seeds and yields of major crops, and reveal usage of inorganic and organic fertilizers in selected districts of East Shewa and West Shewa zones of Oromia regional states of Ethiopia. The study districts of the zones represented mid altitude and highland agro-ecologies of the country. The dominant soil type in East Shewa zone was Vertisols while that of West Shewa was Nitisols. In both zones, observations of soil texture and crops growth performance were used to judge soil fertility by farmers. Teff, barely, wheat and faba bean were the major crops grown where the productivity was the lowest for Teff (951 kg ha^{-1}) and the highest (2337 kg ha^{-1}) for wheat. Chemical fertilizer usage was lower for faba bean compared to the cereals. Usage of sewage, bio-slurry, green manure, cover crops and mulching were not common. About 62% of respondents reported that livestock manure was not sufficient to fertilize own crop fields still could be used in combination with chemical fertilizers. Future research should focus on characterizing crop productivity under different levels of agricultural inputs under farmers' management.

Keywords: Bio-slurry; chemical fertilizer; green manure; mulching; Nitisol; organic fertilizer;Vertisols

Introduction

Agriculture in Ethiopia is not only the backbone of the country's economy but also determines the growth of all other sectors. However, the agricultural production is overwhelmingly subsistence (Getu and Almaz, 2022). Smallholder farmers who practice rain-fed mixed farming dominate the sector. The small-scale farmers that make about 90% of the total agricultural product till about 95% of the total area under agriculture using animal power (Hanjira *et al.* 2009) which indicate that crop production is highly dependent on livestock production. The livestock manures are also potential organic fertilizers for crop fields. However, the proportion of crop fields treated with organic fertilizer has showed a decreasing trend in the last decade (Desta *et al.* 2023).

In relative term, use of chemical or inorganic fertilizer increased from 12 kg ha^{-1} in 1996 to 36 kg ha^{-1} in 2018 in Ethiopia, and consequently, the main cereals' production also increased from 1.65 t ha^{-1} in 2009 to 2.394 t ha^{-1} in 2018 (Tilahun *et al*. 2022). However, both use of chemical fertilizers and crop yield are quiet low relative to other developing countries. According to same source, soil fertility reduction in Ethiopia is evolving as a serious contest causing low crop yields. At the country level, nutrient balance indicated a depletion rate of 122 kg N $ha^{-1}year^{-1}$, 13 kg P $ha^{-1}year^{-1}$, and 82 kg K $ha^{-1}year^{-1}$ which could be the major cause for yield reduction (Haileslassie *et al*. 2005). Unless these soil nutrients are replaced, the agricultural productivity even will go down. Due to high mineral fertilizer prices, use of available alternative organic fertilizers is vital. Nitrogen fixing legumes, livestock manure and compost are organic fertilizers, which could partially or fully replace the chemical fertilizers in general. Exhaustive list of atmospheric nitrogen fixing legume plants are available for Ethiopian farmers. Different legume plants could be screened based on their potential of soil fertility improvement. Knowledge of soil names and types is essential in making crop production decisions. Knowledge of soil types could be used to reduce the negative impacts of unpredictable rain on smallholder farming (Rankoana, 2023). Through soil analysis, farmers can make informed decisions about the crops to be produced, determine the quantity and types of fertilizers to be used, and strategize their soil management practices to optimize their crop production. Understanding the nutrient composition of the soil enables farmers to prevent insufficient or excessive application of any fertilizer to their crop fields. In general, success of soil management depends on understanding of how soils respond to agricultural land use practices over time (Elias, 2017). However, the major soil types which could determine the management to be made to different crops are not well known in East Shewa and West Shewa zones. It is also not clear whether farmers could conduct soil fertility analysis of their crop land. Usage of inorganic and organic fertilizer types including livestock manure of soil fertility improvement means in East Shewa and West Shewa zone also requires documentation. As per the plan of Korea Africa Food and Agriculture Cooperation Initiative-Crop-Livestock Agriculture (KAFACI-CLA) project which was implemented in 16 African countries including Ethiopia, investigating use of other fertilizers alternative to chemical fertilizers across the 16 project implementing countries was required. These alternative fertilizers included sewage, bio-slurry, green manure, cover crops, mulching, and livestock manure. Therefore, the objectives of the current work were (1) to investigate major soil types and means of judging soil fertility by farmers, (2) to inventory crops grown, usage of improved seeds and yields of major crops and (3) to reveal usage of chemical and other types of fertilizers in East Shewa and West Shewa zones of Oromia regional states of Ethiopia.

Materials and Methods

The study areas

The survey was conducted in two administrative zones of Oromia Regional State of Ethiopia namely East Shewa and West Shewa that represent mid altitude and highland agro-ecologies, in respective order. East Shewa is found on the eastern direction and West Shewa is found on the western direction. The capital town of East Shewa zone, Adama, is found at about 100 km from Addis Ababa and that of West Shewa, Ambo, is found at about 115 km from Addis Ababa. The geographical map of the surveyed districts and kebeles from both East Shewa (Figure 1) and West Shewa (Figure 2) are indicated hereunder. Adea and Lomme districts from East Shewa and Ejere and Welmera districts from West Shewa were considered in the present study. Different colors are used to demarcate study districts while the surveyed kebeles are filled by unique colors. The districts or regions/sub-cities bordering the study districts are indicated in Table 1.

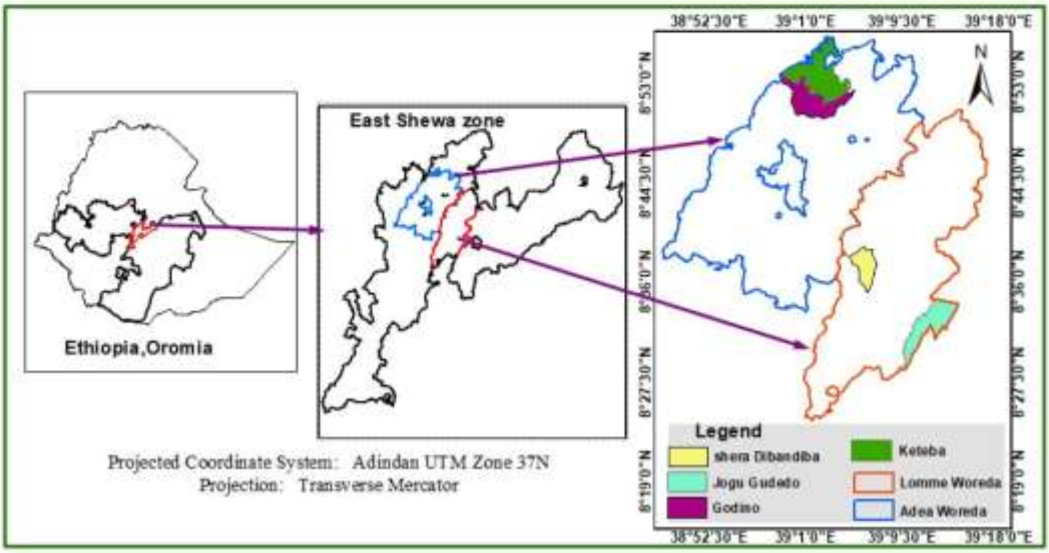

Figure 1. Map of districts and kebeles where the survey was conducted in East Shewa zone of Oromia region, Ethiopia.

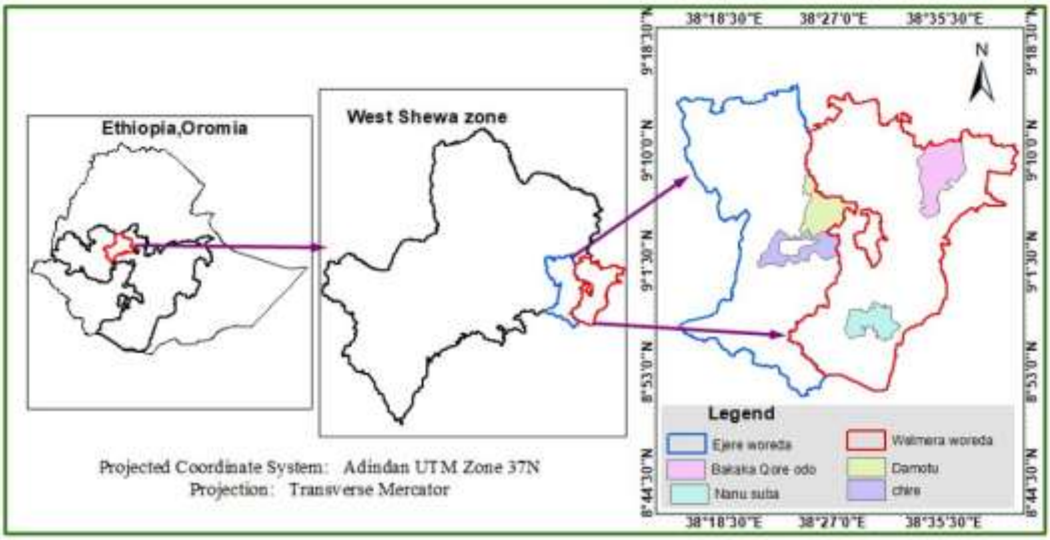

Figure 2. Maps of districts and kebeles where the survey was conducted in West Shewa zone of Oromia region, Ethiopia.

Table 1. Administrative zones, districts or sub cities bordering surveyed districts from different directions

District	North	West	South	East
Welmera	Mulo district	Ejere district	Sebeta Hawas	Sheger city
Ejere	Meta Robi district	Ejersa lafo	Southwest Shewa Zone	Welmera district
Ada'a	Akaki and Gimbichu districts	West Shewa zone	Dugda Bora district	Lome district
Lomme	Amhara Region	Ada'a district	Koka Reservoir	Adama city

The respondents' selection strategy was multistage. There was a mobility and logistics limitations at the time of conducting the survey to reach various zones and districts in the country; hence, the research team of KAFACI-CLA project in Ethiopia agreed to conduct the current survey in East Shewa and West Shewa Zones of Oromia, Ethiopia. The project team were composed of researchers from livestock, pulse crops, socio-economics, soil chemistry and livestock feeds. The districts were almost selected purposively. Higher officials at regional and respective zonal level were requested to suggest districts that practice crop-livestock production systems most and easily accessible as well. District level officials and livestock experts were given free chance to suggest any Kebele from their districts. In the same way, Kebele level development agents and Kebele managers identified farmers; they were, however, informed to focus on farmers that rear livestock and produce crops simultaneously in addition to considering female headed households. Experts and officials at district level played great role in mobilizing respective kebele development agents and other kebele administrative personnel. The kebele development agents and kebele administrators, in turn, facilitated the interview of the questionnaire through randomly selecting and appointing respondent farmers and communicating the enumerators for ease time management. Finally, 203 respondent farmers were interviewed from the two zones during September 18 to November 27, 2023. Out of the 203 respondent farmers, however, two interviews were discarded because of failing to fulfil the minimum requirement; the data analysis was based on the interview of 201 (94 from East Shewa and 107 from West Shewa) respondents. Detail of districts in which the survey was conducted is given in Table 2. The formula used for selecting the sample of the respondents is indicated herewith:

Formula developed by Cochran (1977) using pre-survey preliminary field assessments:

$$n = \frac{Z^2 pq}{e^2}$$

Where, n is the sample size, Z the standard normal distribution variable represented by the normal curve that cuts off an area α at the tails ($1 - \alpha$ equals to the desired confidence level, e.g., 95%), e is the desired level of precision, P is the estimated proportion of cooperative members in the population, and q is $1 - P$ representing the proportion of non-member farmers in the population. The value for Z is found in statistical tables which contain the area under the normal curve. It is recommended to assume maximum variability (P=0.5) with a 95% confidence level and ±5% precision level to produce a more conservative sample size (Israel, 2013). A desired level of precision of 0.0693 (~ 0.07) or less is well enough to have a representative sample. In this study, we set a desired level of precision at 0.07 and obtained a sample size of 201 as follows:

$$n = \frac{(1.96)^2(0.5)(0.5)}{(0.07)^2} = 201$$

Table 2. Summary of information where the KAFACI-CLA project main survey was conducted in Ethiopia

№	Kebele	District	Zone	Number of participants
1	Bakaka Kore Odo	Welmera	West Shewa	32
2	Chirri	Ejere	West Shewa	29
3	Damotu	Ejere	West Shewa	23
4	Godino	Adea	East Shewa	26
5	Jobo Gudedo	Lume	East Shewa	22
6	Kataba	Adea	East Shewa	23
7	Nano Suba	Welmera	West Shewa	23
8	Shara Dibandiba	Lume	East Shewa	23
Total	8	4	2	201

Questionnaire and Data collection: A semi-structured questionnaire was uploaded to a free open-source tool, called Kobo Toolbox (https://www.kobotoolbox.org/) that was used for the collection of the data. This tool is similar to the Open Data Kit (ODK) and others open-source mobile data collection means. The Kobo Toolbox helps to collect, transfer, and process the data collected using Android phones and tablets with or without internet connectivity.

Data collection and analysis: Rainfall pattern and cropping seasons, household characteristics, farming experiences, soil types and analysis of cropping fields, major crops grown, adoption of agricultural inputs including chemical fertilizers, usage of other fertilizers than chemical fertilizers including livestock manure and yields of major crops were collected. The use of chemical fertilizer (Urea and NPS) for major crops was judged by calculating the proportion of plots sown without any fertilizer, plots on which less than 100 $kgha^{-1}$ fertilizer was applied, plots on which 100 $kgha^{-1}$ fertilizer was applied and plots on which greater than 100 $kgha^{-1}$ fertilizer was applied. In the case of understanding the respondents crop land soil types, enumerators got explanation of the characteristics of respective soils and categorized to one of the soil types presented as alternative in the current survey work. These soil types were Andosols, Cambisols, Nitisols and Vertisols. Consensus on the characteristics of these soil types was reached on before starting the survey. In analyzing percent and yields of crops grown in the two zones, relatively smaller number of observations were used. This was due to the fact that yields from considerably smaller plots were ignored in analyzing crop yields where these were used to calculate the percentage of crops grown. Descriptive statistics, general linear model and logistic regression methods were used to analyze the data.

Results and Discussion

Cropping season

Out of 201 respondents in the surveyed area, 95.52% mentioned that the rainfall pattern was uni-modal which means that crops were produced once per year (Figure 3). In the context of this study, the cropping season refers to the number of months in a year during which sowing begins for major crops and harvesting is completed for those same crops. The cropping season was reported to be during different ranges of months where the majority of the respondents indicated that it was during June to December. Considerable number of respondents also indicated that it was during June to January.

Risks associated with rainfall variability are one of the most visible concerns of rainfed agricultural production in developing countries. The opportunity of producing crops twice in a year is exploited when the rainfall pattern of an area is bimodal which was not the case for the current study locations. Rainfall variability was linked to risks such as late onset, early cessation, short and prolonged dry periods, and drought with a high frequency and moderate-to-severe intensity.

Where there is a moderate to strong intensity of drought, planned interventions such as climate advisory service, water conservation practices, supplemental and deficit irrigation, using drought tolerant and early maturing crops, and using multiple cropping and livelihood diversification have to be introduced to the area to cope with the effect of risks associated with rainfall variability in addition to farmers' own adaptive strategies (Habte *et al*. 2023). However, in the current study area, none of such rainfall risks were reported where the rainfall in North Shewa, an adjacent zone to both study zones, was reported to be highly variable both in space and time (Wagaye and Anteneh, 2020).

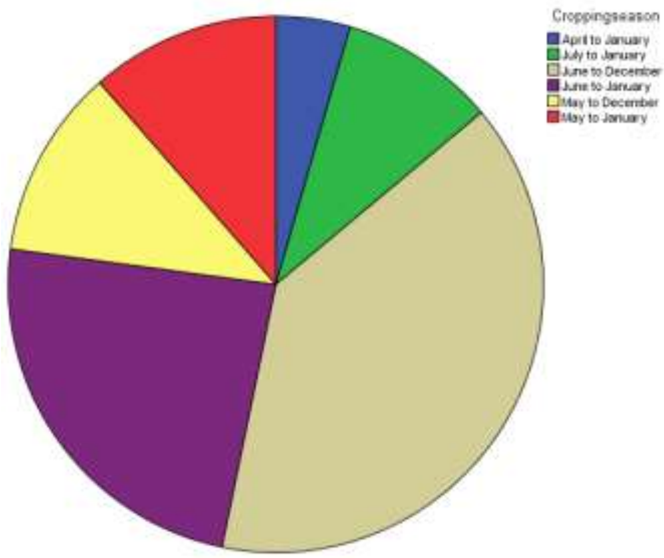

Figure 3. Cropping seasons in East Shewa and West Shewa zones, Ethiopia.

Demographic characteristics of the respondents

The age, family size and farming experiences of the heads of the households of the respondents during the survey is given in Table 3. The age of the respondents ranged from 22 to 75 years where there was no significant difference between the zones. The overall least squares mean age of respondents was 46.72±11.364 years. Age is a significant factor influencing survey responses, affecting participation rates and the quality of data collected. An increasing age of respondents and cognitive impairment are usual suspects for increasing difficulties in survey interviews and a decreasing data quality (Danuta and Marta, 2021; Schanze, 2023) where engagement of younger age respondents could increase the likelihood of incomplete survey responses. The average age of respondents in the current study could show that information was collected from middle age respondents justifying the reliability of the information.

The overall least squares mean of family size of the respondents' house hold was 5.14±1.800 where the range was from 2 to 10. The family size showed significant difference by the two zones where relatively higher number of family size was reported in West Shewa zone compared to the east Shewa zone. The average family size in Ethiopia was estimated to be about five (CSA, 2016; CSA and World Bank, 2020; ILO, 2021). The family size of the respondent in the current study is in agreement with the existing evidences. The implication of family size could be for minimum wage setting and adjustment at national or regional level (ILO, 2021), evaluation and improvement of existing government programs or initiatives (CSA, 2016) and to estimate the dependency ratio within the household (CSA, 2016; World Bank, 2020).

The average experience of respondents in agricultural farming was 24±12 years where the range was from 2 to 55 years. In general, the age of respondents and experiences of the respondents could indicate whether the information gathered from these respondents was reliable. Studies indicated that farming experiences can contribute to the entrepreneurial decision of urban resident's relative to those without experience in agricultural farming (Zhou and Li, 2022). Farming experience was found to be useful in early stages of adoption of a given agricultural technology (Ainembabazi and Mugisha, 2014) as well.

Table 3. Age and family size of the respondents for the crop livestock related questionnaire in Ethiopia

Parameter	Overall mean		East Shewa		West Shewa		Ranges
	N	LSMeans	N	LSMeans	N	LSMeans	
Age of HH (year)	201	46.72±11.364	94	46.43±1.18	107	46.97±1.09	22 – 75
Family size per HH (number)	201	5.14±1.800	94	4.46±0.18	107	5.72±0.173	2 – 10
Farming experiences (year)	201	24.24±11.667	94	24.09±1.21	107	24.37±1.12	2 – 55

LSMean=Least Squares Means; HH=Household head; N=Number of respondents

Primary and secondary activities of farmers

Agricultural activity was the sole primary activity for all the farmers in the present studied areas. Majority of the respondents (about 86%) did not have additional secondary activity than agriculture which indicated that the agricultural activity was the mainstay of the farmers but few of them were employee (6%), art workers (1%) and traders (7%) (Figure 4). The fact that majority of the respondents did not have secondary activity to agriculture did not show significant differences by the study sites. Other studies, however, indicated that non-agricultural participation ranges from 17 to 37% in Amhara and the then SNNPR regions, respectively (Mosa *et al*. 2019). The same source also indicated that the rate of non-agricultural activity participation varies across the different economic sectors such as trade (52%), manufacturing (36%) and service provisions (12%). The presence of secondary activity may help the rural farmers in diversifying their income and livelihoods. Rural households could also engage in non-agricultural activities when they do not have agricultural land, and have low earnings. According to Mosa *et al.* (2019), the major constraints limit the participation of farmers on non-agricultural or secondary activities are poor access to road, credit facility, market opportunities and lack of education/training.

Figure 4. Percentage of Respondents with different activities in East and West Shewa zones, Ethiopia

Soil types in cropping fields in East Shewa and West Shewa zones

According to the data gathered from the respondents in the surveyed districts of East Shewa zone of Ethiopia, the majority of soil types in the surveyed areas were Vertisols while other soil types including Nitisols were also reported (Table 4). On the other hand, Cambisols and Andosols were known to be not common soil types in current surveyed districts of East Shewa zone. Vertisols are among the most extensive soil types in the Ethiopian highlands, occurring in a wide range of agro-ecological zones where complex crop-livestock farming systems are practiced (Elias *et al*. 2022). According to Santra *et al.* (2017), understanding the interplay between land use systems and soil properties is key to find avenues to sustainable agricultural production. Vertisols generally show a large spacial difference in soil properties, even over relatively short distances. As a result, these soil types remain the most difficult resource systems in the world to manage successfully (Somasundaram *et al.* 2018; Kovda, 2022). On the other hand, vertisols are generally hard when dry and sticky when wet with a very low infiltration rate when the surface is sealed (Debele & Deressa, 2016).

The majority of soil types in surveyed districts of West Shewa zone were found to be Nitisols where considerable proportion of respondents indicated that portion of their crop fields were vertisols in this zone (Table 4). Nitisols are among the most extensive agricultural soils in the Ethiopian highlands but soil degradation threatens productive capacity of these soil types (Elias, 2017). The crops grown in

East and West Shewa zones include, but not limited to, teff (*Eragrostis tef*), wheat (*Triticum spp.*), barley (*Hordeum vulgare*) faba bean (*Vicia faba*), field pea (*Pisum sativum*), grass pea/rough pea (*Lathyrus sativus*), chickpea (*Cicer arietinum*), lentils (*Lens culinaris*), linseed (*Linum usitatissimum*), noug (*Guizotia abysssinica*) and fenugreek (*Trigonella foenum-graecum*) (ESS, 2023). Sustainable agricultural production on Nitisols depends on the replenishment of organic matter and application of fertilizers in proper balance and right amounts (Elias & Agegnehu, 2020).

Table 4. Number of farmers that indicated their cropping field soil types in East Shewa and West Shewa zones of Ethiopia

Zone	Plot with soil type (%)	0%	(0-25%]	(25-50%]	(50-75%]	(75-100%]
East Shewa	Nitisol	72.0	11.8	9.7	3.2	3.2
	Vertisol	20.4	9.7	15.1	19.4	35.5
	Cambisol	92.5	2.2	3.2	0.0	2.2
	Andosol	78.5	7.5	4.3	6.5	3.2
	Others	90.3	0.0	1.1	0.0	8.6
West Shewa	Nitisol	1.9	6.5	10.2	9.3	72.2
	Vertisol	64.8	16.7	13.0	3.7	1.9
	Cambisol	100	0.0	0.0	0.0	0.0
	Andosol	100	0.0	0.0	0.0	0.0
	Others	100	0.0	0.0	0.0	0.0

Soil fertility analysis in the study area

Means of judging soil fertility includes soil test at laboratory, plant tissue analysis, soil texture observation and crop growth observation. These methods were investigated in the current study area (Table 5). In in the surveyed districts of both zones, respondents revealed that they use neither plant analysis nor soil test to know their soil fertility status by themselves. Soil test was reported to be done by other organizations like agricultural researches, agricultural offices or other non-governmental organizations and the analysis was focusing on knowing soil acidity. The organizations collect soil sample from farmers' crop field and conduct soil analysis at Holeta Agricultural Research Center laboratories, for instance according to reports from Welmera and Ejere districts of West Shewa zone. Instead, long-term fertility history and crops growth observation were used to judge the fertility of the crop field soils by farmers.

Laboratory based soil test results are pH level in the soil which helps to judge whether application of lime is needed, plant available phosphorus and potassium levels to know if these levels are sufficient or if fertilizer is needed, magnesium and calcium levels in the soil, the percentage of organic matter in the soil and amounts of nitrogen, phosphorus, and potassium (USDA, 2022). A soil sample should be tested at least once every three years, or when there is a change in crop to be produced. A soil sample should also be taken if problems occur during the growing season. More details about soil testing frequency are explained in Staben *et al*. (2003). Studies indicated that the frequency of testing crop field soils depend on the farmers experiences. Beginning or young farmers may be the most frequent soil testers (Successful farming, https://www.agriculture.com/about-us-7487846). In the surveyed districts of the two zones, soil texture and crops grown observations were practical which are supposed to be the indirect indicators of soil nutrients.

Table 5. Means of soil fertility analysis in East and West Shewa districts of Ethiopia

Zones	N	Soil analysis		Plant analysis		Soil observation		Crop observation	
	201	Yes	No	Yes	No	Yes	No	Yes	No
East Shewa	93	0	93	0	93	90	3	88	5
West Shewa	108	25	83	0	108	76	32	103	5

Major crops grown in the study area

List of crops grown in the study districts of East and West Shewa zones of Oromia Regional States of Ethiopia are given in Table 6. The dominant crops grown were wheat, teff, faba bean, in respective order. Teff was dominantly produced in East Shewa where wheat, barley and faba bean were dominantly grown in West Shewa zone of Ethiopia. On the other hand, some like onion, avocado, sugarcane, and tomato that grow in East Shewa are not grown in Welmera and Ejere districts of West Shewa. Similarly, sorghum and chat are not grown in Adea and Lomme districts of East Shewa zone. However, this is limited to the information obtained from the respondents and might not be generalized for the entire districts or zones. Exhaustive crops grown in East and West Shewa zones were found in CSA (2022). According to this source, the crops grown in both East Shewa and West Shewa zone were the same and included cereals (teff, barley, wheat, maize, sorghum, finger millet, oats (‘Aja’) and rice), pulses (faba bean, field pea, beans, chick peas, soya bean, lentils, grass pea, fenugreek, mung bean and lupine), oil seeds (neug, linseed , groundnut, safflower, sesame and rape seed), vegetables (lettuce, head cabbage, kale, tomato, green pepper, red pepper and Swiss chard), root crops (beat root, carrot, onion, potato, yam, garlic, taro and sweet potato), fruit crops (avocados, bananas, guavas, lemon, mangos, oranges, papayas and pineapples), ‘chat’, coffee, hops and sugarcane. The list of crops identified during the present survey study was in agreement with the list of crops grown in the zones. On the other hand, few or none of the respondents were engaged in the production of field pea, maize, onion, beans, lentil, sorghum, ‘chat’, linseed, avocado, sugarcane and tomato in the surveyed areas. In agreement with our results, the production of these crops nationally is very low (CSA, 2022). Although maize production is high in the two zones, the interviewed respondent did not report maize as their major crop. This could be due the fact that, regardless of the random selection, kebeles considered in the current survey were not maize growing ones.

Table 6. Percentage of crops grown by the two zones in Ethiopian as indicated during the survey

Crop types	Zone				Total	
	West Shewa		East Shewa			
	N	%	N	%	N	%
Barley	52	15.3	14	5.1	66	10.7
Tef	98	28.8	82	29.6	180	29.2
Wheat	101	29.7	80	28.9	181	29.3
Faba bean	47	13.8	34	12.3	81	13.1
Chick peas	10	2.9	14	5.1	24	3.9
Field peas	1	0.3	22	7.9	23	3.7
Grass peas	8	2.4	1	0.4	9	1.5
Maize	2	0.6	10	3.6	12	1.9
Oats	11	3.2	2	0.7	13	2.1
Others*	10	3.0	18	6.2	28	4.5
Total	340	100.0	277	100	617	100

*Onion, potatoes, haricot beans, Lentil, Sorghum, Chat, Linseed, Avocado, Sugarcane, Tomatoes

Yield of major crops in the study areas

According to the survey result of the current study, the productivity of major crops was generally low in ranging from 951 kg ha^{-1} teff in West Shewa to 2337 kg ha^{-1} wheat in East Shewa. In relative terms, the yield of crops from East Shewa were higher than that of West Shewa (Table 7). The reported productivity of the major crops was lower than the report of CSA (2022). In CSA (2022), it was reported that the yield of cereals, pulses and oil crops was reported to be 2900.1 kg ha^{-1}, 1900.0 kg ha^{-1}and 1040.0 kg ha^{-1}, respectively, which was considerably higher than that of our findings from the surveyed districts of East Shewa and West Shewa zones. The reason for being low to this extent could be low adoption and use of improved varieties, low application of inputs, continual usage of un-optimized crop management practices, and uncontrolled biotic and abiotic stresses (Belachew *et al.* 2022; CSA, 2022).

Table 7. Yield (kg ha^{-1}) of major crops in East Shewa and West Shewa zones

	Zone	N	Mean	Std. Error	T-value
Barley	West Shewa	44	1662.70	282.272	0.17
	East Shewa	12	1761.67	374.663	
Tef	West Shewa	85	951.43	121.565	4.8***
	East Shewa	81	1301.07	50.686	
Wheat	West Shewa	88	1193.32	98.289	5.9***
	East Shewa	78	2337.30	173.624	
Faba bean	West Shewa	39	1407.41	178.734	2.3**
	East Shewa	32	2072.71	224.360	
Chick peas	West Shewa	10	1275.80	240.044	2.2**
	East Shewa	14	2168.13	289.754	

Area cultivated and improved seed usage

The area cultivated and proportion of improved seeds used during 2021/2022 cropping season per household for major crops produced in East Shewa and West Shewa zones is given in Table 8. Among these major crops known to be grown in the two zones, farmers used relatively largest farm size for teff (0.25 – 6.00 ha) and smallest for Faba bean and barely (0.065 – 1.500 ha). The farm size used for barley and wheat ranged between these values. Among the major crops identified, the percentage of area covered by seed was the highest for wheat (79.8%) and lowest for faba bean (49%). In the case of teff and barely, the percentage of improved seed was about 74.1% and 68.2%, respectively. The area coverage of crops reported in the current report is in agreement with reports of CSA (2022)

Table 8. Total area cultivated and proportion of improved seeds used during 2021/2022 cropping season for major crops produced in the surveyed districts of East and West Shewa zones of Oromia regional states, Ethiopia

Major crops	Number of plots	Range of area of plots (ha)	Total area covered (ha)	% of area covered by improved seeds
Teff	181	0.25 – 6.00	304.6	74.1
Barely	66	0.0625 – 1.500	36.49	68.2
Wheat	186	0.075 – 4.00	162.71	79.8
Faba bean	78	0.0625 – 1.500	24.78	49.0

Usage of Urea and NPS fertilizers

Usage (%) of Urea and NPS on major crops cultivated during 2021/2022 cropping season per household in the study area is given in Table 9. Among the major crops cultivated in the surveyed areas, the majority of faba bean plots were sown without urea (86%) or NPS (54%). Besides, about 24% of faba bean plot received NPS below the recommended 100 kgha^{-1}. It could be inferred that the pulse crops are grown almost without or with sub-optimal application of chemical fertilizer. Daemo (2024) recommended application of 125 kg NPSB per ha fertilizer rate for high yield and profitability of faba bean production. However, farmers are not applying the recommended amount when it comes to pulses. In fact, faba bean offers ecosystem services such as renewable inputs of nitrogen into crops and soil via biological N2 fixation, and a diversification of cropping systems. Several studies have demonstrated substantial savings (up to 100–200 kg N per ha) in the amount of N fertilizer required to maximize the yield of crops grown after faba bean (Jensen *et al.* 2010). Regarding the major cereal crops identified, about a third of the plots of barley and wheat received 100 kg ha^{-1} NPS and 100 kg ha^{-1} urea, respectively (Table 9). Considerable number of respondents (about 46%) used more than 100 kg NPS for teff and wheat (about 51%).

Table 9. Use of Urea and NPS on major crops cultivated during 2021/2022 cropping season per household in surveyed districts of East and West Shewa zone of Oromia regional states, Ethiopia

Major crop name	Number of plots	Not used (%)		Less than 100 kg ha^{-1} (%)		100 kg ha^{-1} (%)		Greater than 100 kg ha^{-1} (%)	
		Urea	NPS	Urea	NPS	Urea	NPS	Urea	NPS
Teff	181	9.94	12.15	40.88	17.12	27.07	24.31	22.11	46.42
Barely	66	21.21	15.55	34.85	25.36	28.79	31.82	15.15	27.27
Wheat	186	11.29	13.97	30.65	13.44	31.72	22.04	26.34	50.55
Faba bean	78	85.89	53.85	8.01	24.36	3.84	12.82	2.26	8.97

Usage of Sewage and Bio-slurry for soil fertility improvement

The number of farmers that used sewage (waste matter such as water or human urine or solid waste) and bio-slurry as means of soil fertility improvement was negligible; only three out of 201 respondents for each sewage and bio-slurry. This could be due to luck of availability of these organic fertilizers in the area or unfamiliarity of the farmers with these types of alternative fertilizer sources. However, studies indicated that usage of sewage for fertilizing crop fields are feasible options particularly those originating from municipalities (Zhang *et al.* 2023). The benefits of applying sewage to agricultural land include increased supply of major plant nutrients (in particular N and P), provision of some of the essential micronutrients (e.g. Zn, Cu, Mo, and Mn), and improvement in the soil physical properties, i.e., better soil structure, increased soil water capacity, and improved soil water transmission characteristics (Korentajer, 1991). The same source also indicated that the benefits of sewage application may be limited by its potential health hazards where measures that could minimize these health hazards are also indicated. Warnars and Hivos (2014) indicated that biogas produced from cattle, pig, and buffalo dung (and/or human excreta and kitchen waste), together with the by-product bio-slurry, can offer a solution to poor access to modern energy services and help mitigate poverty, climate change and soil fertility problems. Bio-slurry from biogas can be an excellent fertilizer and use of 10 to 20 tons/ha in irrigated areas and 5 tons/ha in dry farming could increase crop revenues by 25 percent on average (Warnars and Hivos, 2014). Other study also indicated that the combined bio-slurry and chemical fertilizer application at the dose of 25% bio-slurry and 75% chemical fertilizer gave the highest plant height (251.3 cm), grain yield (7.09 t ha^{-1}), biomass yield (24.4 t ha^{-1}) and stover yield (11.5 t ha^{-1}) (Kebede *et al.* 2023). The usage of sewage was almost not common in the surveyed areas whereas the usage of bio-slurry depended on the availability of biogas plants at the farmers' levels. Respondents that mentioned the usage of bio-slurry were those who participated on another separate project that helped them construct biogas infrastructure.

Usage of green manure, cover crop and mulching as soil fertility improvement methods

Green manuring is a practice of plowing or turning the grown green plants into the soil for the purpose of improving fertility status, physical and biological condition of the soil. It is a form of sustainable agriculture that focuses on the use of organic matter to improve soil fertility and crop yields.

Out of the total respondents interviewed about the use of green manure, cover crop and mulching as soil improvement method, only one, three and three respondents, respectively, said that they use the methods. In general, the most majority of them do not use the methods as soil improvement method. Some respondents indicated that they did not use these methods because the methods were time consuming, labor intensive and there are sometimes difficulties in identifying specific crops for such purposes. Utilization of green manuring might be difficult for smallholder farmers in Ethiopia where the area for croplands is quite small and the crop production is rainfed based. Dengia *et al.* (2024) evaluated seven green manure plant species including sunn-hemp, lablab, cowpea, soybean, mung bean, dhaincha, and sugarcane trash and recommended utilization of these green manure plant. However, green manuring could be considered in state farms where mono cropping is practiced year after year.

Green manuring and sustainable agriculture go hand in hand in order to maintain long-term productivity and environmental health (Patra *et al.* 2023). Studies showed that the usage of some green manure has an added advantage to soil fertility improvement. For instance, Sintayehu *et al*. (2014) indicated that green manure amendments of rapeseed and Ethiopian mustard significantly reduced disease incidence by 21% and 30% and disease severity by 23% and 29%, respectively. These results indicated that Ethiopian mustard and rapeseed crops have potential as green manure for the management of FBR disease of shallot crop.

Similar to green manuring, cover cropping is a helpful practice in improving the physical, chemical, and biological soil properties, optimizing nutrient use efficiency and reducing the dependency of crops on external supplies of nutrients. Since the interactions between cover crops and the nutritional status of soil and plants are complex and dynamic, understanding the complexity and dynamism could be useful to set up an appropriate and site-specific management of fertilization (Scavo *et al.* 2022). Mulching could also be used for the environmental modification of forests, agriculture lands, and urban landscapes. The advantage of mulches could include buffering soil temperature, prevent soil water loss by evaporation, inhibit weed germination, and suppress weed growth. Further, mulches can protect soils from wind, water, and traffic-induced erosion and compaction (Ni *et al.* 2016). Same source indicated that mulching can improve crop production by enhancing soil quality by conserving soil moisture, enhancing soil biological activities, and improving the chemical and physical properties of soil.

Sufficiency of farm gate produced livestock manure to fertilize the crop fields

The chi-square, probability of chi-square and point estimate of odds ratio for sufficiency of farm gate produced livestock manure in East Shewa and West Shewa zones is given in Table 10. The likelihood ratio chi-square of 15.71 with a p-value of <0.0001 indicated that the model as a whole fitted significantly better than an empty model in analyzing the sufficiency of livestock manure to fertilize the crop fields. The point estimate odds ratio value indicated that the sufficiency of farm gate produced livestock manure in the surveyed districts of East Shewa compared to that of West Shewa increased by 3.258 times. This means, a greater number of respondents from surveyed districts of East Shewa zone reported that farm gate produced manure is sufficient to fertilize crop fields compared to respondents from surveyed districts of Westh Shewa zone. In general, about two third (61.81%) of the respondents indicated that farm gate livestock manure was not sufficient for fertilizing crop fields. The proportion of respondents reporting that livestock manure is sufficient to fertilize their crop field was higher in East Shewa zone (24.62%) compared to West Shewa zone (13.57%) (Table 11). In agreement with our finding, in many parts of Ethiopia (Mekonnen and Köhlin, 2008) and in other Sub-Saharan African countries (Haffmann *et al.* 2001; Powell *et al.* 2004), it is widely acknowledged that quantities of manure available to farmers are limited because of low numbers of livestock per household, thus constraining crop production. Other studies (Jagisso *et al.* 2019), however, indicated that enormous amount of manure with substantial fertilizer value and economic benefit had been accumulated over the years at farm level. The same study also showed that a considerable scope exists for increasing the yields of marginal lands by using manure. Ketema & Bauer (2011) showed that where the prices of chemical fertilizers are very high, manure is labor-intensive in its application. According to these authors it was implied that the ability to afford high fertilizer prices decreases the probability to apply manure; and endowment with adequate labor input decreases the probability to opt for chemical fertilizer.

Table 10. Chi-square, probability of chi-square and odds ratio point estimate of odds ratio for sufficiency of farm gate produced livestock manure in East Shewa and West Shewa zones

Parameters	Values
Chi-square	15.71
Probability of chi-square	<0.0001
Point estimate Odds ratio of East Shewa versus West Shewa	3.258

Table 11. Percentage of respondent that reported farm gate produced livestock manure sufficiency to fertilize crop fields in East Shewa and West Shewa zones (total number of respondents was 199).

Zone	Sufficient	Not sufficient
East Shewa	24.62	22.11
West Shewa	13.57	39.70
Total	**38.19**	**61.81**

The respondent farmers were asked to which crops they give priority when farm gate livestock manure was not sufficient to fertilize all of their crop fields. The crops were latter categorized in to fruits and vegetables, cereals and pulses. The overall survey result revealed that fields of cereals (48.78%) followed by that of fruits and vegetables (19.51%) were given priority to receive livestock manure when there was shortage to apply to all of their crop fields. When the priority was seen zone wise, priority differences were observed where cereals fields were given priority in the case of the two zones (16.26% in East Shewa zone and 32.52% in West Shewa zone). Followed to fields of cereal crops, however, fields of pulse crops (13.82%) were the second to receive livestock manure followed by fields of fruits and vegetables (13.82%) in the case of West Shewa zone. On the other hand, fields of fruits and vegetables were given the second priority (11.38%) in East Shewa zone followed by fields of pulse crops (4.88%). According to (Tafes Desta *et al.* 2023), significant proportion of crop fields of different categories were treated with organic fertilizers which was in agreement with the current report. The same source, however, indicated that the proportion of crop field treated with organic fertilizer showed a decreasing trend over the past decade. Livestock manure could be applied to crop fields in sole form or in combination with chemical fertilizer. The combined efficacy of NPS blended fertilizer and cattle manure significantly affected the days to flowering, days to physiological maturity, plant height, panicle length, number of panicles per plant, weight of thousand-grain, above-ground biomass yield, and grain yield of Amaranth in Southern Ethiopia (Mekonnen, 2022). On the other hand, manure could be used as a whole or partial substitute for commercial fertilizers, whose prices rose sharply in recent years. According to Mekonnen (2022), the highest price 22,759 ETB ha^{-1} was received from combined application of 60 $kg \cdot ha^{-1}$ NPS fertilizer and 12 $t \cdot ha^{-1}$ cattle manure.

Table 12. Percentage of respondents considering different crop types when farm gate manure was not sufficient to fertilize crop fields (total number =123)

Crop type	East Shewa	West Shewa	Total
All crops	3.25	9.76	13.01
Fruits and vegetables	11.38	8.13	19.51
Cereals	16.26	32.52	48.78
Pulses	4.88	13.82	18.70

Conclusion

Majority of the respondents indicated the cropping was during months of June to December. The average experience of respondents in agricultural farming was 24±12 years. Agricultural activity was the sole primary activity for all the farmers in the present studied areas and majority of the respondents (about 86%) did not have additional secondary activity. The majority of soil types in the surveyed areas of East Shewa zone were Vertisols while that of West Shewa zone were Nitisols. Long-term fertility history and crops growth observation were used to judge the fertility of the crop field soils by farmers. The dominant crops grown in the surveyed areas were wheat, teff, barely and faba bean, in respective order where the productivity was the lowest for Teff (951 $kgha^{-1}$) and the highest (2337 $kgha^{-1}$) for wheat. Relatively largest farm size for teff (0.25 – 6.00 ha) and smallest for Faba bean (0.0625 – 1.500 ha). The percentage of area covered by seed was the highest for wheat (79.8%) and lowest for faba bean (49%). Chemical fertilizer usage was lower for faba bean compared to the cereals. Usage of sewage, bio-slurry, green manure, cover crops and mulching were not common in the current surveyed districts. About 62% of respondents reported that livestock manure was not sufficient to fertilize own crop fields, which still could be used in combination with chemical fertilizers. Future research should focus on characterizing crop productivity under different levels of agricultural inputs under farmers' management.

Acknowledgments

The current work was funded by Korea Africa Food and Agricultural Initiative-Crop Livestock Agriculture (AFACI-CLA) project. Holeta Agricultural Research Center facilitated the survey for which the authors are grateful. The authors also would like to thank the respondent farmers for sharing their experience. We also would like to thank Dr Endale Yadesa and Mr. Gadisa Mulata for their assistance in data collection.

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