Determinants of soil fertility management practices in Gedeo Zone, Southern Ethiopia: logistic regression approach

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ABSTRACT

Soil fertility in smallholder farms remains a major issue in Ethiopia and for many developing countries where more than 90% of the population’s food is provided by smallholder farmers. This study was aimed to identify determinants of soil fertility management practices in smallholder farmers of the Gedeo zone, southern Ethiopia where the agricultural landscapes dominated by coffee and enset crops. The study is based on cross-sectional data obtained from a total of 270 randomly selected households. Data were collected using a structured survey questionnaire and focus group discussion (FGD) held with key informants from each sample kebele. The data collected were analyzed using descriptive and inferential statistics, and a logistic regression model. The result of the study showed that to maintain soil fertility the majority of farmers relied on a number of organic farming practices that take full advantage of the nutrient cycles. The commonly used soil fertility management practices were green manure (98.1%), mulching (71.9%), minimum tillage (97.4%) and multilayered agroforestry (100%).

The results showed that the socioeconomic status of farmers had an effect on the adoption of soil fertility management practices. Logistic regression analysis showed that the family size of the household had a positive significant (p < 0.05) effect on the adoption of compost and farmyard manure while the dependency ratio of the farmer households had a negative impact on both compost and farmyard manure adoption. The differences in education status of household head and coffee shrubs holding had a strong positive relationship with farmers’ mulch adoption. The study also shows that livestock holding of the household was significant (p < 0.01) positive association with the adoption of farmyard manure. Moreover, the coefficient for the agriculture annual income and differences in agroecological zones had strong positive effects on the adoption of compost at and cover cropping. The findings suggest that soil fertility management practices in the study area could be enhanced by improving the income of farmers and targeting young families where all spouses and working-age household members work on farms. Moreover, attention should be given to enhancing intensive livestock management systems that support more livestock for the provision of farmyard manure and advising farmers to possess a manageable number of coffee shrubs.

1. Introduction

Agriculture is a centerpiece of economic development in Ethiopia, accounting for 34.1% of gross domestic product (GDP), employing more than 79% of the labour force and accounting for 79% of foreign earnings and is the major source of raw material and capital for investment and market (FAO, 2020). According to ADF (2002) report, in Ethiopia, about 95% of the agricultural output originates from subsistence smallholder farms in the highlands. Low soil fertility and inefficient management of soils have been the major challenges facing productivity among smallholder farmers in many developing countries in general (Adekunle et al., 2017), in Ethiopia specifically (Sileshi et al., 2019; Denise and Meike, 2020). In a smallholder mixed farming system, the loss of soil fertility results from, soil erosion and excessive nutrient mining through complete crop harvest for food, animal feed and fuel, without adequate replenishment (Tolessa et al., 2001; FAO et al., 2017; Mekuanint et al., 2020). Rugged topography together with heavy human and livestock pressure, and poor conservation measures also plays part in aggravating the process of decline in land productivity (Wassie, 2020). The increased loss of trees and vegetation cover in farming landscapes resulted in high rates of soil erosion, loss of soil fertility and shortages of fuel wood which lead farmers to use dung for fuel instead of using it for soil fertility

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maintenance (Haileslassie et al., 2006). Consequently, this has led to a decline in the productivity of crop and livestock systems and a high-level of food insecurity.

To improve soil fertility, the Government of Ethiopia has made many efforts, most of which mainly focus on the adoption and dissemination of cereals-based conventional agriculture that uses chemical fertilizer and pesticides and physical soil and water conservation neglecting other diversified indigenous agriculture systems and practices. Unfortunately, inorganic fertilizer used as major soil nutrient management is unsustainable, causing soil degradation and environmental pollution and its increased prices make it unaffordable for many farmers (Byerlee et al., 2007; Adekunle et al., 2017). One of chemical soil degradation that affect Ethiopian highlands soil is soil acidity (Endalew et al., 2014). Currently, it is estimated that about 40% of the total arable land of Ethiopia is affected by soil acidity and this is partly caused due to the excessive application of acid-causing fertilizers (Abdenna et al., 2007; Addisu, 2009). Moreover, the leaching of fertilizers into water systems caused the invasion of aquatic weeds like water hyacinth (emboch) (Honlah et al., 2019).

On the other hand, farmers of the Gedeo zone follow the indigenous way of soil fertility management (Tadesse, 2002) which is organic and more sustainable, and compatible with farmer's socioeconomic status (Adekunle et al., 2017). As a result, it plays a significant role in the ecological conservation and economic development of the country. As an ecological role, the agricultural system of the Gedeo zone has registered in the tentative list of UNESCO as world heritage for its high carbon sequestration and biodiversity conservation (Mesele, 2013; UNESCO, 2016). Concerning economic contribution, the system is the producer of a large variety of organic products such as Ensete (Ensete ventricosum) high-quality food, coffee, fruits, vegetables, honey, timber, highland sheep, and a variety of crops (Lummina, 2015). Among many organic agricultural products, Yirgacheffe and Sidama brand coffee are organic (Kodama, 2007; Mesele, 2013; Ashena et al., 2014). According to Getachew and Abiyot (2017), 23 primary coffee farmers cooperatives found in Gedeo zone are certified in both organic and fair-trade certificates and 40% of Ethiopia's premium grade coffee is provided from this system.

However, understanding the soil fertility management practices and their determinants in a particular agricultural system has received little attention in Ethiopia. Smallholder farmers are quite different in their biophysical and socio-economic settings and their associated experience in managing soil fertility. Therefore it is important to understand the diverse indigenous soil fertility management and how they are affected by various determinant factors for designing appropriate intervention measures. The hypothesis of this study was “socio-economic characteristics of the farmer have effects (either positive or negative) on the adoption of soil fertility management practice”. Thus, this study was aimed to identify soil fertility management practices used by smallholder farmers in the Gedeo zone, southern Ethiopia. It also examines the relationship between socio-economic characteristics and soil fertility management practices employed by farmers.

2. Materials and methods

2.1. Description of the study area

The present study was carried out in the Gedeo zone of the Southern Nations’, Nationalities’ and Peoples’ Regional State (SNNPRs) of Ethiopia (Figure 1). The Gedeo zone is located between latitudes 5° 50’ 26” and 6° 12’ 48” N, and longitudes 38° 03’ 02” and 38° 18’ 59” E (Bogale, 2007).
with altitude ranges from 1450-3200 m above sea level. The study area is characterized by diverse topographic features within limited distance (less than 100 km), thus resulted in complex and diverse climatic conditions (Birhane and Melesse, 2015; Abiyot et al., 2021).

The area located in the inter-tropical convergence zone, receiving rainfall from two sources, the Atlantic and Monsoon currents. As a result, the zone experiences a bimodal pattern i.e., short rain season starting from March and ending in May and long rain season starting from July and ending in October (Tadesse, 2002). The average annual rainfall of the study area is 1500 mm lay within the range of 1200-1800 mm. The mean monthly temperature of the zone range from 18 to 25 °C.

The study area has been divided in three agroecological zones based on altitudinal differences (Figure 1b and Table 1): The highland (Dega), midland (Woinadega) and lowland (Kola), agroecological zones (Tadesse, 2002; Mesele, 2013; Birhane and Melesse, 2015). The highland agroecological zone, with altitudes ranging between 2500 and 3200 m asl, and covers a surface area of approximately 26% of the study area. The midland agroecological zone, with altitudes range between 1750 and 2500 m asl which covers 65% of study area. The lowland agroecological zone lies in the altitude range <1750 m asl, covers 9% of study area.

The primary land use is rain-fed agriculture, with smallholder farming and diverse agricultural production (Lummina, 2015). The total area of the zone is 1347m² comprising agricultural land (agroforestry-perennial and annual crops land) (94.5%), grassland (1.4%), wetland (0.8%), natural forest (0.5%), plantations (0.1%) and others (2.7%) (Bogale, 2007). The major agricultural products of the area include enset and enset products (enset seedling, kocho, bula, and fiber), coffee, cereal crops, root crops, fruits, vegetables, herbs, spices, medicines, honey, fibers, fuelwood, and timber for subsistence and local market. Livestock is equally an important means of livelihood and an important source of manure.

As the study area is part of the southern Rift Valley System of Ethiopia, the geology is complex and characterized by tertiary and quaternary age rhyolite and basalt volcanic materials (FAO/UNDP, 1984). The soil of the Gedeo zone is described as very deep, well-drained, red brownish to dark reddish brown, and classified as Eutric Nitosols (MoA, 1995; Alemayehu, 2015). According to FAO soil classification, the dominant soil type covering 67% of the total area of the zone is Chromic Luvisols, followed by Haplic Nitosols accounting for 26% of the total area of the zone. The remaining area is covered with Rhodic Nitosols (3.4%), Eutric Vertisols (1.9%), Haplic Luvisols (1.8%) and Haplic Luvisols (0.1%) (FAO, 1984).

### 2.2. Sampling methods and sample size determination

A multistage stratified sampling technique was applied to choose sample districts, Kebele and households. In the first stage, the zone was stratified into three agroecological zones depending on elevation gradient namely highland, midland and lowland agroecological zones (Figure 1b). In the second stage, four districts (Bulle, Dilla zurea, Wonago and Yirgacheffe) were purposively chosen with the purpose of capturing the climate variability (Figure 1c) from six districts in the Gedeo zone, Southern Ethiopia. In the third stage, following a simple random sampling technique, 10% of total or 14 kebeles (which is the smallest administrative unit in Ethiopia but higher than a village consists of about 500 households and 800 ha of land) were selected with probability proportional sample size in each stratum (agroecological zone) (Table 1). Accordingly, 2, 9 and 3 kebeles were sampled from lowland, midland, and highland agroecological zone, respectively. Finally, after securing a fresh list of the household from 14 kebeke households, a random sample of 270 households were selected based on probability proportional to the sample size sampling technique. The sample size for the study was determined following Kothari (2004), 

$$n = \frac{Z^2pq}{4\epsilon^2} + 1$$

Where is the sample size from a finite population, N is total size of the household population, Z is the confidence level (α = 0.05), p is the sample proportion of successes (frequency estimated for a sample of size n), where p is 0.5 which is taken for all developing countries, q = 1-p and e is level of precision (acceptable error). Thus N = 21079, Z = 1.645, p = 0.5, q = 0.5, e = 0.05.

### 2.3. Data sources and methods of data collection

Sources of data for this study were both qualitative and quantitative data from primary and secondary sources. The primary data for this study were collected from sample households using a structured questionnaire. A questionnaire was administered by 12 Development agents and 5 kebele managers who are conversant with the local language (Gedeufa). The questionnaire was pre-tested in order to clarify issues if any. In addition to the structured questionnaires, field observation and focus group discussions held with key informants from each sampled kebeles to generate additional information on the soil fertility management practices and to complement the primary data. The survey was conducted from the first week of August to the last week of December 2020. Secondary data were extracted from published and unpublished documents obtained from Gedeo Zone Agricultural Development Department and SNNPRS Agricultural development Bureau.

The study was approved according to ethical principles in human guidelines and regulations by the Ethics Committee of Dilla University. Before data collection, all participants of the survey were fully informed about all aspects of the study and gave their informed consent in writing.

### 2.4. Data analysis

In this study descriptive, inferential and econometric data analysis methods were employed. The empirical data were analyzed using descriptive and inferential statistics. The descriptive statistics which were used for analyzing data for this study include, mean, standard deviation and percentages. Besides, the F-test was also used to test whether there is a statistically significant difference between categorical variables. The logistic regression model was employed to identify the influencing factors of soil fertility management practices among smallholder farmers in the study area. Statistical analysis was performed using SAS-STAT version 13 software (Statacorp, 2017).

### 3. Results and discussion

#### 3.1. Socioeconomic characteristics of sampled household

The result of demographic characteristics shows that out of a total of 270 sampled households 238 or 88% of households were male-headed (Table 2). The percentage of male-headed households in this study is higher as compared to the national average (67%) (CSA, 2013). This suggested the dominance of males in the study area. The result also indicates that about 94, 88 and 85% of households were male-headed at highland, midland and lowland agro-ecological zone, respectively. The

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Table 1. Distribution of sample size across agroecological zones based on proportional sampling technique.

| Agroecological zones | Altitude range* (masl) | Zonal total kebele | Sampled kebele | Total HHs in sampled kebele | Sampled HH size |
|----------------------|------------------------|--------------------|----------------|-----------------------------|-----------------|
| Highland             | >2600                  | 31                 | 3              | 2749                        | 36              |
| Midland              | 1450-2600              | 92                 | 9              | 13797                       | 182             |
| Lowland              | <1450                  | 12                 | 2              | 3937                        | 52              |
| Total                |                        | 135                | 14             | 20483                       | 270             |

Source of household data: GZFEDD (2018) unpublished document; *Mesele (2013).

HH: Household.
chi-square test shows that there was no significant (P ≤ 0.05) difference in the gender of the household heads among the agroecological zones of the study area.

The mean age of the household heads was 46.1 years with a standard deviation of 14.12. This is above the national average of 44 years (CSA, 2016). The mean age of the sampled households heads was 39.9, 46.7, and 48.2 years for highland, midland and lowland agro-ecological zones, respectively. The mean comparison of age of household revealed that there was statistically significant (P ≤ 0.05) difference among agroecological zone of the study area. The highest (48.2) household age was recorded in the lowland agro-ecological zone compared to highland (39.9) and midland (46.7) agroecological zone.

As far as the educational status of the household heads is concerned, 71.5% of farmers in the study area had attained formal education in different levels which is higher as compared to a report of Ethiopia public health institute (EPHI, 2013) that is (57%). The chi-square test showed that agroecological zones did not affect on the education level of the household head.

The average household size of the study area was 6.70 persons, which is larger than the national average of 4.6 persons per household (CSA, 2014). The chi-square test result revealed that there was no statistically significant (p < 0.05) difference in the family size among agroecological zones.

### 3.2. Households asset holding

The land is the basic livelihood asset for all farm activities and it is important for both crop and livestock production (Rahman and Manprasert, 2006; Bezu and Holden, 2014). The mean size of farmland owned by the sample households was 1.48, 0.57 and 0.47 ha for the highland, midland and lowland agroecological zone, respectively. The overall average holding of the area was 0.67 ha, which is less than the regional and country average of 1.2 and 3.1 ha, respectively (CSA, 2014). The mean landholding size of the highland agroecological zone was significantly (p < 0.01) different from lowland and midland agroecological zones (Table 2).

Coffee is the most important cash crop and main source of livelihood in the study area (Tadesse et al., 2018). Gedeo Zone is the major organic coffee producing area in the Southern region of Ethiopia. Coffee is grown as a garden (cottage or smallholder) crop, intercropped with Enset (Ensete ventricosum) under the evergreen shade trees of Erythrina brucei, Milletia ferruginea and Albizia gummifera (Tadesse, 2002; Mesele, 2013). The finding of this study shows that the mean coffee shrub owned by households was 954.8 which was significantly (P ≤ 0.1) varied among agroecological zones of the study area. The highest coffee shrub holding was recorded in lowland (1221) agroecological zone followed by midland (1013) and highland (624) agroecological zones.

*Table 2. General socioeconomic characteristics of the sample respondents by agroecological zones.*

| Variables          | Highland | Midland | Lowland | Total   | F     |
|--------------------|----------|---------|---------|---------|-------|
| Gender of the HH head | 0.94 ± 0.23 | 0.88 ± 0.55 | 0.85 ± 0.32 | 0.88 ± 0.32 | 0.371NS |
| Age category | 39.9 ± 10.77 | 46.7 ± 14.14 | 48.2 ± 15.41 | 46.1 ± 14.12 | 4.329* |
| Family size | 7.11 ± 3.01 | 6.8 ± 2.83 | 6.07 ± 2.67 | 6.7 ± 2.84 | 2.38NS |
| Education status | 5.16 ± 2.62 | 6.57 ± 4.80 | 4.80 ± 4.71 | 6.04 ± 4.41 | 1.41NS |

* mean significant at 0.1 probability levels; Ns: not significant; HH: household.

Livestock is also an integral part of the Gedeo agricultural system and contributes to both subsistence and cash income generation and nutrient recycling. In the study area farm households owned a wide range of livestock types including cattle, sheep, goats, horse, mule, donkey and chickens. This agrees with the finding of Tadesse, 2002 that livestock is major component in Gedeo agricultural system. The total livestock population of each household was converted to tropical livestock units (TLU) using a conversion factor of 1 for cow, 0.8 for heifers, 0.1 for sheep and goats, 0.01 for chicken, 0.5 for a donkey, 0.8 for a mule and 0.7 for a horse (Jahnke, 1982). Accordingly, the mean livestock holding of farmer households was 1.38 TLU with a standard deviation of 1.84 which is lower as compared with the country average (5.2 TLU) and lower reported by Assef (2005) that average herd size at the northern highland of Ethiopia was 9.1 TLU for the rich, 4.3 for the medium and 2.0 for the poor group. The mean livestock holding across agroecological zone was 4.24, 1.13 and 0.91 TLU for highland, midland and lowland agroecological zone, respectively. It was significantly different across agroecological zone of the study area at less than (p < 0.01) probability level (Table 3). This may be due to access for grazing land and various advantages of livestock in highland agroecological including, livestock used as draught power; an alternative source of income, a means of transportation and serve a store of wealth.

### 3.3. Soil fertility management practices

#### 3.3.1. Land preparation and tillage practices

Two types of tillage practices were identified in the study area: (1) zero or minimum tillage; the practice that minimizes the disruption of soil by using special types of equipment (e.g., hoe, shole, maricha) to plant vegetables, legume crops, and various seedlings. Farmer also mentioned a peculiar zero tillage practice that is performed by protecting the agricultural lands from animal and human entrance for two to three months. Then, during sowing season farmers sow grain mostly barely, wheat and pea in the grass and slash (mida) the grass from their bottom using a special hand tool called sholicha and use the grass as mulching. According to Duncan’s Multiple Range Test significant at 0.1 and 0.01 probability levels, respectively; hh: household; TLU: A Tropical Livestock Unit – it is a standard used to quantify different livestock types & sizes using a cattle with a body weight of 250 kg.

*Table 3. General socioeconomic characteristics and asset holding of the sample respondents by agroecological zones.*

| Variables          | Highland | Midland | Lowland | Total   | F     |
|--------------------|----------|---------|---------|---------|-------|
| Landholding (ha) | 1.57 ± 1.12a | 0.76 ± 1.17b | 0.49 ± 0.62b | 0.78 ± 1.11 | 8.235*** |
| Plot of Land(no) | 5.75 ± 4.57a | 2.83 ± 2.24b | 2.36 ± 1.63b | 3.02 ± 2.61 | 17.198*** |
| Coffee shrubs (stem/ha) | 623.9 ± 89.8 | 1012.9 ± 923.5 | 1221.1 ± 1943.0 | 1954.8 ± 1065 | 3.487* |
| Enset plant (stem/hm) | 1499.8 ± 1677a | 493.5 ± 597b | 145.6 ± 203a | 520.7 ± 800 | 28.818*** |
| Livestock (TLU) | 4.24 ± 3.47a | 1.13 ± 1.16b | 0.91 ± 1.48b | 1.38 ± 1.84 | 43.632*** |

* and *** mean significant at 0.1 and 0.01 probability levels, respectively; hh: household; TLU: A Tropical Livestock Unit – it is a standard used to quantify different livestock types & sizes using a cattle with a body weight of 250 kg. Means with the same alphabet on a row are not significantly different at 5% probability according to Duncan’s Multiple Range Test.
to the farmer, the practice has an important role in suppressing weed growth, protecting the soil from erosion, and increasing soil fertility. (2) Frequent tillage; the practice in which farmers use tools such as oxen or hand hoe to loosen the soil before planting cereal crops. The survey result shows that the majority of (97.4%) respondents used zero/minimum tillage. This is due to the characteristics of the agricultural system that integrate annual crops, perennials and trees in a single farm which obstruct animal plowing using traditional Maresha. In addition, the intensity and frequency of tillage on organic based agriculture is lower than that of conventional based conservation tillage (Marcelo et al., 2010). As shown in Table 3 out of all respondents, only 2.6% of farmers prepare their land by frequent tillage which involves repeated cultivation (3–5 times depending on the required soil tilth and crop types) with the local maresha plough (oxen-drawn implement with a single tine) combined with residue removal. All farmers employed in frequent tillage practice resided in the highland agroecological zone (Table 4). This might be due to the fact that farmer in lowland and midland depends on perennial crops like coffee, fruit and enset while farmers in the highland produce annual crops to some extent.

As noticed during the focus group discussion, the choice of land preparation method depends on the target crop and soil fertility status. Zero tillage is mostly used in highly fertile soil which involves placing the seed on the soil surface and slashing and mulching afterward or an opening of a 2 cm–30 cm wide hole (depending on seed/seedling size) in the ground (which is locally known as “Hoffa”) for seed or seedling placement while minimum tillage is used for averaged soil to plant cereal crops. Tillage in the case of enset and coffee crops in fertile soil is only permissible as a one-time intervention using a hoe to loosen the soil before planting the saplings or seedlings. Land preparation and tillage practices are like other agricultural practices seeking sustainability, which requires careful selection of methods and combination with other practices to succeed in maintaining productivity while improving soil quality (Ludvig et al., 2012).

About 92.5% of farmers’ land preparation depended on manpower using a traditional tool such as a hoe, while 7.5% of farmers prepare their land using the draft animal for planting annual crops (Figure 2). This result is in line with the findings of Tadesse, 2002 who found that the Gedeo implicitly applies principles of minimum tillage using simple hand tools. In the study area, there were no practices of vegetation clearing and burning during land preparation. Such management practices leave significant amounts of residues on the surface, to protect soils from erosion (David et al., 2013).

![Figure 2. Farmers land preparation options.](image)

3.3.2. Recycling, regeneration and addition of organic materials and nutrients

Return of organic matter and other resources removed from the soil through harvesting by the recycling, regeneration and addition of organic materials is one of the major characteristics, given much emphasis in organic production systems (IFOAM, 2005). The result of this study shows that the majority (97.4%) of farmers in the study area depend on organic soil fertility management practices (Table 4). Abiyot (2013) also stated that in the Gedeo zone of coffee growing areas farmers are not utilizing chemical fertilizer as a source of nutrients. Integration of livestock with cropping which was practiced by farmers of the study area can be the basis of a balanced and sustainable farming system, allowing nutrient recycling and effective resource use (Tadesse, 2002). Among many organic soil fertility management practices farmyard manure, compost, moona, crop residue, agroforestry green manuring and mulching were widely practiced in the study area.

**a) Farmyard manure (FYM):** The farmers in the study area extensively use FYM. It is considered as environmentally and economically friendly means of fertilization, decreasing the dependence on synthetic fertilizers (Regan and Andersen, 2014). The practice comprises mainly the use of livestock bedding, waste fodder, enset leaf and leftover, tree leaves and crop residue and weed for soil fertility. These materials were primarily dumped in the homestead and exposed to the sun, rain and wind for several weeks until their transfer to the farm. The ‘heap’ method of composting is common practice and most of them were half decomposed. During fieldwork, we also observed that most manure heaps were uncovered that may have resulted in nutrient losses through volatilization during sunny weather (Onyedur et al., 2008). The large proportions (88.9%) of farmers were practiced at highland followed by midland (66.7%) and lowland (41.7%) agroecological zones (Table 4). The low practices of farmyard manure among farmers residing in midland and lowland agroecological zones have been attributed to a lack of sufficient livestock number due to the absence of grazing area (Tadesse, 2002). The result of this study corroborates with the findings of Abebe and Debebe (2019) and Marenya and Barret, 2007, who reported the direct correlation of utilization of farmyard manure with its availability. The major challenge during utilizing farmyard manure in the agricultural field is mobilization of sufficient manure and labor for soil fertility management. According to Tittonell et al. (2010) field plots close to homestead receive a higher application rate than fields further away. As a remedy to this fact, farmers in the study area developed the strategy which employed the temporary shifting of dwelling/farmhouse to the targeted farm field that requires more management which is locally known as Urane. Urane is a kind of in-situ land

| Table 4. Farmers soil fertility management practices across the agroecological zone of the study areas. |
| Soil fertility management practices | Agroecological zones (%) |
|-----------------------------------|--------------------------|
|                                   | Highland | Midland | Lowland | Overall |
| Organic practices (yes, No)       |          |         |         |         |
| Farmyard manure                  | 88.9     | 73.1    | 48.1    | 70.4    |
| Compost                          | 50       | 52.2    | 63.5    | 54.1    |
| Green manuring                   | 86.1     | 100     | 100     | 98.1    |
| Mulch                            | 41.7     | 80.2    | 63.5    | 71.9    |
| Moona                            | 33.3     | 0       | 0       | 4.4     |
| Agroforestry                     | 100      | 100     | 100     | 100     |
| Crop residue                     | 52.8     | 72.2    | 63.9    | 63.0    |
| Chemical fertilizer (DAP and Urea)| 19.4     | 0       | 0       | 2.6     |
| Tillage practices                |          |         |         |         |
| Minimum/zero tillage             | 80.6     | 100.0   | 100     | 97.4    |
| Frequent tillage                 | 19.4     | 0.0     | 0.0     | 2.6     |

Source: Own survey data, 2020
management system, whereby farmers augment the fertility of soils through the application of animal manure and the growing of trees (Abiyot, 2013) which is one of the soil fertility practices that play a key role in building sustainable agriculture systems.

b) Compost: Compost preparation and utilization is one of the soil management practices considered in the study area to replenish soil fertility. Its preparation in the study area is mainly consisting of green vegetation from farms and roadside, ash from the kitchen, animal dung, coffee pulp from pulping industries and open market wastes. The survey result showed that generally about 54.1% of farmers were used compost to maintain soil fertility with 63.9, 55.6 and 47.2% at lowland, midland and highland agroecological zones, respectively (Table 4). Generally, farmers highlighted during the focus group discussion that the scarcity of composting material was a major constraint for compost production in the study area regardless of differences in agroecological zones. This is in line with many studies (Svotwa et al., 2009; Abera et al., 2020; Zerssa et al., 2021) who stated that the availability of composting material is a major challenge for its use.

c) Green manuring: It is common practice in the study area and performed by almost all (98%) farmers (Table 4). It consists of leaving selected indigenous herbs to grow until blooming and ploughing it to incorporate into the soil. Farmer uses herbaceous plants such as Lache (Impatiens species), Budhe (Dioscorea sp.), Hishshe (Swertia abyssinica), Shagoda (Heteropogon contortus), Dobe (Tragia cinerea), Nuxa as green manure. As the farmer explained during the discussion, in addition to herbaceous plants, they also use leaves of shrubs like Dumbo'la (Solanecio gigas), Reeje (Vernonia myriantha), and Ebicha (Vernonia amygdalina) and tree such as Dhadhato (Millettia ferruginea) and Welena (Erythrina brucei) by spreading their leaf directly into the farm (Figure 3).

d) Mulching: It is a commonly used practice irrespective of agroecological zones in the study area. Enset leaf and green grass were the most common organic mulching materials. As shown in Table 4, about 71.9% of farmers were practicing mulching. This might be due to the nature of mulching practices that mostly is not labour-intensive, highly cost-effective, compatible and easy, and cheap to adopt (Junge et al., 2009). The use of mulch was higher (80.2%) in midland agroecological zone as compared to lowland (41.7%) and highland (63.5%) agroecological zones. The high use of mulching in midland agroecological zone might be associated with the availability of a high population of enset plants that its leaf is suitable mulching material.

e) Moona (direct use of animal manures): In the study area, farmers employed animal faces and liquid animal manures directly to the farm, which is locally known as Moona. It is done by gathering several cattle at a farm plot for a specified period of time. The practices facilitate the utilization of 50% of the N excreted through cattle urine (Rufino et al., 2007). Moona practice was employed by the farmers residing in the highland agroecological zone (Table 4). This is due to the practice’s need a large number of animals for farm fertilization and such a large quantity of livestock are found in the highland agroecological zone. According to the survey findings, 33% of respondents at the highland agroecological zone used moona to improve the soil fertility of their farms. A similar study by Yoseph et al., 2019 identified moona as one a traditional way of soil acidity amendment practices in the highland area of Gedeo zone southern Ethiopia.

f) Agroforestry: Agroforestry is widely considered as the most holistic, economically feasible and environmentally sustainable soil fertility management practice that enhance soil fertility, reduce erosion and improve water quality (Jose, 2009; Hassan et al., 2016; Meragiaw, 2017). It is a centerpiece of organic agriculture in the tropics (Kilcher, 2007). The survey result revealed that all farmers (100%) in the study area practiced agroforestry (Table 4). This implies that agroecological zone differences did not prohibit farmers from participating in agroforestry practices. This indicates the deep-rootedness of the tree planting culture in the Gedeo community (Tadesse, 2002). However, as observed during the survey the

Figure 3. Herbaceous and shrubs used as green manure: Dumbola (Solanecio gigas) (a), Dobe (Tragia cinerea) (b), Lache (Impatiens spp) (c) and slashed herbaceous to incorporate into the soil (d).
intensity of agroforestry and vegetation type varies across agroecological zone where enset based in highland, enset coffee in middle and coffee fruit in the low land (Mesele, 2013).

Farmers in the study area deliberately grow selected different trees, shrubs and herbaceous plants that improve soil fertility and microclimatic condition of their farm. Among which the following are commonly used in the system: (a) indigenous tree species such as Wolena (Erythrina brucei Schweiñf), Dhadhato (Milletia ferruginea (Hochst.) Bak.), Od’e (Ficus sur Forsk.), Qilixa (Ficus elastica Roxb. ex Hornem.), Wedessa (Cordia africana Lam.), Biribissa (Podocarpus falcatus (Thunb.), (b) shrubs such as Dumbola (Solaneo giga), and Ebicha (Veronica amygdalina). (c) Herbaceous enset (Ensete ventricosum (Welw.) Chesman), Muze (Musa x paradisiaca L.). Such trees and herbaceous are regularly replenishing soil fertility and productivity through a continuous supply of organic matter through litterfall production and protection from soil erosion and leaching (Tadesse, 2002; Faleyimu and Akinyemi, 2010; Mesele, 2013). They can also generate an income from their fiber, wood, fruits and fodder (Mesele, 2007).

3.3.3. Erosion prevention measures

The survey result shows that the most commonly used erosion control practice was biological soil erosion prevention methods rather than erosion control that involved physical or engineering soil and water conservation measures. These methods employed by farmers include mullyayer agroforestry (100%), green manuring (98.1%), minimum tillage (92.4%) and mulching (79.9%) across the agroecological zones (Table 4). Thus about 89.3% of respondents had no apprehension for soil erosion problems. The low incidence of erosion in the study area may be attributed to the fact that the severity of physical constraints has led to innovative farming practices that use diverse and creative solutions. Evidence suggested that besides improving soil fertility, organic soil fertility management practices including conservation tillage, use of organic fertilizer, green manuring and agroforestry are attributed to control soil erosion in organic farms (Govaerts et al., 2007; Machado et al., 2015). The finding of this research is contrary to the report of (Guzha et al., 2018; Moses et al., 2019) who stated that in East Africa, the inappropriate soil tillage practices involving soil excavation, clearing of the soil green biomass cover, and unsuitable soil conservation measures have accelerated surface runoff. During the survey, it was also noticed that In the study area enset (Ensete ventricosum (Welw.) Chesman) is the staple food crop and keystone for erosion conservation as live cover and cultivated as mixed cropping practice with coffee, fruits, indigenous tree and root crops. These crops planted in stagger shape as hedgerows on slope gradient of over 30% have intercepted the runoff and thereby reduce soil erosion. Tadesse, 2002 also reported that soil erosion averted in the Gedeo agricultural system is by the use of water stocking enset plants. Funnel-like enset leaves collect rainwater towards a barrel-like pseudo-stem, where it is stored and slowly distributed, via the roots, following moisture gradient, avoiding erosion due to the direct impact of rainwater. Similarly, Birhane and Melesse (2015) reported that despite slope greater than 100% under agriculture in the Gedeo zone, there is no evidence of soil erosion problem in the area. As noticed from the discussion, other crops such as beans, pumpkin, sweet potatoes (at lowland and midland) and cabbage and leek (at highland) are deliberately grown to control soil erosion as live cover. These practices keep the soil under cover throughout the year and protect soil against erosion by reducing water runoff. Moreover, the practices are the prime source of organic matter replenishment and help to improve several soil properties, such as water infiltration, water storage and particle aggregation (Wainwright et al., 2002).

3.4. Determinants of soil fertility management practices

The binary logistic regression model was employed to establish the relationship between dependent (soil fertility management practices) and independent variables (demographic and socioeconomic factors) affecting soil fertility management practices in the study area. For that reason, 13 explanatory variables were selected to explain the dependent variable (Table 5).

The age of the household head had a negative significant (p < 0.1) effect on adoption of farm yard manure (Table 5). This suggests that younger farmers had a higher probability of adopting farmyard manure than older farmers. This is due to the fact that farmyard manure practices generally require more physical effort and relatively healthier and stronger younger farmers are more likely to implement them than older household heads. The finding also agrees with Somda et al. (2002) who reported that age of households head had a negative significant effect on the adoption of compost in Burkina Faso. Moreover, Jane et al. (2009) also noted that the age of the household head negatively influenced adoption of integrated soil fertility management practices in Kenya.

| Variable                  | Compost (log-likelihood) | Farmyard manure (log-likelihood) | Green manuring (log-likelihood) | Mulching (log-likelihood) |
|--------------------------|--------------------------|----------------------------------|---------------------------------|--------------------------|
| Age                      | -0.004 (0.7)             | -0.045 (0.013)*                  | 0.005 (0.819)                   | 0.008 (0.561)            |
| Education status         | -0.045 (0.128)           | 0.038 (0.457)                    | 0.060 (0.355)                   | 0.068 (0.083)*           |
| Marital status           | -0.277 (0.513)           | -0.955 (0.131)                   | -0.406 (0.569)                  | 0.227 (0.648)            |
| Family size              | 0.126 (0.042)*           | 0.288 (0.003)**                  | 0.047 (0.667)                   | 0.102 (0.203)            |
| Dependancy ratio         | -0.002 (0.421)           | -0.007 (0.037)*                  | 0.002 (0.673)                   | 0.000 (0.918)            |
| Land size (ha)           | -0.103 (0.681)           | 0.501 (0.359)                    | 0.248 (0.721)                   | -0.338 (0.323)           |
| Coffee number            | 0.000 (0.717)            | 0.0001 (0.904)                   | -0.001 (0.207)                  | -0.001 (0.097)           |
| Enset number             | 0.000 (0.464)            | 0.0002 (0.058)                   | 0.001 (0.51)                    | 0.001 (0.375)            |
| Livestock holding (TLU)  | 0.154 (0.117)            | 2.204 (0.000)**                  | -0.118 (0.51)                   | 0.065 (0.603)            |
| Agricultural total income| 0.000 (0.054)*           | 0.001 (0.148)                    | 0.000 (0.008)**                 | 0.000 (0.000)**          |
| Off-farm income          | 0.000 (0.94)             | 0.001 (0.243)                    | 0.0001 (0.827)                  | 0.000 (0.534)            |
| Agroecology              | 0.812 (0.017)*           | -1.079 (0.032)*                  | 0.990 (0.078)*                  | 0.224 (0.553)            |
| Constant                 | -2.180 (0.070)*          | 5.146 (0.005)**                  | -0.476 (0.796)                  | 2.247 (0.106)            |
| Log-likelihood           | -1.583 (0.037)           | -80.866 (0.005)**                | -59.609 (0.796)                 | -110.274 (0.106)         |
| Wald²                    | 26.98                    | 144.65                           | 24.82                           | 56.71                    |
| Pseudo R                 | 0.0125                   | 0.0244                           | 0                               | 0                       |

Notes: Values in parenthesis are P>|z|; *, ** and *** indicate significant at 0.1, 0.05 and 0.01 respectively.
The education status of the household head was found to have a positive and significant relationship with farmers’ mulch adoption. Education would therefore be a critical factor in influencing the adoption of mulching in the study area. However, other soil fertility management practices are not significantly affected by the education status of the household head. This finding concur with the finding of previous studies (Asfaw and Admasie, 2004; Miheretu and Yimer, 2017).

The family size of the household positively and significantly influenced the adoption of compost (p < 0.1) and farmyard manure (p < 0.05), which implies that households with large family sizes had a higher probability of utilizing compost and farmyard manure as compared to households with small size. This might be due to the fact that as both compost and farmyard practices are labor-intensive, the size of the household should have a positive impact on their application. This is in congruent with the findings of Gebremedhin and Swinton (2003) who stated that the presence of more working-age household members favored adoption of labor-demanding soil fertility management.

The dependency ratio of the farmer households had a negative impact on both compost and farmyard manure adoption however, only farmyard manure was significantly (p < 0.1) affected by the dependency ratio. This might be due to the presence of more working-age household members who favored the adoption of labor-demanding farmyard manure. Household labour is the most important source of labour supply for farmer households. The results are consistent with the finding of Martins et al. (2009), who reported that household labour is a major constraint to the adoption of labour-intensive technologies such as animal manure and compost.

The number of coffee shrubs in the farm is an important determinant of its production. Coffee shrub holding of the household had a negative and significant (p < 0.1) effect on the adoption of mulching. This result suggests that households with a small number of coffee shrubs are more likely to adopt mulching. The other soil fertility management practices were not significantly varied due to differences in coffee shrub’s holding.

Livestock holding of the household was positive and significant (p < 0.01) association with the probability of adoption of farmyard manure (Table 5). This result suggests that animal manure generated from own livestock is important for farmyard manure and hence households with many livestock are more likely to adopt farmyard manure. This study finding also agrees with the finding of Marenya and Barret, 2007 who reported that livestock numbers owned by the household were positively associated with the adoption of manure in western Kenya.

The coefficient for the agriculture annual income had a positive and significant effect on the adoption of compost at (p < 0.1), green manuring (p < 0.05) and mulching (p < 0.01). Households with high annual agriculture income are more likely to practice organic soil fertility practices. The possible reason for a positive relationship between annual farm income and farmer soil fertility practices is that wealthy farmers produce a surplus, this also can be sold, increasing cash earnings that can enable them to do hair labour for the production and maintenance of compost and farmyard manure. This finding is consistent with the result of Jayne et al. (2009) who report that good farm management implies efficient resource use, increase in productivity and increase in wealth which is critical for the adoption of farm management.

Based on altitudinal differences Tadesse, 2002 and Mesele (2013) have categorized the study area into three, viz. highland, midland and lowland agroecological (Table 1). Results of the logistic regression model showed that the agroecological zone had positively and significantly (p < 0.1) influenced the probability of adopting compost and green manuring implying that farmers located at lowland agroecological zones have a higher probability of the adoption of these inputs than lowlands. On the other hand, agroecological zones had significant (p < 0.1) and negative effects on farmyard manure adoption. This could be because of the higher availability of livestock in highland agroecology zone than lowland.

4. Conclusions

Results from the present study showed that farmers in the study area practiced various indigenous organic soil fertility management practices including compost, farmyard manure, green manuring mulching and agroforestry. The use of chemical fertilizer was negligible and limited at the highland agroecological zone. In agreement with our hypothesis, the results showed that the socioeconomic status of farmers affected the adoption of soil fertility management practices. The family size of the household had a strong positive influence on the adoption of compost and farmyard manure. The dependency ratio of the farmer households has a negative impact on farmyard manure adoption while differences in household head education status and coffee shrubs holding of the household had a positive and significant relationship with farmers’ mulch adoption. Livestock holding of the household was significant (p < 0.01) positive association with the probability of adoption of farmyard manure. The coefficient for the agriculture annual income and differences in agroecological zones had positive and significant associations with the adoption of compost and green manuring. Hence to promote organic soil fertility management practices, government and concerned bodies should focus on enhancing farmers’ income targeting on young families where all spouses and their working-age household members work on the farm, reducing dependency ratio through awareness creation on the importance of family planning and enhancing intensive livestock management that supports more livestock for provision of farmyard manure. Furthermore, the farmer should be advised to possess a manageable number of coffee shrubs.

Declarations

Author contribution statement

Abiyot Mebrate: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Nigussie Zeray; Tadesse Kippie: Analyzed and interpreted the data; Wrote the paper.

Getahun Haile: Analyzed and interpreted the data.

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Data will be made available on request.

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The authors declare no conflict of interest.

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