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Soil survey and fertility assessment and mapping of Argo-Gedilala subwatershed in Dugda district, central rift valley of Ethiopia

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Detailed study on soil fertility assessment based on the understanding of the soil system are not available for the most part of Ethiopia. With the cognizance of this fact, the present study was conducted to assess the soil fertility status and to prepare the fertility map of Argo-Gedilala Subwatershed in Dugda District, Central Rift Valley of Ethiopia. Eighteen composite soil samples (0-20cm depth) were taken for fertility assessment of the soil from the land mapping units of the subwatershed and mapping the status of selected soil fertility parameters was done using ordinary kriging technique in ArcGIS 10 software. The bulk density is at an acceptable range 1.3 to 1.4 g cm-3 for mineral agricultural soils. The soil organic matter contents of LUs (04, 05 and 06) 680.47 ha (64.77%) in the study area can be categorized in the range of low soil organic matter content and LUs (01, 02 and 03) 369.31 ha (35.23%) can be categorized in the medium range at the subwatershed. The average percent total N content of the LUs (02, 04, and 05) 567.7ha (54.05%) were found to be low; LUs (01, 03 and 06) 482.61ha 45.95% were found to be moderate. The mean available P of soils of LUs (04and05) 443.17 ha (42.19%) was categorized as very low range and LUs (01, 02, 03 and 06) 607.15 ha (57.82%) classified as low range. Exchangeable Ca2+, LUs (01, 02, 03, 05 and 06) 824.88 ha (78.55%) were very high while LU04 which covered an area of 225.44 ha (21.46%) were rated as high. The soils of the study area had low organic matter, available P and total nitrogen content, which can be seen as production constraints of all cultivated lands. To overcome the identified limitations, increasing the organic matter levels through continuous application of manure and/or compost should be integrated with chemical fertilizers.

Key words: Fertility status, land-mapping units, ordinary kriging.

INTRODUCTION

In Ethiopia, low agricultural productivity and related shortage of additional cultivable lands are problems to most Sub-Saharan African (SSA) countries (Bationo et al., 2006; AGRA, 2007; Sommer et al., 2013). From the many reasons suggested for the current low agricultural production in SSA, are majorly induced by land...
degradation, nutrient mining, recurrent droughts, variable rainfall and crop pest damages (Tadesse, 2001; Badeghe, 2009; Ringheim et al., 2009; IFPRI, 2010).

Agriculture is the mainstay of the country’s economic activity and its contribution to the national economy is significant. It accounts for about 43% of the growth domestic product (GDP), 90% of exports, and 80% of total employment (CSA, 2013). However, increasing pressure due to increased in human population has degraded vital natural resources in the country and became a serious threat to sustainable agriculture (Gete and Hurni, 2001).

Declining soil fertility has also been stressed to be the fundamental barrier to agricultural development and the major reason for the slow growth in food production in Ethiopia (Hintsa et al., 2016). Mining of nutrients due to low level of fertilizer use and unbalanced application of nutrients, complete removal and/or burning of crop residues, leaching due to inadequate runoff management, continuous monocropping coupled with low inherent fertility are among the main causes for low and declining soil fertility in the country (Chillot and Hassan, 2009). On the other hand, the fertilizer usage in the country is mainly subjective without being based on soil fertility data and using blanket rate of application. Abreha and Yusuf (2008) reported that the fertilizer recommendations given to farmers are not considering the crop need, soil nutrient dynamics and agro-ecological factors. These have resulted in a steady decline of nutrient levels in the soil (Diriba et al., 2013) and poor nutrient management in all Ethiopian regions (Wondwosen and Sheleme, 2011).

Soil test-based fertility management has been one of the effective tools for increasing productivity of agricultural soils that have a high degree of spatial variability. The purpose of producing a soil fertility map is to determine plant nutrient availability and distribution and the pattern of nutrient depletion in the project area. However, there is scarcity of spatial information on soil fertility status in the district. In order to fill the aforementioned gaps and support the local community to tackle soil fertility the need to know of soil fertility status is very significant. Hence, this paper assesses the soil fertility status and to prepare the fertility maps of Argo Gedilala subwatershed since, a detailed study in the district is not available.

MATERIALS AND METHODS

Description of the study area

Location, topography and climate

The study was carried out in Argo-Gedilala sub watershed in Dugda district, Oromia in Ethiopian Great Rift Valley, which lies between 8° 30'00"- 8° 60'00" north and 38° 35’00"-38° 37’00" east with an elevation that ranging between 1869 to 1966 m above sea level (masl) (Figure 1). The total area of the sub watershed is about 1049.44 ha. The topography of the watershed is characterized by flat, level land, constituting plains to gently sloping and strongly sloping. The slope gradient of the study area ranges from 0 to 12%. On the basis of slope percentage, the study area has been classified into four slope classes: 0-1, 1-2, 2-5, and 5-10% (FAO, 2006). The area is a good representative of ecologies that experience high population pressure, soil fertility depletion, acute land and food shortages due to low production and strong crop-livestock interactions (DWOA, 2014). Attributed to the long history of crop cultivation and deforestation, the soils of most parts of the area are found to be exposed to wind and water erosion (Field survey, 2019). Annual rainfall is between 700 to 800 mm, which is most falling from July and August. The temperature is cool and only varying between 15°C to 28°C.

Soil types of the study area

At district level, the area is covered by dark brown and sandy loam, clay loam and clay soils (DWOA, 2014), which are classified into Vertic Cambisols and Luvic Phaeozems, Lithosols (Leptosols) and Fluvisols. Fluvisols are derived from alluvium on the lakeshore. Gelelyc Mollic Fluvisols are derived from lacustrine deposits along the shores of Lake Zeway.

Farming system

Agriculture is the mainstay of the district’s population and hence it provides almost the largest livelihood share of the population. The major farming system in the study area is mixed livestock and crop production system with traditional and indigenous knowledge inherited farming practices and farm implements by oxen plough. The crop production in the area is dominated by cereal crops particularly wheat, maize, teff and sorghum and rarely barley in the study area (DWOA, 2014).

Site selection and soil sampling

Site selection

The study area was divided into different land units (LUs) in terms of land use types, surface soil color, altitude, slope gradient surface land features, and soil management practices, dominant previous and current cropping history. Accordingly, 6 land units were identified and demarcated. Once the representative LUs were identified, a description of sampling site and soil sampling was carried out for each land unit (Table 1). Based on site and soil surface characteristics coupled with auger sampling point description, six sampling land units (LUs) were identified. In order to assess the fertility status of the soils in the watershed, ten to fifty subsamples soils (at 0-20 cm depth) were collected from each land mapping units (MUT/sampling point) to form one composite soil samples based on quarter method. Then a total of 18 composite surface soil samples (3 soil samples × 6 sampling land units) were collected in polyethylene bags and properly labeled.

Soil sample preparation

The sampled soils were carefully bagged, labeled, packed and transported to the laboratory for analysis. The disturbed soil samples collected from each land units at room temperature, ground using mortar and pestle and made to pass through 2 mm sieve in the laboratory for all the selected soil parameters except for soil OC and total N prior to analysis. For the analysis of OM and total N, the soil samples were further passed through 0.5 mm sieve. Finally, the soil samples were analyzed for selected Physico-chemical properties following the standard analytical procedures.
Table 1. Important attributes of the land units in Argo-Gedilala sub watershed.

| Land units | Slope (%) | Area(Ha) | Area (%) | Land use types | Dominant previous crop | Dominant current crop | Residue management |
|------------|-----------|----------|----------|---------------|------------------------|----------------------|--------------------|
| LU01       | 0-1       | 162.16   | 15.44    | Cultivated    | Maize                  | Wheat                | Cleared            |
| LU02       | 2-3       | 124.54   | 11.86    | Cultivated    | Teff                   | Maize                | Cleared            |
| LU03       | 1-2       | 83.31    | 7.93     | Cultivated    | Maize                  | Teff                 | Cleared            |
| LU04       | 7         | 225.44   | 21.46    | Cultivated    | Wheat                  | Maize                | Cleared            |
| LU05       | 3         | 217.73   | 20.73    | Cultivated    | Wheat                  | Maize                | Cleared            |
| LU06       | 5         | 237.30   | 22.58    | Cultivated    | Teff                   | Wheat                | Cleared            |

Note: Mgt. = Management

Soil laboratory analysis

Analysis of soil physical and chemical properties

Particle size distribution was analyzed on field by feel method and in the laboratory by the Bouyoucos hydrometer method using sodium hexametaphosphate as a dispersing agent as described by Sahlemedhin and Taye (2000). Bulk density (BD) was determined from the weight of undisturbed (core) soil samples, which was first weighed at field moisture content and then dried in an oven at 105 °C to constant weight (Baruah and Barthakur,1997) and average particle density of the minerals soils (2.65g/cm³) (Landon,1991). Finally, the total porosity was calculated from the values of bulk (BD) and particle (PD) densities.

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\text{Total porosity(\%) = } (1 - \frac{\text{BD}}{\text{PD}}) \times 100
\]

Soil pH was measured in a 1:2.5 soil: water suspension potentiometrically by using pH meter and electrical conductivity of a saturated soil paste extracted (ECe) at 25 °C was determined using electrical conductivity meter as described by Sahlemedhin and Taye (2000). Organic carbon (OC) was determined using Walkley black method. The percent soil organic matter was calculated by multiplying the percent organic carbon by a factor 1.724, considering the fact that organic matter is composed of 58% carbon. Total nitrogen contents in soil were determined by using the kjeldhal procedure by oxidizing the organic matter with sulphuric acid and converting the nitrogen into NH₄⁺ as ammonium sulphate (Sahlemedhin and Taye, 2000). Available p was determined using the standard Olsen extraction method (Okalebo et al., 2002). Total exchangeable bases were determined after leaching soil samples with ammonium acetate. Amounts of Ca²⁺ and Mg²⁺ in the leachate were measured by titration using the EDTA method and K⁺...
and Na⁺ were analyzed by flame photometry. Cation exchange capacity (CEC) was determined after saturating the samples with 1N ammonium acetate (pH =7) as described in (Okalebo et al., 2002). Percent base saturation was calculated by dividing the sum of the base forming cations (Ca, Mg, Na and K) by the CEC of the soil and multiplying it by 100.

**Soil fertility status and mapping**

After the respective coordinate points marked using GPS were fed into the GIS environment; then, polygons for the watershed and for each LU were created by digitizing the recorded boundary points. The area of each LU was estimated from the created polygons using Arc map 10.1. Based on soil laboratory analysis results, soil fertility indices were generated and ratings were made; and the soils were classified into different fertility categories, that is, very low, low, medium, high and very high on the basis of the content of each selected soil parameters. The status of each mapped soil fertility parameters were identified for each land units (LU). For each fertility classes, different symbol colors and patterns were selected from symbol selector of Arc Map 10.1. Finally, Mapping of soil nutrients status was carried out using Arc GIS software version 10.1. Ordinary kriging was used to predict unknown values of soil nutrients concentration for non-sampled areas based on the nearby surveyed data. Fertility status of each LU in the study area was mapped for selected soil fertility parameters which were mapped are pH, OM, total N, available P, CEC, exchangeable bases (Ca, Mg, K), CEC and PBS.

**Statistical analysis**

Descriptive statistics (mean, range, standard deviation, coefficient of variation) of soil parameters were computed using Statistical Package for Social Science (SPSS) software model to analyze the relationships among and within a selected soil's physicochemical properties. The ratings (very low, low, medium, high and very high) of determined values were used based on conventional standards to indicate differences in soil parameters at different slope gradients and land units.

**RESULTS AND DISCUSSION**

**Soil texture, bulk density and total porosity**

The soil textural class of all land units in the study area was predominantly clay and clay loam (Table 2). Accordingly, the lowest clay content (34.84%) was recorded for soils LU04, while the highest mean clay content (44.69%) was for LU 01. On the other hand, the lowest silt (23.91%) and sand (23.67%) content of the soil were recorded for LU04 and 02 respectively. While the highest mean silt (33.33%) and sand (35.33%), content were recorded for soil of LU03 and 05, respectively.

Generally, clay size fraction followed by silt fraction is the dominant soils around the study area. The textural classes of soils in almost all the land units are clayey followed by clay loam. The most probable reasons for the variation in the textural class in the study area might be differences in topography and parent material. The highest (1.24 g cm⁻³) and the lowest (0.62 g cm⁻³) mean bulk density values were recorded for LU05 and 01 respectively (Table 2). The variation in bulk density could be attributed to variation in soil organic matter content, soil texture, and intensity of cultivation (Sharma and Anil, 2003). Similarly, the highest bulk density for LU05 could be due to lower soil organic matter content and higher degree of soil compaction due to intensive cultivation since this LU has been cultivated for a long period of time. According to Bohn et al. (2001), the acceptable range of bulk density is 1.3 to 1.4 g cm⁻³ for mineral agricultural soils. Most of the soil bulk density values of the different land units of the area were not very high, which signifies that the soils in the sub-watershed were not compact to limit root penetration and restrict the movement of water and air in the soil. This indicates the existence of loose soil conditions in almost all land units and, therefore, the soils of the study area have a good structure.

The total porosity of the soils, in general, varied with bulk density (Table 2). Accordingly, the percent total porosity of all the land units was very high (> 40%) according to the FAO (2006) rating. Total porosity increases as the bulk density decreases while it decreases as bulk density increases. The lowest (52.33%) and highest (76.48%) total porosity values were recorded for soil of LU05 and 01 unit, respectively. This implies that there is better aggregation that can create conducive soil physical conditions for crop production in the area.

**Soil pH**

Soil pH values were varied among the land units (Figure 2). The lowest (6.82) and highest (7.15) pH values were recorded for LU05 and 01 (Table 3) respectively. As per the ratings established by Tadesse (1991), soils of all land units qualify for the neutral range. The variation in pH values among land units might be due to differences in parent material, topographic position, land use type, removal of basic cations by crop harvests, and prevailing weather conditions. Regardless of the differences observed in soil pH among the land units, the pH values recorded in the sub-watershed are within the range that are quoted as suitable for production of many crops, for these ranges represents pH values that are ideal for availability of most of the essential nutrient elements and 7.0 was considered as an ideal for plant growth. Thus, the pH values of soils of the study area are ideal for plant growth and the availability of most of the plant nutrients might not be affected with this pH ranges. These pH values suggest that there is no rises of aluminum toxicity in the study area.

**Soil OM, TN, and Av.P in the study area**

The organic matter content of soils in the sub-watershed showed spatial variation among soil OM values of the
Table 2. Physical characteristics of soils under different land units in Argo-Gedilala subwatershed.

| Parameter | Descriptive measures | LU01  | LU02  | LU03  | LU04  | LU05  | LU06  |
|-----------|----------------------|-------|-------|-------|-------|-------|-------|
| Sandy%    | Mean                 | 25.33 | 23.67 | 23.67 | 31.27 | 35.33 | 28.67 |
|           | Std                  | 3.06  | 2.08  | 3.79  | 11.40 | 9.87  | 10.32 |
|           | CV%                  | 12.06 | 8.80  | 16.00 | 36.45 | 27.92 | 35.99 |
| Silt%     | Mean                 | 30.00 | 32.33 | 33.33 | 23.91 | 26.00 | 30.67 |
|           | Std                  | 4.00  | 4.04  | 4.16  | 8.90  | 5.29  | 6.11  |
|           | CV%                  | 13.33 | 12.50 | 12.49 | 37.20 | 20.35 | 19.92 |
| Clay %    | Mean                 | 44.69 | 44.67 | 43.00 | 34.84 | 38.67 | 40.67 |
|           | Std                  | 1.15  | 6.11  | 4.36  | 12.42 | 5.03  | 8.08  |
|           | CV%                  | 2.59  | 13.68 | 10.14 | 35.66 | 13.02 | 19.88 |
| BDg/mcm$^3$ | Mean                | 0.62  | 0.90  | 0.81  | 0.96  | 1.24  | 1.20  |
|           | Std                  | 0.04  | 0.21  | 0.21  | 0.40  | 0.12  | 0.18  |
|           | CV%                  | 6.48  | 23.14 | 25.72 | 41.62 | 9.65  | 14.97 |
| TP%       | Mean                 | 76.48 | 66.16 | 69.56 | 53.28 | 52.33 | 54.59 |
|           | Std                  | 1.53  | 7.83  | 7.83  | 20.88 | 4.50  | 6.80  |
|           | CV%                  | 1.99  | 11.83 | 11.25 | 39.94 | 8.44  | 12.45 |

Textural class - Cl Ci Cl Cl CL CL Cl

LU=Land unit, Cl=clay, CL=Clay Loam, CV=Coefficient of Variation, BD=Bulk density, STD=Standard deviation, TP=Total porosity.

Figure 2. Land units selected for soil sampling and sample points.

According to Gazey and Davies (2009), pH between 5.5
Table 3. Soil pH, organic carbon, total nitrogen and available phosphorus values of the Land units in Argo-Gedilala subwatershed.

| Parameter | Descriptive measures | LU01     | LU02     | LU03     | LU04     | LU05     | LU06     |
|-----------|----------------------|----------|----------|----------|----------|----------|----------|
| pH%       | Mean                 | 7.15     | 7.03     | 7.10     | 7.08     | 6.82     | 6.84     |
|           | Std                  | 0.13     | 0.11     | 0.02     | 0.04     | 0.07     | 0.11     |
|           | CV%                  | 1.75     | 1.60     | 0.33     | 0.62     | 1.08     | 1.58     |
| TN%       | Mean                 | 0.14     | 0.12     | 0.13     | 0.11     | 0.12     | 0.13     |
|           | Std                  | 0.01     | 0.01     | 0.01     | 0.01     | 0.01     | 0.01     |
|           | CV%                  | 7.37     | 6.71     | 8.40     | 4.13     | 4.61     | 3.98     |
| OC%       | Mean                 | 2.02     | 1.69     | 1.77     | 1.17     | 1.23     | 1.24     |
|           | Std                  | 0.31     | 0.04     | 0.19     | 0.45     | 0.11     | 0.07     |
|           | CV%                  | 15.43    | 2.13     | 10.58    | 38.29    | 8.98     | 5.85     |
| Av.p (mg kg⁻¹) | Mean | 9.80     | 6.94     | 7.81     | 4.98     | 4.93     | 6.10     |
|           | Std                  | 3.42     | 0.16     | 0.86     | 1.92     | 0.93     | 1.86     |
|           | CV%                  | 34.85    | 2.25     | 11.03    | 38.49    | 18.80    | 30.48    |

TN=Total Nitrogen, OC=Organic carbon, Av.p=Available phosphorus.
available P were recorded for soils of LU01 and 04, respectively. This variability in soil available P content might be the result of different soil management practices, specifically, type and rate of organic fertilizers and the rate of inorganic fertilizers utilized in cultivated land. Besides these factors, variation in parent material, soil texture, degree of P-fixation, soil pH and slope gradient, which can cause downward movement of P with runoff water from top slope and accumulation at the bottom slope, might also contribute for the difference in concentration of available P content among land units. According to Cottenie (1980), available soil P values < 5.5-9.10-17.18-25 and> 25mg kg-1 are rated as very low, low, medium, high and very high, respectively. Based on this rating, the mean available P of soils of LUs (04 and 05) 443.17 ha (42.19%) was categorized as very low range and LUs (01, 02, 03 and 06) 607.15 ha (57.82%) classified as low range.

Exchangeable bases, cation exchange capacity and percentage base saturation

Exchangeable bases in soils of different land units in the sub-watershed also exhibited spatial variations (Table 4). Ca$^{2+}$ followed by Mg$^{2+}$ dominantly occupies the exchange complex of the soils. Cations in productive agricultural soils are present in the order Ca$^{2+}$ > Mg$^{2+}$ > K$^+$ > Na$^+$ and deviations from this order can create ion-imbalance problems for plants. Corroborating this result, Tuma (2007) also reported the same order of abundance of basic cations on the exchangeable complex of fluvial soils in Gamo Gofa zone, Ethiopia, and pointed out that such an order is favorable for crop production. Exchangeable basic cations varied for Ca, Mg Na and K among the land units (Table 4). The highest (23.19 cmol (+) kg-1) and the lowest (18.07 cmol (+) kg-1) mean values of exchangeable Ca were recorded for LUs 01 and 04, respectively. According to FAO (2006) rating of exchangeable bases, LUs (01, 02, 03, 05 and 06) 824.88 ha (78.55%) were very high in their exchangeable Ca$^{2+}$, while LU04 which covered an area of 225.44 ha (21.46%) were rated as high in exchangeable Ca (Figure 4). Similarly, exchangeable Mg levels in soils of LUs (01, 02, 03 and 06) 607.15 (57.82%) were within the range of very high while land units 04 and 05 with an area of 443.17(42.19%) were high (Figure 5). The exchangeable K, on the other hand, in all land units was rated as high (Figure 6). The exchangeable Na for LUs (01, 02 and 06) 523.84 ha (49.89) was low while LUs (03, 04 and 05) 526.48 ha (50.11) were rated as medium (Figure 6).

The CEC of the soils in the study area was varied among the land units (Table 4). The highest (44.78 cmol (+) kg-1) and the lowest (29.89 cmol (+) kg-1) mean values of CEC were recorded in LUs 01 and 04, respectively. Intensive cultivation reduced the CEC of soil of cultivated land as reported by Mesfin (1998) and Gao.
Table 4. Exchangeable bases, cation exchange capacity and percent base saturation in Argo-Gedilala subwatershed.

| Parameter | Descriptive measure | LU01 | LU02 | LU03 | LU04 | LU05 | LU06 |
|-----------|---------------------|------|------|------|------|------|------|
| Ca (cmol(+) kg\(^{-1}\)) | Mean | 23.19 | 20.63 | 21.68 | 18.07 | 20.15 | 20.37 |
| | Std | 1.07 | 1.10 | 1.45 | 7.18 | 0.38 | 1.35 |
| | CV% | 4.61 | 5.34 | 6.67 | 39.73 | 1.88 | 6.65 |
| Mg (cmol(+)kg\(^{-1}\)) | Mean | 9.37 | 8.14 | 8.09 | 6.01 | 5.94 | 8.54 |
| | Std | 0.65 | 0.59 | 0.55 | 2.31 | 0.91 | 0.56 |
| | CV% | 6.93 | 7.25 | 6.81 | 38.42 | 15.26 | 6.51 |
| K (cmol(+)kg\(^{-1}\)) | Mean | 0.64 | 0.73 | 0.83 | 0.86 | 0.91 | 0.68 |
| | Std | 0.16 | 0.25 | 0.12 | 0.35 | 0.10 | 0.20 |
| | CV% | 25.54 | 33.67 | 14.02 | 38.42 | 15.26 | 6.51 |
| Na (cmol(+)kg\(^{-1}\)) | Mean | 0.25 | 0.26 | 0.38 | 0.43 | 0.43 | 0.23 |
| | Std | 0.16 | 0.11 | 0.18 | 0.25 | 0.28 | 0.09 |
| | CV% | 61.95 | 41.66 | 46.98 | 57.08 | 64.82 | 38.64 |
| CEC (cmol(+)kg\(^{-1}\)) | Mean | 44.78 | 42.29 | 40.51 | 29.89 | 32.51 | 36.79 |
| | Std | 1.99 | 3.86 | 3.73 | 10.62 | 4.85 | 0.74 |
| | CV% | 4.43 | 9.13 | 9.20 | 35.52 | 14.93 | 2.02 |
| PBS (%) | Mean | 74.76 | 70.60 | 76.72 | 76.81 | 85.26 | 81.11 |
| | Std | 2.56 | 4.74 | 5.00 | 28.06 | 8.86 | 6.16 |
| | CV% | 3.42 | 6.72 | 6.52 | 36.53 | 10.39 | 7.60 |

CEC=Cation exchange capacity; PBS= Percent base saturation.

and Chang (1996). Similarly, Alemayehu (2007) and Fantaw (2011) reported that depletion of OM as a result of intensive cultivation contributed to lower CEC of the soils. The lowest CEC in LU04 was in line with the relatively low clay content under this land unit (Table 2). This is in agreement with the finding of Teshome et al. (2013) in soils of Abobo area, Western Ethiopia, while very high recorded CEC in LUs 01, 02 and 03 with an area of 369.85 ha (35.23%) were due to the high content of clay and OM, respectively in comparison to other land units. This is also in consent with findings of Yihenew et al. (2015) who revealed that higher clay and probably the predominance of 2:1 clay minerals, like smectites and organic matter contents contributed to high CEC. Based on the rating suggested by Hazellon and Murphy (2007), CEC of soils of (LU04, 05 and 06) 680.47 ha (64.76%) were categorized high and that of LU, 01, 02 and 03 were categorized as a very high (Figure 7).

The highest (85.26%) and the lowest (70.60%) mean descriptive values of PBS were recorded for LUs05 and02, respectively (Table 4). According to the ratings of Hazellon and Murphy (2007), the PBS of soils LUs 01, 02,03 and 04 with an area of 595.29 ha (56.69%) qualified for high range while LUs (05 and 06) 455.03 ha (43.31%) were in the range of very high in PBS status (Figure 8). The trends in PBS are similar to those observed in exchangeable basic cations, especially Ca and Mg, since factors and processes that affect the extent of basic cations also affect PBS. Thus, variability in PBS could also be because of variation in pH, OM content, soil texture, parent materials, and intensity of cultivation, leaching, slope and soil management practices. Soils with high PBS are considered relatively more fertile as bases that contribute to higher PBS are essential plant nutrients (Havlin et al., 1999). Accordingly, the soils of the study area had high to very high PBS and could be considered fertile interms of PBS.

**Conclusion**

A total of 18 composite surface soil samples (0-20cm) were collected from different land mapping units to evaluate the fertility status of the study area. The soil textural class of all land units in the study area was predominantly clay. Soil pH of all land units qualify for the neutral range. The average mean organic matter content of the soil of the land units ranged from 1.17% (LU04) to
Figure 4. Soil available phosphorus status map of Argo-Gedilala subwatershed.

Figure 5. Soil exchangeable calcium (A) and magnesium (B) status map of Argo-Gedilala subwatershed.
Figure 6. Soil exchangeable potassium (A) and sodium (B) status maps of Argo-Gedilala subwatershed.

Figure 7. Soil cation exchange capacity status map of Argo-Gedilala subwatershed.
The soil organic matter content of all LUs in the study area can be categorized in the range of low to medium soil organic matter content. The average percent total N content of the soils in the study area ranged from 0.11% (LU04) to 0.14% (LU01). The highest and the lowest concentrations of available phosphorus were recorded for land units 01 and 04, respectively. The mean available phosphorus in all the cultivated lands was categorized as very low to low within the study area. The highest (44.78 cmol (+) kg⁻¹) and the lowest (29.89 cmol (+) kg⁻¹) mean values of CEC were recorded in LUs 01 and 04, respectively. The highest (23.19 cmol (+) kg⁻¹) and the lowest (18.07 cmol (+) kg⁻¹) mean values of exchangeable Ca were recorded for LUs 01 and 04, respectively. Similarly, exchangeable Mg levels in soils of land units 01, 02, 03 and 06 were within a very high range, while land units 04 and 05 had high content of this nutrient. The exchangeable K⁺ was also rated as high in all land units. The exchangeable Na⁺ was low in land units, 01, 02, and 06, while land units 03, 04 and 05 were rated as medium in terms of this element status.

In conclusion, almost all of the studied soil properties varied from LUs to LUs most likely due to variation in slope gradient, elevation, parent material, and soil management practices. The soils of LUs (04, 05 and 06) the study area were low in organic matter while LUs (01, 02 and 03) were medium in organic matter. The mean available P of soils of LUs (04 and 05) was categorized as very low range and LUs (01, 02, 03 and 06) classified as low range and 2.02% (LU01). The average percent total N content of the LUs (02, 04, and 05) were found to be low; LUs (01, 03 and 06) were found to be moderate in total nitrogen content which were identified as production constraints. To overcome these limitations it can be recommended that increasing the level of organic matter through continuous application of manure, compost or by any other mechanism, should be integrating with the use of chemical fertilizers.

**CONFLICT OF INTERESTS**

The authors have not declared any conflict of interest.

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