Characterization of Soil Fertility for Wheat Production at Shiebench District in Bench Maji Zone, Southern Ethiopia

Zenebu Belay1*, Heluf Gebrekidan2 and Wassie Haile2

1MizanTepi University, Ethiopia
2Haramaya University, Ethiopia

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*Corresponding author: Zenebu Belay, College of Agriculture and Natural Resources, MizanTepi University, Mizan Teferti, Ethiopia, Email: zenebelay2003@gmail.com

Abstract

In Ethiopia, declining soil fertility presents a major challenge to bring sustainable productivity. An experiment was conducted during the 2011 main cropping season at Bakbes and Ziyagn experimental sites of Shiebench District of Bench Maji Zone with the objective of soil fertility characterization for wheat production. One fresh soil profile pit was opened at each site; and soil samples of each layer of the profile and composite surface soils were analyzed for selected soil physiochemical properties. Profile soils of both Bakbes and Ziyagn sites have clay textural class, where as the mean particle size distribution of the composite surface soils of both sites revealed clay loam soil texture. The pH (H2O) values of the profiles varied from 4.90 to 5.40 and from 4.60 to 4.90 at Bakbes and Ziyagn sites, respectively while the mean pH of the composite surface soils of Bakbes and Ziyagn sites were 5.63 and 4.93, respectively. The mean OM contents of the composite surface soils were 6.24 and 5.90% at Bakbes and Ziyagn sites respectively. The mean N contents of the soil profiles varied from 0.18 and 0.17% to 0.57 and 0.61% at Bakbes and Ziyagn sites respectively. The mean available P contents of the composite surface soils were 0.42% and 1.632 mg kg⁻¹ at Bakbes and 0.40% and 4.21 mg kg⁻¹ at the Ziyagn site. The mean CEC values of the composite surface soils were 40 and 30.32 cmol (+) kg⁻¹ at Bakbes and Ziyagn sites, respectively while the mean exchangeable Al and acidity contents of the composite surface soils were (0.16 and 0.29) and (1.44 and 2.13) cmol (+) kg⁻¹ at Bakbes and Ziyagn sites, respectively. In conclusion, the use of various types and methods of amendments in combination with inorganic fertilizers and use of non-acidifying fertilizers are suggested to minimize the negative effects of soil acidity.

Keywords: Soil fertility; Composite sample soil; Profile soil; Wheat

Introduction

In Ethiopia, declining soil fertility presents a major challenge to bring about increased and sustainable productivity in order to feed the ever-increasing population of the country. As a result, millions are suffering from poverty and malnutrition. Eyasu [1] indicated that under increasing demographic pressure, cultivation becomes permanent. In many cases, removal of vegetation covers, depletion of soil nutrients and OM, and accelerated soil erosion have all led to the drastic decline in soil productivity. Soil acidity and soil fertility declines are forms of soil degradation adversely affecting sustainable crop production in Ethiopia in general and in the Southern Nations-Nationalities’ and People’s Regional State (SNNFRS) in particular.

Soil fertility is a function of its physical, chemical and biological properties on which we have to have not only quantitative but also qualitative information to formulate the appropriate fertility management programs. As soil fertility is the most valuable asset, to maintain where it is high and to improve where it is low, assessment is a prerequisite to rate soils on the basis of their fertility status. Generally, the depletion of soil fertility due to continual nutrient mining by crop removal without adequate replenishment, combined with imbalanced plant nutrition practices has posed a serious threat to agricultural production [2].

Soil acidity is one of the factors limiting wheat production in the Shiebench District where the present study was conducted. Wheat is one of the major important small cereal crops in Ethiopia. As a result, Ethiopia is one of the largest wheat producers among the countries in the Sub-Saharan Africa. However it was only recently that the area under wheat has surpassed that of barley Fasil et al. [3] because of its significance as a cash crop, a high level of production per unit area, and its role in supplying the dietary requirements of peasant farmers. Wheat is grown in the highlands of the country at altitude ranging from 1500 to
3000 meters above sea level (masl), situated between 6-16° N latitude and 35-42° E longitude. However, the most suitable agro-ecological zones of wheat fall between 1900 and 2700masl [4]. Wheat crop can be grown in most locations where annual rainfall ranges from 250-1750mm [4]. Wheat is produced across a wide range of soil conditions, although it is best adapted to fertile, well-drained silt loam and clay loam soils.

However, information about the status of soil fertility and the recommended multi-nutrient fertilizer rates and sources along with micronutrients and chemical amendments to improve acid soil properties for different crops grown on different soil types in the country at large and the specific study area of Shiebench District, Southern Ethiopia in particular is very much limited. Accordingly, there is a need to evaluate the status of soil fertility of the study area for the improved production of wheat. Therefore, the present study was proposed with the following specific objective:

a. To characterize the fertility status of the soils at the study sites (Bakbes and Ziagn, SNNPRS) based on their selected psychico-chemical properties.

**Materials and Methods**

**Descriptions of the study area**
The field experiment was conducted during the 2011 main cropping season under rainfed condition to characterize the fertility status of the soils at the study sites (Bakbes and Ziagn). The study was conducted on soils of Shiebench District in Bench Maji Zone of the SNNPRS which is located at 650 km far from Addis Ababa to the southwest direction, and 55km northeast direction to the capital of Bench Maji Zone; MizanTeferi, on the way from Addis Ababa to MizanTeferi (Figure 1). The area has an elevation ranging between 1600 and 2400masl.

The study area is characterized by bi-modal rainfall pattern. The area receives a mean annual rainfall of 1570mm (Figure 2) and the mean monthly minimum and maximum temperatures are 9.3 and 22.9 °C, respectively (Figure 2) (Teppi Meteological Station). Maize, wheat, teff, sorghum, rice and faba beans are among the dominant crops widely grown in the study areas while peas and some oil crops are also grown.

Soil profile description, sample preparation and analysis

Profile description and soil sample preparation: The study was conducted at two different sites, and on each site a soil profile pit of 1.5m width, 1m length and 2m depth was opened to describe the morphology and soil samples were taken from each layer of both profiles for laboratory characterization of selected soil physical and chemical properties. Besides, composite surface samples were taken using auger from the experiment area from a depth of 0-15cm.

The composite surface soil and soil profile samples collected were air dried at room temperature by spreading on plastic sheet. After drying, the samples were crushed in a metal mortar and pestle and sieved through a 2mm sieve and through 0.5mm sieve for total N and OM determination. Finally, the samples (surface and profile) were analyzed in National Soil Testing Laboratory for soil texture, pH, OM, total N, available P, available K, CEC, exchangeable bases, and exchangeable acidity (exchangeable Al + H) and micronutrients (Zn, Cu, Mn and Fe).

Analysis of soil physical and chemical properties: Soil texture was determined using the Bouyoucos hydrometer method. The soil pH was measured potentiometrically in the supernatant suspension of a 1:2.5 soil to water ratio using a pH meter. The Sahlemedhin & Taye [5] wet digestion method was used to determine soil organic carbon content and percent soil OM was obtained by multiplying percent soil organic carbon by a factor of 1.724. Similarly, total N was analyzed using the Kjeldahl digestion and distillation method as described Sahlemedhin & Taye [5] by oxidizing the OM in concentrated sulfuric acid solution (0.1N H2SO4) and converting the N into NH4+ as ammonium sulfate. Determination of available P was carried out by the Olsen method using sodium bicarbonate as extracting solution [6].

Exchangeable bases (Ca, Mg, K and Na) of the soils were extracted by ammonium acetate (1M NH4OAc at pH 7) solution. Exchangeable Ca and Mg in the extracts were determined by atomic adsorption spectrophotometer while exchangeable K and Na in the extracts were measured by flame photometer [7]. The CEC of soil was determined from the ammonium acetate saturated samples through distillation and measurement of ammonium using the modified Kjeldahl procedure as described by Okalebo et al. [7] and reported as CEC. Finally, Percent base saturation (PBS) was computed as the percentage of the sum of exchangeable bases to the CEC of the soil.

The base titration method which involves extraction of soil samples with 1M KCl solution and titration with 0.02M NaOH using phenolphthalein solution with a permanent pink end point as an indicator, with alternate stirring was employed to determine exchangeable acidity. Finally, the amount of base (NaOH) consumed was considered equivalent to the total
exchangeable acidity (exchangeable Al + H) as described by Okalebo et al. [7]. Extractable (available) micronutrients (Zn, Cu, Mn and Fe) in the soil samples were extracted with DTPA as described by Sahlemedhin & Taye [5]. The amounts of the micronutrients in the extracts were determined by atomic absorption spectrophotometer in comparison with standards at 248.3, 279.5, 324.7 and 213.9 nm wave lengths for Fe, Mn, Cu, and Zn, respectively.

Results and Discussion

Physicochemical properties of soils of the study area

Soil texture: In the present study, there were no differences in textural classes of the profile samples of both sites (Bakbes and Ziyagn). Accordingly, both sites had clay textural class throughout their depths (Table 1), whereas the mean texture of the composite surface soils of both sites was clay loam, those soils which have clay loam textural classes are best adaptable for wheat. Generally, the clay content of the soil profile characterized at the Bakbes site increased consistently with increasing soil profile depth from 52% in the surface layer to 92% in the subsurface (80-135 cm) and slightly decreased to 90% at the extreme subsoil (135-190 cm) depth of the profile. On the contrary, the sand and silt contents of the profile decreased with depth from 21% and 27% in the surface layer to 7% in the subsurface (80-135 cm) depth of the profile, respectively.

Similarly, the clay content of the soil at the Ziyagn site increased consistently with increasing soil profile depth from 44% in the surface layer to 68% at the lower subsoil (85-145 cm) layer and then declined to 66% at the extreme subsoil (145-195 cm) depth of the profile (Table 1). Contrary to clay, the sand and silt contents of the profile at the same site decreased with depth from 25% in the surface layer to 9% in the bottom layer of the profile for sand and from 31% in the surface layer to 23% at the subsoil depth of (85-145 cm) and then increased again to 25% in the bottom layer of the profile for the silt fraction. The increase in clay content and decrease in the sand and silt fractions with increasing soil depth except the bottom subsurface layers observed in these profiles might be attributed to the translocation of clay from the surface to subsurface horizons.

Table 1: Selected physicochemical properties of the soil profiles and composite surface soil samples of the study areas.

| Depth (cm) | Soil profile at Bakbes site | Particle size (%) | Textural class | pH | OM (%) | Total N (%) | Av. P (mg kg⁻¹) |
|-----------|-----------------------------|------------------|---------------|----|--------|-------------|----------------|
| 0-35      |                             | 21               | 27            | 52 | Clay   | 5.2         | 6.27           | 0.57           | 3.66           |
| 35-80     |                             | 5                | 19            | 76 | Clay   | 5.4         | 4.34           | 0.41           | 1.72           |
| 80-135    |                             | 1                | 7             | 92 | Clay   | 5           | 1.55           | 0.21           | 1.14           |
| 135-190   |                             | 1                | 9             | 90 | Clay   | 4.9         | 0.76           | 0.18           | 1.72           |
| Soil profile at Ziyagn site |                             |                  |               |    |        |             |                |                |
| 0-30      |                             | 25               | 31            | 44 | Clay   | 4.9         | 6.18           | 0.61           | 2.26           |
| 30-85     |                             | 15               | 37            | 48 | Clay   | 4.9         | 5.2            | 0.49           | 2.34           |
| 85-145    |                             | 9                | 23            | 68 | Clay   | 4.9         | 1.95           | 0.21           | 3.38           |
| 145-195   |                             | 9                | 25            | 66 | Clay   | 4.9         | 1.59           | 0.17           | 5.38           |

Composite surface (0-15 cm) soil samples from experimental plots at Bakbes site

| Block 1 | 37 | 36 | 27 | Loam | 5.6 | 6.2 | 0.43 | 14.5 |
| Block 2 | 35 | 34 | 31 | Clay loam | 5.6 | 6.32 | 0.44 | 16.24 |
| Block 3 | 33 | 36 | 31 | Clay loam | 5.7 | 6.2 | 0.4 | 18.24 |
| Mean    | 35 | 35.3 | 29.6 | Clay loam | 5.63 | 6.24 | 0.42 | 16.32 |

Composite surface (0-15 cm) soil samples from experimental plots at Ziyagn site

| Block 1 | 37 | 32 | 31 | Clay loam | 5 | 6.01 | 0.4 | 4.16 |
| Block 2 | 37 | 32 | 31 | Clay loam | 4.9 | 5.87 | 0.4 | 4.22 |
| Block 3 | 37 | 32 | 31 | Clay loam | 4.9 | 5.82 | 0.4 | 4.26 |
| Mean    | 37 | 32 | 31 | Clay loam | 4.93 | 5.9 | 0.4 | 4.21 |

OM = Organic matter; Av. P = Available (Olsen) phosphorus

Soil reaction (pH): The results of the laboratory analysis for pH did not show a consistent relationship with the profiles studied at both sites. According to the classification of soil pH established by Jones [8], soil above 80 cm depth of the profile at the Bakbes site met the requirement of the strongly acidic soil class while the rest of the subsoil failed under the very strongly acidic soil category and very strongly acidic throughout the profile at the Ziyagn experimental site (Table 1). The mean

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pH values of the composite surface soils of Bakbes and Ziyagn experimental sites were moderately acidic (5.63) and very strongly acidic (4.93), respectively (Table 1). Generally, the pH of subsurface (80-190cm) layers was lower than the pH of surface layer. This decrease in pH may be due to observed decrease in exchangeable Ca and Mg with depth (Table 2). The decrease in the basic cations concentrations with depth, in turn, may suggest that the downward movement of these constituents within the profile by leaching is very low.

**Organic matter and total nitrogen**: The organic matter (OM) contents of the profiles (Table 1) decreased consistently with depth ranging from 6.27% at the surface layer to 0.76% at the extreme subsurface (135-190cm) layer at the Bakbes site and from 6.18% at the surface layer to 1.59% at the extreme subsurface (145-195cm) layer of the profile at the Ziyagn experimental site. On the other hand, the mean OM contents of the composite surface soils were 6.24 and 5.90% at Bakbes and Ziyagn sites, respectively. Based on the rating recommended by Tekalign [9] the mean OM contents of the composite surface soils at both sites met the limit for classification as high.

Similarly, the surface layer of the profile at Bakbes site and surface and subsurface (30-85cm) layers of the profile at Ziyagn site had high OM contents, while the subsurface (35-80cm) layer of the profile at Bakbes site was rated medium. On the other hand, the remaining layers of the profiles considered in the study had low OM contents except the extreme subsurface (135-190cm) layer of the profile at the Bakbes site which was rated as very low.

The findings of the present study pertaining to the distribution of soil OM with soil profile depth were similar with that of Dawit et al. [10] who indicated that the top soils are characterized by higher accumulation of humified soil OM content which decreases with increasing soil depth. The highest OM contents recorded on the composite surface and surface layers of the profiles is apparently attributed to the contribution of crop residues, particularly roots, animal manure and green manure that are applied on to the surface and decomposed within the surface soil adding to the OM pool of the soils in the study area as explained by Dawit et al. [10].

The total N contents of the soil profiles decreased consistently with increasing soil depth and varied from 0.18 and 0.17% at the extreme layer to 0.57 and 0.61% at the surface layer at Bakbes and Ziyagn sites, respectively. The mean total N contents of the composite surface soils were 0.42% at Bakbes and 0.40% at the Ziyagn site. According to Tekalign [11], the total N contents of the surface and subsurface (35-80cm) layers of the profile at the Bakbes site, the surface and subsurface (30-85cm) layers of the profile at the Ziyagn site and the mean total N contents of the composite surface soils of both sites fall under high whereas, the subsurface layers below 80cm of the profile characterized at Bakbes and below 85cm of that at the Ziyagn site were medium in their N contents. Apparently, the higher values of total N of the soil at both sites correspond to the higher values of OM suggesting the strong correlation between the two soil parameters as reported by many researchers [12,13].

**Available soil phosphorus**: The available phosphorus (P) contents of the profile at the Bakbes site decreased from 3.66 mg kg\(^{-1}\) at the surface layer to 1.14 mg kg\(^{-1}\) at the subsurface (80-135cm) layer and then increased again to 1.72 mg kg\(^{-1}\) in the bottom (135-190cm) layer of the profile (Table 1). On the contrary, the available P contents of the profile at the Ziyagn experimental site increased consistently from 2.26 mg kg\(^{-1}\) at the surface layer to 5.38 mg kg\(^{-1}\) in the bottom subsoil (145-195cm) layer. The mean available P contents of the composite surface soils were 16.32 and 4.21 mg kg\(^{-1}\) at Bakbes and Ziyagn experimental sites, respectively (Table 1). With regard to the rating of soil available P as determined by the Olsen method, Olsen et al. [6]. Thus, the available P contents throughout the depth of the profiles of both sites except the bottom subsoil (145-195cm) layer of the profile at the Ziyagn experimental site were rated as low and the bottom layer of the profile at Ziyagn (5.38 mg kg\(^{-1}\)) had medium available P content. According to the same author, the mean available P contents of the composite surface soils (16.32 and 4.21 mg kg\(^{-1}\)) could be rated as high and low at the Bakbes and Ziyagn experimental sites, respectively, where response of crops to P fertilization at low P level could be very high.

Except in the extreme subsurface layer, the content of P at Bakbes experimental site showed a decreasing trend with soil depth. This is in agreement with the findings of Tekalign et al. [11] who reported that top soil P is usually greater than that in the subsols due to sorption of the added P, greater biological activity and accumulation of organic materials on the surface soils. On the other hand, Mohammed et al. [14] observed low levels of available P in the surface horizons of the cultivated at the Jelo sub catchment of the Chercher highlands in Eastern Ethiopia. Generally, low content of available P is a common characteristic of most of the soils in Ethiopia Wakene & Heluf [15]. Such low level of available P could be due to P fixation by Al and Fe under the prevalence of strong acidity and low or no P inputs as organic and/or inorganic forms.

**Exchangeable bases**: Exchangeable Ca followed by Mg was the predominant cation in the exchange sites of both the profiles and the composite surface soil colloidal materials of the soils in both field experimental sites (Table 2). The exchangeable Ca contents decreased consistently with increasing soil depth at both of the study areas and the values varied from 7.41 cmol (+) kg\(^{-1}\) and 3.25 cmol (+) kg\(^{-1}\) at the bottom layers to 18.68 cmol (+) kg\(^{-1}\) and 9.97 cmol (+) kg\(^{-1}\) at the surface layers of the soil profiles studied at the Bakbesand Ziyagn experimental sites, respectively. Similarly, exchangeable Mg contents decreased linearly with increasing soil depth from 3.23 cmol (+) kg\(^{-1}\) and 1.47 cmol (+) kg\(^{-1}\) at the surface layers to 2.07 cmol (+) kg\(^{-1}\) and 0.24 cmol (+) kg\(^{-1}\) at the bottom subsurface layers at Bakbes and Ziyagn experimental sites, respectively (Table 2).
Table 2: Selected chemical properties of the soil profile and composite surface soil samples of the study areas.

| Depth (cm)             | Exchangeable bases | acidinity and CEC (cmol(+) kg\(^{-1}\)) | Micronutrients (mg kg\(^{-1}\)) |
|------------------------|--------------------|----------------------------------------|----------------------------------|
|                        | Na     | K     | Ca     | Mg     | Al   | Acidity | CEC | PBS | Fe   | Mn   | Zn | Cu   |
| Soil profile at Bakbes site |       |       |        |        |      |          |     |     |      |      |    |      |
| 0-35                   | 0.49   | 18.68 | 3.23   |        | 0.24 | 0.68     | 42.28| 53  | 59.01| 15.4 | 4.14| 0.57 |
| 35-80                  | 0.29   | 14.19 | 3.07   |        | 0.32 | 0.46     | 30.7 | 57  | 49.8 | 7.57 | 1.86| Trace|
| 80-135                 | 0.51   | 9.16  | 2.61   |        | 0.64 | 0.61     | 19.61| 63  | 8.6  | 1.72 | 0.51| Trace|
| 135-190                | 0.56   | 7.41  | 2.07   |        | 0.72 | 0.91     | 17.08| 59  | 3.3  | 0.27 | 0.79| 1     |
| Soil profile at Ziyagn site |       |       |        |        |      |          |     |     |      |      |    |      |
| 0-30                   | 0.14   | 9.97  | 1.47   |        | 1.16 | 1.22     | 23.71| 49  | 42.95| 29.11| 3.68| 0.2  |
| 30-85                  | 0.09   | 6.02  | 0.45   |        | 1.36 | 2.51     | 20.29| 32  | 32   | 9.27 | 1.25| 0.51 |
| 85-145                 | 0.09   | 4.42  | 0.43   |        | 1.6  | 1.52     | 18.3 | 27  | 32.67| 0.9  | 1.13| 0.67 |
| 145-195                | 0.05   | 0.05  | 0.24   |        | 2.16 | 2.51     | 15.28| 23  | 29.93| 14.47| 0.99| 0.69 |
| Composite surface (0-15 cm) soil samples from experimental plots at Bakbes site |       |       |        |        |      |          |     |     |      |      |    |      |
| Block 1                | 0.35   | 1.33  | 25.44  | 7.2    | 0.08 | 0.32     | 40.73| 84  | 30.99| 48.62 | 7.62| 1.49 |
| Block 2                | 0.22   | 1.48  | 27.34  | 7.36   | 0.16 | 0.32     | 39.56| 92  | 30.55| 47.95 | 6.53| 1.65 |
| Block 3                | 0.3    | 1.53  | 31.36  | 8.11   | 0.24 | 0.24     | 39.71| 104 | 30.46| 47.29 | 6.47| 1.76 |
| Mean                   | 0.29   | 1.46  | 28.04  | 7.56   | 0.16 | 0.29     | 40   | 93  | 30.6 | 7.95 | 6.87| 1.6  |
| Composite surface (0-15 cm) soil samples from experimental plots at Ziyagn site |       |       |        |        |      |          |     |     |      |      |    |      |
| Block 1                | 0.2    | 0.31  | 5.66   | 3.66   | 1.6  | 2.32     | 29.65| 33  | 26.12| 53.24 | 2.26| 0.42 |
| Block 1                | 0.24   | 0.33  | 4.56   | 3.8    | 1.36 | 2.16     | 30.69| 29  | 26.96| 55.04 | 2.58| 0.62 |
| Block 3                | 0.22   | 0.33  | 3.01   | 3.6    | 1.36 | 1.92     | 30.63| 23  | 26.54| 55.55 | 2.8 | 0.86 |
| Mean                   | 0.22   | 0.32  | 4.41   | 3.68   | 1.44 | 2.13     | 30.32| 28.32| 6.54 | 54.59 | 2.54| 0.63 |

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

Based on the classification set by FAO (2006), the concentrations of these two cations (Ca and Mg) fall under medium to high and under very low to medium at the Bakbes and Ziyagn experimental sites, respectively. The low contents of basic cations could be due to lower pH and higher exchangeable acidity in Ziyagn than at Bakbes site. These high contents of exchangeable Ca and Mg at the Bakbes site shows that the soil parent material primarily releases divalent cations in higher concentration and are retained for longer periods by the soil colloidal particles because of their higher selectivity coefficient over the monovalent cations. The mean exchangeable Ca contents of the composite surface soils were 4.41 cmol(+) kg\(^{-1}\) (low) and 28.04 cmol(+) kg\(^{-1}\) (very high) at Ziyagn and Bakbes experimental sites, respectively. Similarly, the mean exchangeable Mg contents were 3.68 cmol(+) kg\(^{-1}\) (high) and 7.56 cmol(+) kg\(^{-1}\) (high) at Ziyagn and Bakbes experimental sites, respectively (Table 2).

In all of the horizons of the profiles and composite surface soils, the proportions of the cations were in the order of Ca>Mg >K >Na. There was no measurable quantity of exchangeable Na throughout the depth of both profiles which could be due to its highly soluble easily leached nature. On the other hand, exchangeable K contributed very small proportion and did not show any consistent trend with depth of the profile at Bakbes site and the values fall under low to moderate whereas, it decreased with in creasing soil profile depth from 0.14 at the surface layer to 0.05 at the bottom (145-195 cm) layer of the profile at the Ziyagn experimental site (Table 2). The values of the exchangeable K at the Bakbes site fall under very low throughout the depth of the profile. The mean exchangeable Na contents of the composite surface soils were 0.22 cmol(+) kg\(^{-1}\) (low) at Ziyagn and 0.29 cmol(+) kg\(^{-1}\) (low) at Bakbes experimental sites and the mean exchangeable K contents were 0.32 cmol(+) kg\(^{-1}\) (moderate) and 1.46 cmol(+) kg\(^{-1}\) (very high) at Ziyagn and Bakbes experimental sites, respectively.

### Exchangeable aluminum and exchangeable acidity

The exchangeable aluminum (Al) contents of the profiles increased consistently with increasing soil depth at both sites of the study. Exchangeable Al contents varied from 0.24 cmol(+) kg\(^{-1}\) and 1.16 cmol(+) kg\(^{-1}\) at the surface layers to 0.72 cmol(+) kg\(^{-1}\) and 2.16 cmol(+) kg\(^{-1}\) at the bottom layers at Bakbes and Ziyagn experimental sites, respectively (Table 2). On the other hand, exchangeable acidity contents did not show any consistent trend with depth of profiles at both sites. The mean exchangeable Al contents of the composite surface soils were 0.16 and 1.4 cmol(+) kg\(^{-1}\) at the Bakbes and Ziyagn experimental sites, respectively, while the mean exchangeable acidity contents of the composite surface soils were 0.29 at Bakbes site and 2.13 cmol(+) kg\(^{-1}\) at the Ziyagn site (Table 2).
The lowest and the highest exchangeable acidity values were
recorded at Bakbes and Ziyagn sites, respectively. The reason for
the existence of higher concentration of exchangeable acidity at
Ziyagn could be due to the release of certain organic acids from
the functional groups of OM content of Ziyagn. Similar findings
were also reported for the soil at the western slopes of Chilalo
Mountain in the central Ethiopian highland by Ahmed [16].

Cation exchange capacity

As per the rating of soil characteristics, by Landon [17]. The
CEC contents of the profiles soil studied at the Bakbes and Ziyagn
experimental sites ranged from 17.08cmol (+) kg⁻¹ and 15.28cmol
(+) kg⁻¹ at the bottom layers to 42.28cmol (+) kg⁻¹ and 23.71cmol
(+) kg⁻¹ at the surface layers, respectively (Table 2). Therefore,
the rates fall under medium to very high at Bakbes and medium
deepth of the profile at Ziyagn experimental sites.

The mean CEC values of the composite surface soils were 40
and 30.32cmol (+) kg⁻¹ at Bakbes and Ziyagn experimental sites,
respectively, falling under the high CEC at both experimental
sites as per the rating established by Hazleton & Murphy [18].
Generally, the values of CEC in those composite surface soils and
in the soils of the profiles at both experimental sites indicated the
presence of high potential for nutrient retention. The amounts
of OM and clay as well as the type of the dominant clay mineral
present might have been very important in contributing to the
CEC values in the soils. Moreover, the high CEC values imply that
the soil has high buffering capacity against induced chemical
changes.

Percent base saturation

The values of percent base saturation (PBS) of the profile
at Bakbes increased with depth of the profile from 53% at the
surface layer to 63% at subsoil (80-135cm) layer and declined
to 59% at the extreme subsoil (135-190cm) layer (Table 2). Based
on the rating of Hazleton & Murphy [18], the PBS values at the
Bakbes experimental site fall under moderate throughout the
depth of the profile except the subsoil (80-135cm) layer which
fall under high. The PBS contents at the Ziyagn site showed a
decreasing trained from 49% at the surface layer to 23% at the
bottom subsoil (145-195cm) layer (Table 2) and the values fall
under low PBS category throughout the profile depth except the
surface (0-30cm) layer which failed under moderate.

The mean PBS values of the composite surface soils were 28.3
and 93.3% at Ziyagn and Bakbes experimental sites, respectively,
falling under low and very high respectively. Generally, the low
values of PBS for the composite surface soil and the profile soils
at the Ziyagn experimental site could be attributed to the low
contents of exchangeable bases that go beyond CEC value for the
reason already mentioned in the preceding section.

Extractable micronutrients

The lowest and the highest values in the soils of the
profiles at Ziyagn and Bakbes experimental sites for Fe, Mn
and Zn in mg kg⁻¹ were varied from 3.3 to 59.01 and 29.93 to
42.95, 0.27 to 15.4 and 0.90 to 29.11, 0.51 to 4.14 and 0.99 to
3.68mg kg⁻¹, respectively. Generally, Fe contents at both study
sites decreased consistently with increasing soil depth. While
Mn contents decreased consistently with increasing soil depth
at the Bakbes and Zn contents decreased with increasing soil
depth at the Ziyagn site (Table 2). There was no measurable
quantity of Cu in the profile layers at the Bakbes site except in
the surface and the bottom sub soil (135-190cm) layers of the
profile. Whereas the Cu contents at the Ziyagn experimental
site increased with increasing soil depth from 0.2 at surface and
0.69mg kg⁻¹ in the bottom subsoil (145-195cm) layers of the
profile. The mean Fe, Mn, Zn and Cu contents in the composite
surface soils at the Bakbes and Ziyagn experimental sites were
30.6 and 26.54, 47.95 and 54.59, 6.87 and 2.54, 1.60 and 0.63mg
kg⁻¹, respectively (Table 2). According to the rating set by Jones
(2003), Fe contents of the profile soils fall under high throughout the
profile except the bottom subsoil (135-190cm) layer which
fall under medium at the Bakbes and high throughout the profile
at the Ziyagn, experimental sites while Mn contents fall under
medium throughout the profile except the bottom subsoil (135-
190cm) layer which rated low at the Bakbes site while at Ziyagn
site the values rated low to very high. Zn contents of the profiles
fall under medium to high at both study sites while Cu contents
fall under low at Bakbes and under very low to low at Ziyagn,
experimental sites. The mean values of Cu in the composite soils
at both study sites of the profiles fall under low content.

Generally, low contents of Cu and Zn observed in the soils of
the study areas were likely to cause limitation in crop yields as
most plants are sensitive to Cu deficiency such as wheat, barley,
maize, oats and vegetables. Heluf & Wakene [19] also reported
that micronutrients were highly influenced by different land
use systems and significant variation was observed among the
different land use systems. The Cu contents of most agricultural
soils range from 2-100 mg kg⁻¹ which is far greater than the
amount measure in the soil of the present experimental sites.
Therefore, the response of crops to Cu and Zn fertilization at
such Cu and Zn levels could be high.

Summary and Conclusion

Soil fertility declines are forms of soil degradation adversely
affecting sustainable crop production in Ethiopia. Thus, declining
soil fertility presents a major challenge to bring about increased
and sustainable productivity in order to feed the ever-increasing
population of the country. To complement ongoing efforts in this
line, a field experiment was conducted during the 2011 main
cropping season under rainfed condition at Bakbes and Ziyagn
areas of Shiebench District of Bench Maji Zone with the objective
of soil fertility characterization based on their pysical-chemical
properties.

In the present study, the increase in clay content and
decrease in the sand and silt fractions with increasing soil depth
might be attributed to the translocation of clay from the surface
to subsurface horizons. The decrease in pH value with increasing

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soil depth at Bakbes site may be due to observed decrease in exchangeable Ca and Mg with depth. The decrease in the basic cations concentrations with depth, in turn, may suggest that the downward movement of these constituents within the profile by leaching is very low.

The highest OM contents recorded at Bakbes site is apparently attributed to the contribution of crop residues, particularly roots, animal manure and green manure that are applied on to the surface and decomposed within the surface soil adding to the OM pool of the soils. Apparently, the higher values of total N of the soil at both sites correspond to the higher values of OM suggesting the strong correlation between the two soil parameters. The decrease in P content with depth could be due to sorption of the added P, greater biological activity and accumulation of organic materials on the surface soils of Bakbes site. Low level of available P at Ziyagn site could be due to P fixation by Al and Fe under the prevalence of strong acidity and low or no P inputs as organic and/or inorganic forms.

The low contents of basic cations could be due to lower pH and higher exchangeable acidity in Ziyagn than at Bakbes site. These high contents of exchangeable Ca and Mg at the Bakbes site shows that the soil parent material primarily releases divalent cations in higher concentration and are retained for longer periods by the soil colloidal particles because of their higher selectivity coefficient over the monovalent cations. The reason for the existence of higher concentration of exchangeable acidity at Ziyagn could be due to the release of certain organic acids from the functional groups of OM content of Ziyagn.

The high values of CEC in those composite surface soils and in the soils of the profiles at both experimental sites indicated the presence of high potential for nutrient retention. Moreover, the high CEC values imply that the soil has high buffering capacity against induced chemical changes. The low values of PBS for the composite surface soil and the profile soils at the Ziyagn experimental site could be attributed to the low contents of exchangeable bases that go beyond CEC value. The low contents of Cu and Zn observed in the soils of the study areas were likely to cause limitation in crop yields as most plants are sensitive to Cu deficiency.

In conclusion, the results of the current study provides; the use of various types and methods of amendments in combination with inorganic fertilizers including the micro nutrients and use of non-acidifying fertilizers are suggested to minimize the negative effects of soil acidity.

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