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Assessment of Soil Macronutrients and Mapping its Spatial Distribution in Agamsa Watershed, Ethiopia

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Abstract

This study was conducted at Agamsa watershed in Habru District, Northeastern Ethiopia, to assess the soil macronutrient status and mapping its spatial distribution. Nine composite soil samples were collected based on the variability of land at 0 to 30cm soil depth. The texture, bulk density (BD), pH, OM, total N, available P,and exchangeable basic cations like K, Ca, Mg and Na, and CEC content in the samples were determined following the standard analytical procedures. Arc GIS 10.1 was used for soil fertility mapping and soil test values at other locations were interpolated using ordinary Kriging. The result showed thatthe soil textural class was clay loam. The highest soil BD was 1.37 g cm^{-3} whereas the lowest was1.22 g cm^{-3}. The soil was moderately acidic to neutral in pH. The highest and lowest values of total N were 0.21% and 0.06%, respectively while that of OM ranged from 1.17% to 3.71%. The highest and lowest values of available P were 9.65mg $kg^{-1}$and 2.5 mg kg^{-1}, respectively. The relative abundance of basic cations in soil was dominated by Ca followed by Mg, K, and Na and the values ranged from 20.38 to 31.72, 8.92 to 12.08, 0.29 to 0.59, and 0.27 to 0.45cmol$_c$kg^{-1}, respectively. The highest and lowest values of CEC were 53.10cmol$_c$ kg^{-1} and 36.94cmol$_c$ kg^{-1}. The result showed that soils of the study area had good physical fertility status. However, farmers should practice crop rotation, minimize the removal of crop residues, and use organic and inorganic fertilizers to improve the soil quality and its productivity. Moreover, nutrient supplying powers of the soils and demanding levels of the plants need further correlation and calibration works to come up with site-soil-crop specific fertilizer recommendation.

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Assessment; Macronutrient; Mapping; Critical level; Soil fertility

Introduction

Most sub-Saharan Africa (SSA) soils are naturally less fertile (Lelago *et al.*, 2016). This is probably due to nutrient mining from continuous cultivation and low external input of nutrients causing the soil fertility decline (Karltun *et al.*, 2013a). As a result, agricultural productivity per unit area of land is declining through time and food production could not keep pace with population growth (Roy *et al.*, 2003). Low nutrient content in the parent material from which the soils were derived, the imbalance between nutrient inputs and outputs, nutrient loss by erosion, and lack of balanced fertilization are the major threats to agricultural productivity in Ethiopia (Tena and Beyene, 2011). The fertilizer usage in the country is also mainly subjective without being based on the crop need, soil nutrient dynamics, and agroecological factors and using a blanket rate of application (Kidanemariam, 2008). For instance, in most parts of Ethiopia, farmers apply 100 kg ha^{-1} DAP and 50 kg ha^{-1}Urea which supply only P and N irrespective of soil heterogeneity (Lelago *et al*., 2016). Even the supply of N and P is lower than their depletion in the soil results in stunted growth and low crop yields. Soil fertility in the Habru District in general and Agamsa watershed, in particular, is also at stake. Seasonal and annual rainfall variability and inappropriate soil management coupled with complete removal of crop residues has contributed to the loss of huge amounts of fertile soil from farm lands. Knowledge about an up-to-date status of soil macronutrients at different landscapes in the study area and mapping their spatial distribution play a vital role in site-specific fertilizer recommendation to enhance agricultural productivity on the sustainable basis. Therefore, this study was conducted with specific objectives to assess and map the status and spatial distribution of soil macronutrients for Agamsa watershed. The results of this study are expected to add value to the up-to-date scientific documentation of the status of soil fertility for national soil atlas for maximizing crop yields and to maintain the sustainable agriculture.

Materials and Methods

Description of the study area

The study was conducted at Agamsa sub-watershed, which is located in Habru District of Northeastern, Ethiopia (Figure 1). Geographically, the study area lies between 11^0 38' 35.99" to 11^0 40' 16.86" N latitude and 39^0 37' 3.76" to 39^0 39' 43.51" E longitude with an altitude ranging from 1564 to 2038 meters above sea level. The total area of the watershed is about 523 ha and is characterized by flat and hilly topography. The study area is characterized by a bimodal rainfall pattern. The short (*Belg)* rain starts in February and ends in April while the main rainy (*kiremt*) season starts in June and ends in September with the erratic distribution. Its land use is mainly subsistence rain-fed agriculture and has a mean annual rainfall of 500-950 mm and a mean annual temperature of 14-31°C.The existing land use system consists of 47.34% (247.59 ha) cultivated land and 52.66 % (275.4ha) shrublands. The smallholder farmers practice a mixed farming system that integrates both crops and livestock. Farmers use specific soil fertility management strategies for their farms. However, most of them apply the blanket recommendation of mineral fertilizer (100 kg/ha DAP and 50 kg/ha Urea) to their fields. As far as crop residue management is concerned, farmers of the study area were not well aware of the advantage of returning crop residues for soil fertility management. Hence, crop residues are collected for animal feed and fuel.

Soil sample collection and analysis

Field data collection and soil sampling were carried out by considering the slope variation and fertility gradients of the study area. Representative soil samples were collected from each sampling site at a depth of 0 to 30 soil layers. For each sampling site, a minimum of 10 to 15 subsamples was collected and composited within 50 m distance between two sampling points using a random sampling technique. At each sampling site, a GPS (Global Position Systems,

Garmin 76x model) reading was used in taking the coordinates. As a result, a total of nine composite soil samples were collected, by using Edelman auger at the surface layer, for the analysis of soil physical and chemical properties. Then the collected soil samples were air-dried, gently crushed with mortar and pestle, mixed well, and passed through a 2-mm sieve. For the determination of total nitrogen (N) and organic carbon (OC), a 0.5-mm sieve was used. Then, approximately one kg of the composited fine soil sample was transported for analysis at Water Works Design and Supervision Enterprise, Addis Ababa, following the standard procedures (Table 1).

Soil fertility mapping

Based on soil laboratory analysis results, soil fertility indices were generated and ratings were made; and the soils were classified into different fertility categories, i.e., very low, low, medium, high, and very high based on the content of each selected soil parameter. Arc Map 10 with the spatial analyst function of Arc GIS software was used to prepare soil fertility maps and soil test values at other locations were interpolated using a geostatistical technique of ordinary Kriging (OK). Hence, the spatial distribution of soil OM, total N, available P, exchangeable bases (K, Ca, and Mg) were carried out separately for each element with the 3D Analyst/ Raster Interpolation / Ordinary/ Kriging in Arc Map 10.

Statistical analysis

Descriptive statistics were carried out with the help of Statistical Analytical Software (SAS) version 9.2 to reveal the magnitude of selected soil physicochemical properties.

Results and Discussions

Soil particle size distribution

The results of the study revealed that there were no textural differences within the soils of the study area. Accordingly, all the soils had clay loam textural class with the mean percentage value of 33.88, 31.66, and 34.44, for sand, silt, and clay respectively (Table 2). The minimum sand, silt, and clay contents of the soil samples were 31%, 27.5%, and 32%, while the maximum contents were 37.5%, 35%, and 37.5% respectively (Table 2). Hence, clay fraction followed by sand and silt dominates the soils of the study area. The variations of particle size distribution might be due to the slope gradient difference since the removal of the finer particles (mainly clay) by erosion is enhanced on the upper slope areas while the deposition of these particles occurs on the lower slope areas (Aytenew and Kibret, 2016). On the other hand, frequent cultivation might have enhanced weathering of primary particles and contributed to the high clay fraction in the relatively low sloping areas (Aytenew and Kibret, 2016). Hence, slope gradient differences combined with farming practice contribute differences in particle size distribution in the study area.

Bulk density and total porosity

The results of the study revealed that there were no differences obtained among the bulk density values within the agricultural land of the study area. However, there were slight variations in bulk density among the shrub and cultivated land uses. Accordingly, the lowest (1.22 g cm^{-3}) and the highest (1.37 g cm^{-3}) bulk density values were recorded in the study area (Table 2). The relatively lower bulk density values were observed in the shrubland units probably due to the relatively high OM contents which resulted in high total porosity (52.49%). On the other hand, the relatively higher soil bulk density (1.37 g cm^{-3}) was observed in cultivated land units and could be associated with the prolonged history of continuous cultivation practice and the decline in OM content which resulted in deteriorating soil aggregates and consequently increased soil bulk density. Since, the acceptable range of bulk density is 1.3 to 1.4 g cm^{-3} for mineral agricultural soils (Bohn *et al*., 1987), the soil bulk density obtained in this study was within the optimum range. Given this, bulk density values of the soils in the study area showed that the soils were not too compact to limit root penetration and restrict the movement of water and air.

The percent total porosity (TP) of all soil samples of the study area ranged from 42.92% to 52.49% (Table 2). The sources of variation in TP are variation in OM contents and intensity of cultivation. The relatively higher TP (52.49%) in the study area could be attributed to relatively higher contents of soil OM and the resultant lower bulk density values. While the lower value of TP (42.92%) is due to soil compaction attributed to intensive cultivation. However, in the point of view of physical fertility, the TP observed on soils of the study area could enable the soils to provide good aeration and better aggregation for crop production and microorganisms' activity.

Soil water characteristics

The mean water content values at field capacity and permanent wilting point, and mean available water content in the study area are presented in (Table 2). Accordingly, the water content at field capacity ranged from 33.64% to 42.17% while that of permanent wilting point ranged from 20.12 to 26.67%. Similarly, AWHC values in the study area were between 13.19% and 17.23%. The highest water content values at FC and PWP were observed in the shrubland uses probably due to relatively high OM and surface cover while the lowest values were observed in cultivated land uses. Knowledge of available water holding capacity is important for various purposes such as irrigation planning and management. As cited by Teferi and Heluf (2008), Beernaert and Bitondo (1990), rated available water contents as very low, low, medium, high, and as very high when the value is< 8, 8-12, 12-19, 19-21, and > 21%, respectively. Based on this, the AWHC of the soils in the study area was medium. This could be ascribed to its relatively high clay content and low to medium organic matter content.

Soil reaction (pH)

The minimum and maximum values of soil pH (pH_H_2O) in the Agamsa watershed were 5.8 and 6.71, respectively (Table 3). As per the pH ratings suggested by Karltun *et al*. (2013b), 77.78% of the soil samples in the study area were rated as moderately acidic (5.6-6.5) while 22.22%, were neutral (6.6-7.3) (Figure 2). The variation in soil pH might be due to differences in land use type and removal of basic cations by crop harvest (Emiru and Gebrekidan, 2013). Hence, the relatively lower pH values were recorded from shrub than cultivated land uses probably due to the relatively higher OM content in shrubland use produce organic acids through oxidation and provide H^+ ions to the soil solution and thereby reduce soil pH. Continuous cultivation practices and steepness of the topography could also be some of the factors responsible for the reduction of pH in soils in the middle and upper elevation areas (Hussein and Gebrekidan, 2002). Moreover, most nutrients are available for field crops at a pH value of between 5.5 and 7.5 (Gazey and Davies, 2009). Thus, the pH values of soils of the study area are most suitable for plant growth and the availability of most plant nutrients might not be affected by these pH ranges. Exchangeable acidity (H and Al), on the other hand, varied from 0.08 to 0.32 $cmol_c\ kg^{-1}$ with the mean value of 0.19 $cmol_c\ kg^{-1}$ of soil in the study area (Table 3). This small value of EA indicated the easiness to manage the acidity problem in the study areas (Mekonnen, 2014).

The total soluble salt content expressed as electrical conductivity (EC) is an important indicator of soil health. It affects crop yields, crop suitability, plant nutrient availability, and activity of soil microorganisms which influence key soil processes (Hazelton and Murphy, 2016). The value of EC varied from 0.06 to 0.1 ds/m with the mean value of 0.07 ds/m at 25°C (Table 3). The result has fallen into the category of salt-free (< 2.0 ds/m). The normal EC may be ascribed to leaching of salt to lower horizons by the percolating and drainage water (Kumar *et al*., 2014).This was also similar to the research finding reported bySwarnam *et al*. (2004) and Abate *et al*. (2016).

Soil organic matter

The OM content of the soils in the study area ranged from 1.17 to 3.71 % with a mean of 1.94 % (Table 4). As per the ratings of Tadesse *et al*. (1991), 77.78% of the total soil samples were rated as low and 22.22% as medium levels (Figure 2). The variation could be attributed to the difference in land use type (cultivated versus shrub) and slope gradient. For instance, the relatively highest values of OM content were recorded at the shrubland use than the cultivated land uses. This could be due to the contribution of surface cover and relatively lower decomposition of the OM in the shrublands. However, continuous tillage practices loosen the soil system and enhanced the process of OM decomposition in cultivated lands than the shrubland. On the other hand, considering cultivated land units only, relatively higher content of OM observed in soils might be due to their relative level slope gradient where the soil moisture storage is better, resulting in better biomass production. On the other hand, the lower OM content might be due to higher OM decomposition aggravated by intensive cultivation; and most probably the low amount of organic materials applied to the soil due to complete removal of the biomass from the field. Low replenishment of organic sources together with continuous cultivation disperses aggregates and exposes the OM in them to further decomposition. In agreement with this finding, different authors indicated that most cultivated soils of Ethiopia are poor in organic matter content (Haile *et al*., 2014, Negash and Mohammed, 2014, Zelleke *et al*., 2010).

Similar to the organic matter content, the total soil nitrogen content varied from 0.06% to 0.21% with a mean value of 0.09% (Table 4). According to Tadesse et al. (1991), 88.89% of the soils have low total nitrogen while 11.11% have medium contents (Figure 2). The low content of total N in the study area might have resulted from a low level of soil OM content, low application of N rich organic materials, and mineralization of the existing soil OM following cultivation. This is in line with the findings of Nigussie and Kissi (2012), Belachew and Abera (2010) and Emiru and Gebrekidan (2013) who indicated that Ethiopian cultivated lands have insufficient total N due to high leaching lose, crop removal, loss of organic materials and inadequate application of N fertilizers. In the study area, crop residues are collected for animal feed, fuel, and thatching. Similarly, animal dung and wastes are collected for fuel and temporary construction. These could be probably the major factor contributing to reducing soil OM, and thereby to the decline of total nitrogen in the soil system. Moreover, nitrogen is found to be one of the limiting plant nutrients and increasing productivity without the application of N source fertilizers will be difficult in the study area. Therefore, in the management of total nitrogen, it may be imperative to maintain and increase the level of soil organic matter by incorporating plant and animal residues, integrate leguminous plants and applications of organic and inorganic fertilizers.

Soil C: N ratio is a sensitive indicator of soil quality and is often considered as a sign of soil nitrogen mineralization capacity. The minimum, maximum, and mean C: N ratios recorded in the soils of the study area were 10:1, 16:1, and 12.79, respectively (Table 4). High soil C: N ratio can slow down the decomposition rate of organic matter and organic nitrogen by limiting the ability of soil microbial activity, whereas low soil C: N ratio could accelerate the process of microbial decomposition of organic matter and nitrogen, which is not conducive for carbon sequestration (Ge *et al*., 2013). It is generally accepted that C: N ratios between 8:1 and 12:1 are considered to be the most favorable for crop production, implying relatively fast mineralization of nitrogen from the organic materials (Ayele, 2013). Hence, the C: N in the study area falls under the optimum range for active microbial activities except for two sampling unit falls out of the acceptable ranges.

The available P content of the soils of the study area varied from 2.5 mg kg^{-1} to 9.65 mg kg^{-1} with a mean value of 5.34 mg kg^{-1} (Table 4). Based on the critical values established by Olsen (1954), 55.56% and 44.44% of the total soil samples in the study area were rated as low and medium in their AP content respectively (Figure 2). The reason for the low to medium AP contents of soils of the study area could be continuous uptake by crops, crop residue removal, and low inherent AP content of the parent material. This suggestion is in line with Emiru and Gebrekidan (2013) who reported that deficiency of AP is resulted due to losses through crop harvest and erosion. In agreement with this, deficiency of available P could be one of the major limiting factors to boost crop productivity in the study area. In general, the existence of low contents of available P is a common characteristic of most of the soils in Ethiopia (Emiru and Gebrekidan, 2013) which is similar to the P content observed in the soils of the present study area. Therefore, increasing any economical agricultural production would require increasing in AP through various P management practices, such as P fertilization and/or organic manure application.

Exchangeable bases

Exchangeable Ca followed by exchangeable Mg were relatively predominant cations on the exchange sites of soil colloidal materials over the exchangeable K and Na in the order of Ca> Mg > K > Na. Similar findings were reported by other researchers (Kedir, 2015, Kibret and Asfaw, 2014, Lelago *et al*., 2016, Yitbarek *et al*., 2013). The variations in the distribution of exchangeable bases depend on the mineral present, particles size distribution, degree of weathering, soil management practices, climatic conditions, degree of soil development, the intensity of cultivation, and the parent material from which the soil is formed (Gebrekidan and Negassa, 2006, Negash and Mohammed, 2014).

The highest and the lowest values of exchangeable Ca were 31.72 and 20.38with a mean value of 25.29 $cmol_c$ kg^{-1}, respectively (Table 5 and Figure 3). In line with soil fertility, a critical concentration of 0.2 $cmol_c$ kg^{-1} exchangeable Ca is required for tropical soils (Landon, 1991). The results of this study indicate that soils under all sampling units had more Ca concentrations than the critical level. This implies that exchangeable Ca is not a limiting factor in the soils of the study area and the soils under the study area would not require an application of Ca fertilizer as an external input.

The highest and lowest values of exchangeable Mg were 12.08 and 8.92 $cmol_c$ kg^{-1} with a mean value of 10.71 $cmol_c$ kg^{-1} (Table 5 and Figure 3). Similarly, the concentrations of Mg in all the land units of the study area were higher than the critical level of 0.5 $cmol_c$ kg^{-1} which is recommended for tropical soils (Landon, 1991). This implies that responses for the addition of Mg as an external input in the form of fertilizer are unlikely in soils of the present study area.

The high contents of exchangeable Ca and Mg showed that the soil parent material is primarily rich in basic cations and the divalent cations are retained in higher concentrations and for longer periods by the soil colloidal particles (Giday et al., 2015) and minimum leaching. Similar findings were reported by other researchers (Chekol and Mnalku, 2012, Feyssa *et al*., 2011, Getaneh *et al*., 2007, Negash and Mohammed, 2014).

The highest and the lowest values of exchangeable K were 0.59 and 0.29 $cmol_c$ kg^{-1}, respectively with a mean value of 0.43 $cmol_c$ kg^{-1}(Table 5 and Figure 3). The highest exchangeable K content was recorded from the shrubland uses while; the smallest was on other cultivated land uses. The relatively lower exchangeable K in cultivated land units might be due to continuous cropping and crop nutrient removal without replenishing, leaching down the profile by water, and fixation between clay layers in heavy clays. In soils where there is high removal of potassium by crop harvesting or grazing and exchangeable K, levels become below the critical level, plants can give a response to the application of potassium fertilizer (Abbott, 1989). However, all investigated soils under all the sampling units of the study area had higher exchangeable K than the critical level (0.2 $cmol_c\ kg^{-1}$) suggested by (Landon, 1991). This implies that returns from K inputs application for crop production under this study area are less likely and its application in the form of fertilizer is not required.

The maximum and minimum values of exchangeable Na were 0.45 and 0.27$cmol_c\ kg^{-1}$ with a mean value of 0.36$cmol_c\ kg^{-1}$ (Table 5 and Figure 3). From the agricultural point of view, sodium is not a required plant nutrient and therefore is not necessary for plant growth rather; high levels of sodium are detrimental to soil health and plant growth. Based on the critical level (1$cmol_c\ kg^{-1}$) suggested by Landon (1991), the exchangeable. The Na values of the surface soils were low and cannot cause alkalinity or sodicity problems on crops and/or soil. In general from a soil fertility point of view, exchangeable Ca, Mg, K, and Na in all land units qualified at least for medium range and above, hence deficiency of those cations are not likely occurred in the study area.

Table.1 Standard laboratory methods for soil sample analysis

Parameters	**Applied standards for measurement**
Soil texture	Bouyoucos hydrometer method(Bouyoucos, 1962)
Acidity (pH-H_2O)	Digital pH meter (van Reeuwijk, 1986)
Electrical Conductivity, EC (ds/m)	From the suspension prepared for pH analysis
Available Phosphorous, AP ($cmol_c$/kg)	Olsen method(Olsen, 1954)
Total Nitrogen,N (%)	Kjeldahl method(Bremner and Mulvaney, 1982)
Organic Matter, OM (%)	(Walkley and Black, 1934)[OM = Organic Carbon x 1.724]
Exchangeable Ca ($cmol_c$/kg)	Atomic absorption spectrophotometer(Rowell, 1994)
Exchangeable Mg ($cmol_c$/kg)	Atomic absorption spectrophotometer(Rowell, 1994)
Exchangeable K ($cmol_c$/kg)	Flame photometer(Rowell, 1994)
Exchangeable Na ($cmol_c$/kg)N	Flame photometer(Rowell, 1994)
Cation Exchange Capacity ($cmol_c$/kg)	Ammonium acetate method(Chapman, 1965)

Table.2 Selected physical properties of soils of the study area

Descriptive statistics	PSD (%)			PD	BD	TP (%)	Water Content (%)		
	Sand	Silt	Clay	(g cm^{-3})	(g cm^{-3})		FC	PWP	AWHC
Mini.	31.00	27.50	32.00	2.26	1.22	42.92	33.64	20.12	13.19
Maxi.	37.50	35.00	37.50	2.68	1.37	52.49	42.17	26.67	17.23
Mean	33.80	31.66	34.44	2.48	1.28	48.09	38.31	22.4	15.91

BD=bulk density, TP=total porosity, FC= field capacity, PWP= permanent wilting point, AWHC=available water holding capacity, PSD= particle size distribution.

Table.3 Soil pH, exchangeable acidity, and Ec content in soils of the study area

Soil properties	Mini.	Maxi.	Mean
pH (pH_H_2O)	5.8	6.71	6.28
EA ($cmol_c$ kg^{-1})	0.08	0.32	0.19
Ec (ds/m)	0.06	0.1	0.07

EA= Exchangeable acidity, Ec= Electrical conductivity

Table.4 Mean soil OM, TN, and AP contents in soils of the study area

Soil properties	Mini.	Maxi.	Mean
OM (%)	1.17	3.71	1.94
TN (%)	0.06	0.21	0.09
C: N ratio (%)	9.69	15.92	12.79
AP (mg kg^{-1} soil)	2.5	9.65	5.34

Table.5 Mean of soil Ca, Mg, K, and Na contents in the study area

Exchangeable bases ($Cmol_c$ kg^{-1})	Mini.	Maxi.	Mean
Ca	20.38	31.72	25.29
Mg	8.92	12.08	10.71
K	0.29	0.59	0.43
Na	0.27	0.45	0.36

Table.6 Measured CEC and PBS of soils of the study area

Soil property	Mini.	Maxi.	Mean
CEC ($cmol_c$ kg^{-1})	36.94	53.10	44.19
PBS (%)	65.03	93.56	82.92

Figure.1 Location map of the study area

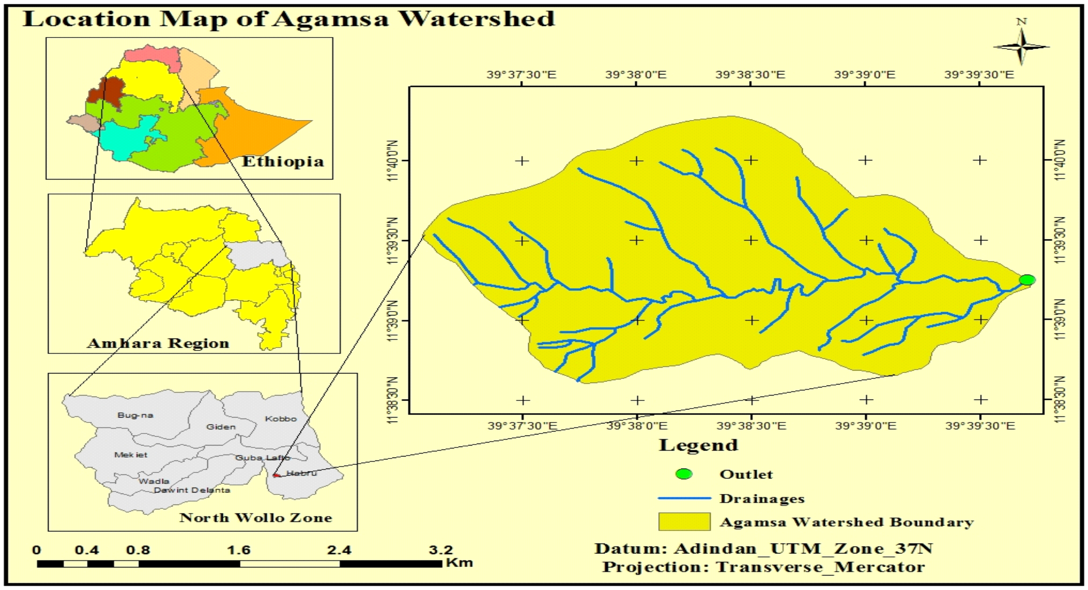


Figure.2 Spatial distributions of OM, TN, AP, and soil pH in Agamsa watershed

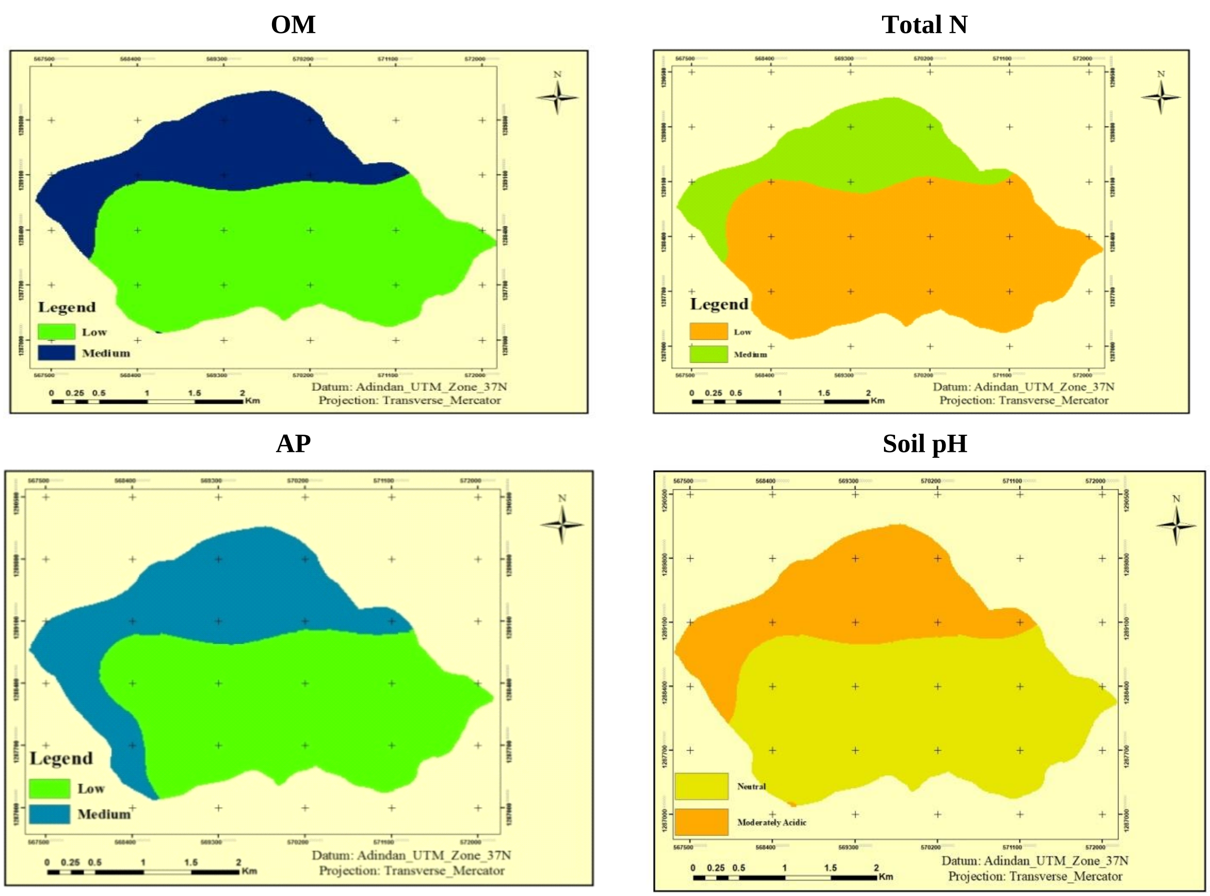
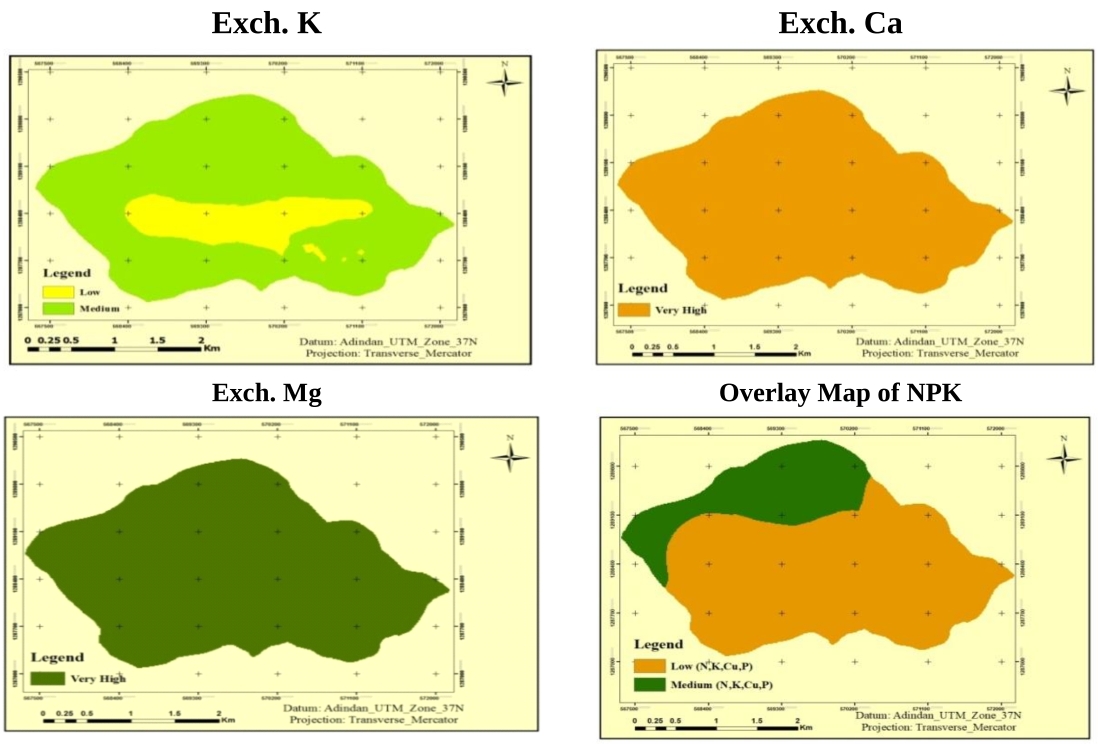


Figure.3 Spatial distribution of exch. bases (Ca, Mg, K and Na) and overlay map of NPK



Cation exchange capacity (CEC)

The recorded CEC of the soils in the study area ranged from 36.94 to 53.10 $cmol_c\ kg^{-1}$ with a mean value of 44.19 $cmol_c\ kg^{-1}$ (Table 6). Based on the ratings of Hazelton and Murphy (2016), all soils in the study area were rated as high (25-40 $cmol_c\ kg^{-1}$) to very high (> 40 $Cmol_c\ kg^{-1}$) which might be attributed to the high specific surface area of the clay particles. Although the OM content of the soil in the study area is low to medium, the amount and type of clay might have been very important in contributing to the CEC values (Giday *et al*., 2015). The type of clay could most probably be montmorillonite and/ or illite (2:1 clay minerals) with extensive internal and external surfaces that can attract or adsorb many cations and might have contributed to the relatively higher CEC values. The results of the investigation, therefore, revealed that soils of the study area are fertile and have high basic cation nutrient reserves for crop production. Similarly, the PBS of the study area ranged from 65.03 % to 93.56% with mean values of 85.3% (Table 6). The trends of the distribution of PBS showed similarity with the distribution of CEC and exchangeable cations since factors that affect these soil attributes also affect the percentage base saturation. Based on the ratings of Hazelton and Murphy (2016), the PBS of the surface soils in the study area was rated as high (60-80 %) to very high (> 80 %) which indicates the generally base-rich nature of the soils of the study area and less vulnerability of soils to leaching

Conclusion and Recommendations

Soil nutrients depletion is one of the major challenges to boost crop production and productivity in Ethiopia. The suitability of the soil for crop production depends on its fertility level, which is evaluated based on the quality of the soil's physical, chemical, and biological properties. Without detailed soil-related information at a specific local level, sustainable crop production and soil resource maintenance could not be achieved. Hence, assessing soil fertility through their physical, chemical, and biological properties and mapping their status can help to apply appropriate soil nutrient management options. Therefore, this study was conducted with the objectives of assessing the soil fertility status and mapping the spatial distribution of the selected soil fertility parameters of Agamsa watershed, Habru District.

Assessment of the fertility status of the soils in the study area was carried out during the 2015/2016 cropping season after crop harvest through examination of selected soil physical and chemical properties. In the beginning, a preliminary field observation was carried out and then a total of nine representative composite soil samples were collected from the soil surface (0-30cm) for laboratory analysis for selected soil physical and chemical properties. Based on the analysis results, the soils were classified into different fertility categories, i.e., very low, low, medium, high, and very high. Arc GIS 10 software was used to prepare soil fertility maps and soil test values at other locations were interpolated using a geostatistical technique of ordinary Kriging (OK). Finally, the fertility status of the soils in the study area was mapped. The selected soil fertility parameters which were mapped include soil OM, TN, AP, and exchangeable basis (Ca, Mg, and K). The collected soil samples were analyzed for particle size distribution, BD, TP, soil water characteristics, pH, EC, Exchangeable acidity, CEC, AP, TN, OM, and exchangeable basic cations (Ca, Mg, K and Na) following standard procedures.

The study revealed that the particle size distributions of the soils were dominated by clay followed by sand and silt. Correspondingly, the clay values in the study area were between 32% and 37.5% and the textural class was clay loam. The BD value in the study area was rated as low to moderate and was found in the acceptable range for mineral agricultural soils. Similarly, total porosity ranged from 42.92% to 52.49% and could enable the soils to provide good aeration and better aggregation for crop production and microorganisms' activity. The water content at FC ranged from 33.64% to 42.17% while that of PWP ranged from 20.12% to 26.67% on the surface soil (0-30cm). Moreover, AWHC values in the study area were between 13.19% and 17.23 % and rated as medium availability in the soils of the study area. Soil pH (H_2O) in the study area ranged from 5.8 to 6.71 and rated as moderately acidic to neutral status. The highest and lowest values of TN were 0.21% and 0.06%, while that of OM ranged from 1.17% to 3.71%, respectively, and rated as low to medium in the study area. Similarly, the highest and lowest values of AP were 2.5 mg kg^{-1} and 9.65 mg kg^{-1}, respectively.

The relative abundance of basic cations on the exchangeable complex of soil was dominated by Ca followed by Mg, K, and Na and the values ranged from 20.38 to 31.72, 8.92 to 12.08, 0.29 to 0.59, and 0.27 to 0.45cmol$_c$ kg^{-1}, respectively. Moreover, the highest and lowest values of CEC were 53.10cmol$_c$ kg^{-1} and 36.94cmol$_c$ kg^{-1}. In general, from a soil fertility point of view, exchangeable Ca, Mg, K, and Na in all sampling units qualified at least for medium range. This implies that soils of the study area might not be deficient in exchangeable basic cations.

In conclusion, most of the physicochemical properties of the studied soils varied probably due to variation in land use /land cover, slope gradient, soil management practices, and parent material. The soils of the study area had good physical fertility status and pH range, where most nutrients are easily available for satisfactory crop production. The soils had sufficient exchangeable bases, CEC and PBS. However, SOM, TN, and AP were ranged from low to medium.

Therefore, the soil fertility management should focus on improving and maintaining OM, TN, and AP levels of the soils. To increase soil OM and total N content, farmers should practice crop rotation and minimize the removal of crop residues and animal manures. Besides, farmers should exercise integrated soil fertility management, such as combining organic and inorganic fertilizer applications. Moreover, soil analysis alone cannot go beyond the identification of toxicity, sufficiency, or deficiency level of soil nutrients due to the complex nature of the soil. Therefore, nutrient supplying powers of the soils and demanding levels of the plants need further correlation and calibration works to come up with site-soil-crop specific fertilizer recommendations.

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Appendix

Table.1 The real numerical data recorded for selected soil physical properties in the study area

S/Point	Sand (%)	Silt (%)	Clay (%)	Texture	BD (g/cm^3)	PD (g/cm^3)	TP (%)	FC (%)	PWP (%)	AWHC (%)	Land-use type
1.	31	33.5	35.5	Clay loam	1.26	2.41	47.71	37.2	20.12	17.08	Cultivated land
2.	34.5	31.5	34	Clay loam	1.37	2.68	48.88	38.42	22.19	16.23	Cultivated land
3.	35.5	27.5	37	Clay loam	1.36	2.51	45.81	38.23	21.43	16.8	Cultivated land
4.	33	33.5	33.5	Clay loam	1.32	2.35	43.82	38.24	23.74	14.5	Cultivated land
5.	32	32.5	35.5	Clay loam	1.29	2.26	42.92	33.64	20.45	13.19	Cultivated land
6.	32	30.5	37.5	Clay loam	1.25	2.54	50.78	36.5	20.22	16.28	Cultivated land
7.	37.5	30	32.5	Clay loam	1.22	2.50	51.20	40.21	23.43	16.78	cultivated land
8.	32.5	35	32.5	Clay loam	1.26	2.48	49.19	42.17	26.67	15.5	cultivated land
9.	37	31	32	Clay loam	1.24	2.61	52.49	40.12	22.89	17.23	Shrub land

Table.2 The real numerical data recorded for selected soil chemical properties in the study are

S/point	**pH**	**AP**	**OM**	**TN**	**C: N**	**EA**	**EC**	**Ca**	**Mg**	**K**	**Na**	**CEC**	**PBS**	**Land-use type**
1.	6.71	4.25	0.95	0.09	13.02	0.16	0.09	23.62	11.79	0.39	0.42	39	92.87	Cultivated land
2.	6.23	2.9	1.34	0.11	12.95	0.16	0.07	21.4	9.96	0.37	0.31	36.9	86.09	Cultivated land
3.	6.71	2.71	0.85	0.06	11.50	0.16	0.08	20.38	12.08	0.32	0.34	45	73.6	Cultivated land
4.	6.29	3.06	1.17	0.12	9.69	0.08	0.1	21.3	12.05	0.29	0.32	43.3	78.43	Cultivated land
5.	6.28	5.07	1.53	0.24	14.79	0.08	0.06	25.92	10.69	0.36	0.27	39.8	93.56	Cultivated land
6.	6.21	2.5	1.52	0.23	12.59	0.32	0.08	26.46	10.82	0.42	0.41	41.5	91.83	Cultivated land
7.	6.13	9.2	3.02	0.11	15.92	0.24	0.06	24.54	9.18	0.48	0.33	53.1	65.03	cultivated land
8.	6.21	8.72	3.70	0.7	14.86	0.32	0.06	29.3	8.92	0.59	0.36	52	75.32	cultivated land
9.	5.8	9.65	3.71	0.21	10.25	0.24	0.06	31.72	10.03	0.42	0.45	47.6	89.53	Shrub land