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Determining Fertility Status of Soil at Different Land Uses at Koka Watershed Tembaro Woreda, Central Ethiopian

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Abstract

The study was conducted in Central Ethiopia, Tembaro Woreda, for two consecutive years, 2023 and 2024, at Bohe and Bachira Kebeles within the Omo River Basin in the Koka watershed. The objectives of this study were to determine the fertility status of different land uses at the study sites. The study results indicate that soil at the study site ranges from moderately acidic to slightly acidic, with low to moderate levels of organic carbon, low to medium total nitrogen and available P, medium to high CEC, moderate levels of Ca, Mg, K, and Na, and optimum amounts of micronutrients such as Fe, Mn, Zn, and Cu. Soil nutrients at the study site range from 5.67–6.55 for pH, 0.04–0.31 dS/m for EC, 4.19–6.11% for OC, 0.35–0.53% for TN, 11.2–23.4 ppm for available P, and 15–27 meq/100 g for CEC; average concentrations for these parameters were 6.11, 0.18 dS/m, 5.35%, 0.44%, 17.3 ppm, and 21 meq/100 g, respectively. Particle size distribution percentages range from 19% to 35% for sand, 32% to 48% for clay, and 22% to 46% for silt; average percentages of sand, clay, and silt were 28.1%, 42.8%, and 29.1%, respectively. Soil textural classes fall between clay and clay loam for the selected croplands. Results show that enset and faba-bean-cultivated land had better nutrient status than other croplands like sorghum, wheat, and maize. Micronutrient levels were optimum across all land-use types. The study concludes that alternative cultivation can improve soil fertility and production while leading to food security.

Keywords: Central Ethiopia, land uses, soil fertility, Tembaro Woreda, watershed

INTRODUCTION

Soil fertility is defined as the quality of soil that enables it to provide nutrients in adequate amounts and in proper balance for the growth of specific crops [1]. It is a crucial factor that determines plant growth as well as the presence or absence of nutrients in soil [2]. Suitable soil productivity mainly depends on its ability to supply vital nutrients to growing plants, as plants take their nutrients mostly from the soil [3]. Soil can be considered as both a source from which nutrients are removed and a sink where nutrients are added [1]. Continuous cropping without adequate recuperative practices causes a decline in soil fertility, depletion of soil nutrients, and endangerment of agricultural suitability. As nutrient depletion is a major form of soil degradation, knowledge of the depletion of plant nutrients from soil may be helpful in devising nutrient management strategies [4].

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Intensive and continuous cultivation without appropriate soil management practices has contributed to land degradation and loss of important soil quality in different parts of Southern Ethiopia [5]. Soil fertility decline includes larger removals of nutrients without inputs (nutrient depletion), declines in pH or increases in exchangeable acidity (acidification), nutrient

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mining, organic matter loss, and increases in toxic elements such as aluminum [1]. Therefore, physicochemical properties, such as soil texture, pH, electrical conductivity, organic carbon, calcium carbonate, and cation exchange capacity of soil, control the availability of nutrients on which plant growth and crop yield depend; these properties must be known for a proper soil fertility management plan [3].

In agricultural ecosystems, nutrient removal occurs not only through leaching and erosion but also through crop yields and residuals. Periodic disturbance of soil, including tillage and weeding in agricultural ecosystems, can cause the removal of nutrients higher than in natural ecosystems [6]. According to Hartemink [7]. soil analytical data indicated that soil nutrients were lower in permanent croplands than in bush vegetation lands of different types of soils. Soil fertility surveys, which include soil sampling and analysis, provide valuable information for the diagnosis and prediction of fertilization needs [8]. and are important for assessing nutrient status to maintain good crop production using better nutrient management. This study was conducted to determine the effects of land-use types on soil fertility status in the Kambata zone, Tembaro Woreda, Central Ethiopia, in the southern parts of Ethiopia.

METHODOLOGY

Study area Description

This study was conducted in Tembaro Woreda, Kambata Zone, Central Ethiopia, as shown in Figure 1. The georeferenced of the study site was recorded between 7.140–7.150 °N (latitude) and 37.310–37.320 °E (longitude), with elevation ranging from 1320 m above sea level to 2045 m above sea level. Tembaro Woreda is bounded to the north by Hadero Woreda, to the south by Gibe Woreda, and to the east and west by Duna and Boloso Bombe Woredas, respectively (CSA, 2014). The land coverage of the study site was 60% midland (woyenedega), 10% highland (dega), and 30% lowland (kolla) (MOA, 2016). Annual rainfall ranges from 700–1200 mm, with daily mean temperature ranging between 18 and 30°C and bimodal rainfall. Keremt is the main production season for major crops, such as teff, faba bean, common bean, and field pea, but the occurrence of rain during the Belg season is equally important, as it has significant implications for household food security [9].

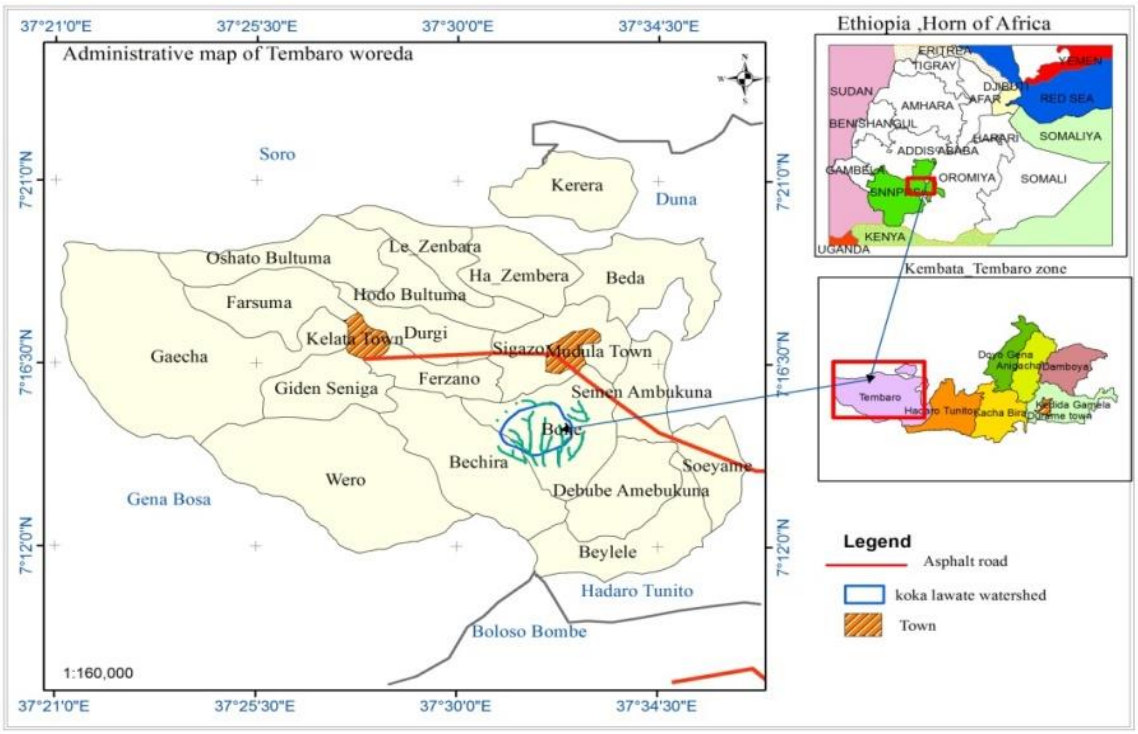


Figure 1. Map of study area Bachira and Bohe Tembaro Woreda, Kambata zone, Central Ethiopia.

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Table 1. Soil physicochemical parameters, methods, and instrument analysis.

Soil test	Method	Instrument reference
Bulk density	Core sampling	Balance & Oven
Texture	Hydrometric methods	Hydrometer
pH and EC	1:2.5 (soil: water)	pH meter
CEC	Ammonium acetate	Distillation & titration
OC (%)	Wackily & Blackly	Titration
TN (%)	Kjeldal analysis	Digestion, distillation and titration
P (ppm)	Olsen	UV-Vis Spectrophotometer
K, Na	Ammonium acetate	Flame photometer
Ca, Mg	Ammonium acetate	AAS
Fe, Zn, Mn, Cu	DTPA extraction	AAS

Sample Collection, Size, and Preparation

Composite soil samples were collected from different sites in the study areas with different land types. The land types used to collect soil samples for this study were different croplands, including enset, maize, wheat, faba bean, and sorghum. Fifty different soil samples were collected from five land types or croplands with three replicates using a soil auger. The soil samples were air-dried, ground, and sieved with a 2 mm sieve for analysis of physicochemical parameters at the Areka Agricultural Research Center soil, water, and plant analysis laboratory.

Method of Soil Analysis

Soil samples collected from different croplands were analyzed using standard analytical techniques. Soil physicochemical parameters were analyzed using standard techniques with respective procedures. Soil pH and EC were analyzed using soil-to-water suspension, organic carbon using Walkley and Black methods, phosphorus using the Olsen method, and other methods listed in the table below.

Statistical Analysis

All soil data were analyzed using analysis of variance (ANOVA) with the Statistical Analysis System (SAS) program (SAS, 2021). Mean separation for significant differences was used to separate significantly different levels at $P \leq 0.05$. Correlation analysis was used to estimate the relationships between selected soil physicochemical properties.

RESULTS AND DISCUSSION

Analyses of Selected Physicochemical Properties of Soil at Koka Watershed Tembaro Woreda

The soil results shown in Table 1 imply the physicochemical properties of different croplands in the Koka watershed in Tembaro Woreda. The pH of the soil ranged from 5.6 to 6.55. The highest pH was observed in enset land (6.55), and the lowest pH was found in maize land (5.6). The average pH for the studied croplands was 6.13, and soil results ranged from moderately acidic to slightly acidic according to the national soil testing manual (ETHIOSIS, 2017). The soil pH of the current study indicates that the sites were strongly to slightly acidic and better for crops than the former study in Kambata zone, Tembaro Woreda; the pH of the previous study ranged from 4.6 to 5.11, as reported by Bore [10]. while the current study has 5.67–6.55 [10]. The electrical conductivity was measured using a conductivity meter, and the results ranged from 0.04 to 0.31 dS/m. The lowest EC was obtained in wheat land (0.04 dS/m) and the highest in enset land (0.31 dS/m), showing that soils at all croplands were salt-free because the results were below 2 dS/m. According to the ETHIOSIS soil map [11]. and nutrient ranges, for soil to be saline, its results must be greater than 2 dS/m for agricultural land; thus, the selected croplands in these study areas were below the recommended results, implying that the soil was salt-free. The amount of SOC was analyzed using Walkley and Black methods, and the study site results ranged from 4.19% to 6.11% for different land uses [12]. The highest OC was recorded in enset-cultivated land (6.11%) and the lowest in wheat-cultivated land (4.19%) (Table 1). The average soil organic carbon for the croplands studied was 5.3, which is in the high organic carbon range according to the ETHIOSIS soil map (ETHIOSIS, 2017).

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The soil fertility status of the study area was high because medium to high organic carbon and slightly acidic soil imply suitability for crop production in the area. The phosphorus level was analyzed using the Olsen method and read on a spectrophotometer at 810 nm [13]. Available phosphorus ranged from 11.2 ppm to 23.4 ppm, with the highest value of 23.4 ppm in enset land and the lowest value of 11.2 ppm in wheat land, with an average concentration of 17.3 ppm, ranging from medium to high according to Olsen ratings. High phosphorus concentrations indicate that the land is better for crop production and yield improvement. Soil nitrogen was analyzed by sulfuric acid digestion and Kjeldahl distillation followed by titration. The total nitrogen ranged from 0.35% to 0.53%, with the highest concentration at 0.53% and the lowest in maize land at 0.35%. Concentrations were higher than those reported by Kebebew [14]. and fell in the high range according to ETHIOSIS reports (2017).

The method for the analysis of soil CEC used 1N ammonium acetate leaching followed by titration. The CEC ranged from 15 meq/100 g to 27 meq/100 g, and the average CEC of the studied croplands was 23.02 meq/100 g, which was at moderate ranges, implying better fertility status for crop production according to Black [15]. The highest CEC was found in the enset land (27 meq/100 g at sample s1), and the lowest was 15.2 meq/100 g in sorghum land, showing that the decomposition of CEC and SOC increases yield and nutrient uptake. CEC was rated from medium to high, according to the national soil analysis manual. The physicochemical parameters reported in the table above show that cultivated land has better fertility status and production because most parameters are within optimum ranges. Parameters such as pH, OC, P, and CEC were higher than those reported in previous studies in the Kambata zone. Previous studies reported OC, P, and CEC values ranging from 1.3% to 4.2%, 5.1 to 10.18 ppm, and 18.16 to 22.96 meq/100 g for CEC, which were lower than those in the current study, with nutrient status ranging from 5.67 to 6.55 for pH, 4.97% to 6.67% for OC, 12 to 22 ppm for P, and 15 to 29.3 meq/100 g for CEC (Table 1).

Particle size proportion is an important physical parameter for examining soil texture, as texture has a significant influence on physical and mechanical behavior. The textural class was analyzed using a hydrometer with sodium hexametaphosphate as a dispersing agent [16]. The sand, clay, and silt contents ranged from 19% to 35%, 32% to 48%, and 22% to 46%, with average percentages of 28.1%, 42.8%, and 29.1%, respectively. The soil textural classes for the selected croplands were clay and clay loam. One confounding factor explaining the variations in physicochemical characteristics is the difference in particle size distribution (Table 1). All land uses had different proportions of sand, silt, and clay, with enset, maize, and wheat having higher clay percentages. Texture is an intrinsic property; however, intensive cultivation contributes to variations in the particle size distribution. The textural classification was clay and clay loam for all farms. This is expected, as soil texture is inherited from the forming materials (Table 2).

Table 2. The ANOVA table of soil means data for different land uses at Tembaro Woreda.

Class	EC	OC	TN	P	pH	CEC
FB	0.09^{ab}	5.14^{a}	0.4^{a}	20.2^{ab}	6.17^{ab}	22.27^{b}
EN	0.2^{bc}	5.9^{b}	0.5^{ab}	19.8^{ab}	6.23^{a}	22.63^{b}
M	0.15^{b}	6^{bc}	0.5^{ab}	21.7^{a}	6.13^{b}	23.89^{a}
Sr	0.08^{ab}	5.4^{da}	0.5^{ab}	12.53^{d}	5.93^{FB}	17.2^{c}
Wh	0.063^{ab}	4.1^{d}	0.37^{d}	15.83^{c}	6.3^{ab}	29.3^{d}
CV	47.5	4.32	7.94	10.32	5.45	13.3
MS	1.004	1.7	0.01	42.5	0.06	56.3
F	3.32	3.35	8	12.3	0.51	5.97
P-value	0.0552	0.000	0.0037	0.007	0.73	0.001
Sign	NS	**	*	***	NS	***

FB: faba bean, EN: enset, M: maize, Sr: sorghum, Wh: wheat, NS: non-significant at 95% confidence interval

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The significance and differences in soil data were analyzed using R software. Table 3 shows that soil EC was NS across land types, even though different croplands had different EC values. The results in Table 3 imply that the source of salinity was not crop difference or alternative cultivation but irrigation sources from lakes and oceans. Soil organic carbon has a statistical difference in the selected croplands (95% CI) because of the decomposition of waste at enset land; the residual effects of maize and sorghum can increase fertility, while wheat land sown on dry land is exposed to erosion, resulting in lower fertility. Nutrients such as OC, TN, P, and CEC showed significant differences (95% CI) across croplands, but EC, pH, and Na were NS; waste matter decomposition can improve nutrients quickly.

The higher organic carbon content in maize and enset lands was due to maize straw and organic waste. The statistical significance of total nitrogen for croplands was NS for maize, enset, faba bean, and sorghum, but significant for wheat. The lowest concentrations were observed in wheat land because wheat was often planted in red soil, which is a less fertile area in local practices.

Exchangeable Base and Micronutrient Analyses

The Soil results reported in Table 1 show exchangeable bases and micronutrients using standard methods. The concentrations of K and Na were optimum in the selected croplands, and the Ca and Mg concentrations were high, with Ca ranging from 10.3 to 20.3 cmol/kg and Mg from 2.1 to 3.5 cmol/kg. The highest Ca and Mg concentrations were in the enset cropland (20.3 cmol/kg and 3.5 cmol/kg) and the lowest (10.3 cmol/kg and 2.1 cmol/kg) in sorghum and faba bean, respectively. The K and Na values ranged from 1.55 to 2.15 cmol/kg and 0.65 to 1.3 cmol/kg, respectively.

The Concentrations of exchangeable bases were higher than those in previous studies in Tembaro Woreda. For example, Ca and Mg ranged from 10.3 to 20.3 and 2.1 to 3.5 cmol/kg, respectively, but previous studies reported 4.9 to 10.94 cmol/kg for Ca and 2.71 to 3.4 cmol/kg for Mg [14]. K and Na were lower than in the previous study, where K ranged from 0.71 to 1.02 cmol/kg and Na from 0.19 to 0.31 cmol/kg [14].

Among the micronutrients reported in this study, Mn was higher than the others, followed by Fe, Cu, and Zn. The concentration of micronutrients ranged from 102 to 113 ppm for Mn, 18.9 to 21.8 ppm for Fe, 8.9 to 11.24 ppm for Zn, and 12.9 to 15.4 ppm for Cu, respectively. All micronutrients were maximum on enset land and minimum on wheat and maize land. All micronutrients were found to be within the optimum range for the selected crop land according to ATA soil analysis and higher than previous works done at Tembaro Woreda (Kebede S. et al, 2022) [14]. The concentration of micronutrients in a previous study ranged from 4.39 to 5.18 mg/kg for Mn, 5.94 to 9.86 for Fe, 3.05 to 4.96 for Cu, and 2.6 to 3.63 for Mn, which were lower than those in this study (Kebede S. et al, 2022) [14].

Table 3. Means of exchangeable bases and micronutrients for different land types at study site (ANOVA table).

Class	Fe	Zn	Cu	Mn	Ca	K	Na	Mg
FB	20.13^{ab}	1.46^{b}	1.9^{c}	106.2^{c}	13.0^{ad}	1.63^{ab}	0.9^{ab}	2.57^{a}
EN	20.78^{b}	1.36^{ab}	2.43^{a}	109.2^{d}	13.7^{ab}	1.88^{c}	0.93^{ab}	2.83^{c}
M	19.6^{bc}	1.39^{bc}	1.5^{d}	105.3^{a}	13.4^{a}	1.48^{db}	1.1^{bc}	2.23^{d}
Sr	20.7^{bd}	1.54^{bd}	2.4^{ae}	107.5^{e}	10.8^{c}	1.71^{bc}	1.0^{FB}	2.47^{ab}
Wh	19.3^{ab}	1.35^{ab}	1.3^{db}	104.8^{ab}	8.7^{e}	1.57^{d}	1.17^{abc}	2.17^{de}
CV	3.56	7.2	30.07	2.39	13.58	5.82	20.41	3.24
MS	1.22	0.015	0.78	9.7	33.8	10.3	0.037	11.8
F	2.37	2.31	2.39	1.5	11.2	8.53	0.87	2.87
P-value	0.04	0.130	0.137	0.03	0.001	0.003	0.515	0.001
Sign	**	NS	NS	**	***	**	NS	***

Fe, Mn, Zn, and Cu units in mg/kg; Ca, Na, K, and Mg in cmol/kg

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The common exchangeable basic cations are K^+, Ca^{2+}, Mg^2, and Na^+, which are held by organic matter and clay. ANOVA for exchangeable basic cations revealed significant variation across systems for K ($p = 0.003$), Ca ($p = 0.001$), and Mg ($p = 0.001$), while Na was $\alpha < 0.515$. The order of concentrations was Ca > Mg > K > Na. The mean Ca values were enset > maize > sorghum > faba bean > wheat (13.7, 13.3, 13, 10.8, and 8.7 cmol/kg, respectively). Higher Ca, Mg, and K levels were observed in the enset land. Higher Na^+ levels were recorded in the faba bean land (Table 3).

Generally, the exchangeable base and micronutrient content vary across land-use types. Bases such as Ca, K, and Mg were statistically significant across croplands, but Na was not significant (95% CI). Ca showed significant differences between sorghum and wheat but not between faba bean, enset, and maize because residual waste and organic matter release better Ca content. Potassium showed significant differences between enset and wheat but not among the others. The Mg concentration was significant among the selected croplands, whereas Na was NS.

The ANOVA for extractable micronutrients Fe, Zn, and Cu indicated variation among land uses, but statistical significance varied: Fe ($p < 0.04$), Zn ($p < 0.137$), Mn ($p < 0.03$), and Cu ($p < 0.13$). The concentrations were generally in the order of Mn > Fe > Zn > Cu. The mean Mn values were enset > maize > sorghum > faba bean > wheat (109.5, 107.3, 106.4, 105.8, and 104.8 mg/kg).

The Extractable micronutrients were optimal for the study areas. Mn was the most dominant and significantly different across croplands, followed by Fe, Zn, and Cu. The latter was not significant across land-use types because these micronutrients were not deficient according to the ETHIOSIS map [17].

The Extractable Fe, Zn, and Mn were maximum in the enset land, while Cu was maximum in the maize land; all were minimum in the wheat land. Fe and Zn showed non-significant differences, but Mn showed significant differences among croplands, except between sorghum and enset.

In Figure 2, the graph implies that available P, CEC, Ca, pH, and OC were the influential parameters. The nutrient order was CEC > P > Ca > pH > OC > Mg > K > EC > Na. The optimum CEC was found in enset and maize lands, but the highest was found in faba bean land due to legumes releasing nutrients.

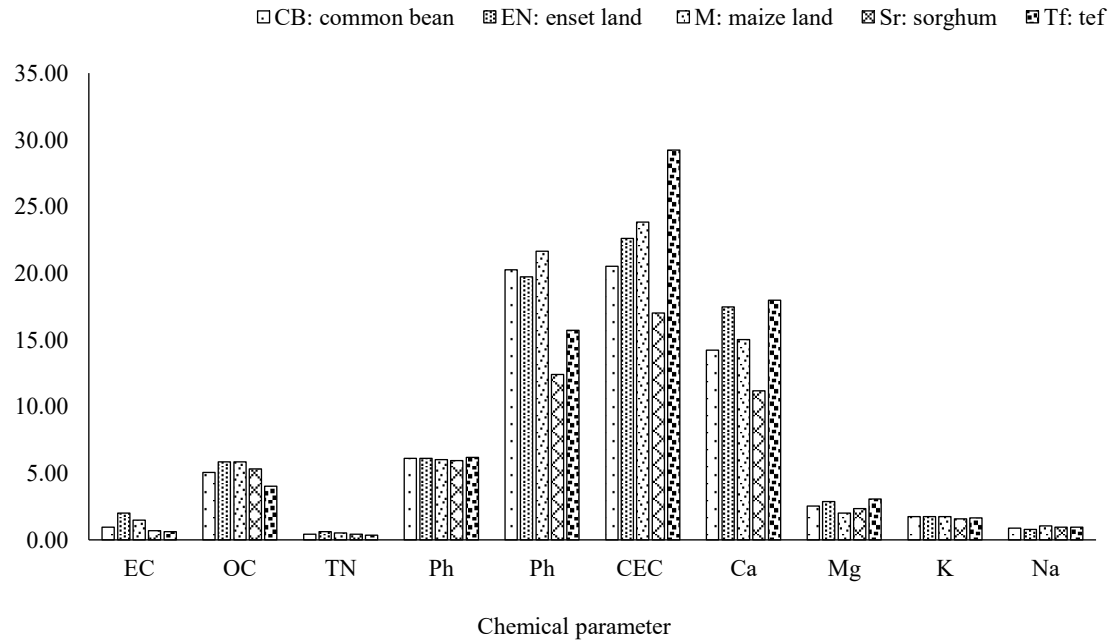


Figure 2. The nutrient status of soil at different selected land types.

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Table 4. The Pearson correlation coefficient of selected physicochemical parameters and micronutrients ($p < 0.05$).

OC	**0.48**	**1**											
TN	0.47	0.83	1										
Ph	0.60	0.64	0.46	1									
P	0.35	0.41	0.44	0.49	1								
CEC	0.30	0.74	-0.41	0.64	0.26	1							
Ca	0.63	-0.36	-0.33	0.87	0.33	0.84	1						
Mg	0.57	-0.53	-0.51	0.57	-0.13	0.64	0.71	1					
K	0.53	0.42	0.23	0.91	0.22	0.61	0.09	0.04	1				
Na	0.62	-0.19	-0.17	0.66	0.08	0.39	0.25	0.31	0.63	1			
Cu	0.06	0.49	0.50	0.30	0.24	0.45	-0.03	-0.23	0.39	-0.28	1		
Zn	-0.32	0.24	0.27	0.63	0.33	0.41	0.32	0.05	0.53	0.44	0.46	1	
Mn	0.40	0.89	0.79	0.26	0.23	0.49	-0.09	-0.34	0.39	-0.07	0.59	0.39	1
Fe	0.30	-0.23	-0.20	0.35	0.41	0.52	0.78	0.77	0.11	0.31	-0.03	0.23	-0.04
	EC	OC	TN	pH	P	CEC	Ca	Mg	K	Na	Cu	Zn	Mn

DF: degree of freedom

Pearson Correlation and Linear Regression

Linear regression of CEC versus pH showed a positive and significant relationship. Increasing pH and CEC increased concentration by 64 percent. TN and SOC were also positively correlated (95% CI) because $p < 0.05$; increasing OC increased TN by 83%. The relationship between Ca and pH was positive, increasing pH increased Ca by 87%.

In Table 4, the Pearson correlation of EC with pH, Ca, Mg, K, and Na was moderate and positive ($r^2 = 0.6, 0.63, 0.57, 0.53$, and 0.62, $df = 4$, $p < 0.05$), but weak with the others. SOC was positively correlated with P, K, and Cu but negatively correlated with Ca and Mg. The correlations between P, K, and Cu were weak ($r^2 < 0.5$). OC with TN and Mn were strong and positive ($r^2 = 0.83, 0.89$), while OC with CEC and pH were moderate ($r^2 = 0.74, 0.64$). The results were considered significant at $p < 0.05$. OC had a negative and significant correlation with Mg ($r^2 = -0.53$, $df = 4$). Parameters such as pH, OC, and CEC were influential; among bases and micronutrients, Ca and Fe were influential as they correlated with more nutrients.

CONCLUSION

Physicochemical analysis of soil across different land-use types in the Tembaro zone was performed using analytical methods. The study provides the chemical and physical characteristics of the soil at the study site; the selected land types had different characteristics owing to the different decomposition rates of residuals and organic waste. Chemical analysis showed that enset and maize lands had better nutrient availability owing to waste decomposition and residual effects.

Physicochemical parameters such as SOC, pH, CEC, and TN were more influential in the selected land uses as they directly influence fertility. Alternative cultivation and leaving residuals on agricultural land improve soil fertility and increase productivity. Based on the results, the soil in enset, maize, and sorghum land has shown significant differences and better properties than that in faba bean and wheat land. The findings show that the dominant factors include clay content, organic carbon, soil reaction, available phosphorus, and CEC. Therefore, local farmers and investors should adopt alternative cultivation and crop rotation systems.

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REFERENCES

1. Hartemink AE. Assessing soil fertility decline in the tropics using soil chemical data. Adv Agron. 2006;89:179-225.
2. Nazif W, Perveen S, Saleem I. Status of micronutrients in soils of district Bhimber (Azad Jammu and Kashmir). J Agric Biol Sci. 2006;1(2):35-40.
3. Kumar M, Babel AL. Available micronutrient status and their relationship with soil properties of Jhunjhunu Tehsil, District Jhunjhunu, Rajasthan, India. J Agric Sci. 2011;3(2):97-106.
4. Roy RN, Misra RV, Lesschen JP, Smaling EM. Assessment of soil nutrient balance: approaches and methodologies. Rome: Food and Agriculture Organization of the United Nations; 2003.
5. Mulugeta L, Sheleme B. Characterization and classification of soils along the toposequence of Kindo Koye Watershed in Southern Ethiopia. East Afr J Sci. 2010;4(2):65-77.
6. Logan TJ. Chemical degradation of soil. Adv Soil Sci. 1990;11:187-221.
7. Hartemink AE. Soil fertility decline in some major soil groupings under permanent cropping in Tanga Region, Tanzania. Geoderma. 1997;75:215-29.
8. Maria RM, Yost R. A survey of soil fertility status of four agroecological zones of Mozambique. Soil Sci. 2006;171(11):902-14.
9. Abera A, Achiso Z. Evaluation of different blended fertilizer types and rates for better production of teff (Eragrostis tef) yield and yield components in Tembaro District, Kembata Tembaro Zone, Southern Ethiopia. East J Trop Agric Sci. 2023;1(4):117.
10. Bore G, Bedadi B. Impacts of land use types on selected soil physico-chemical properties of Loma Woreda, Kambata Zone, Southern Ethiopia. Sci Technol Arts Res J. 2015;4(4):40-48.
11. Abate K, Mohammed M, Kibret K. Soil fertility assessment and mapping of spatial variability at Amareganda-Abajarso sub-watershed, north-eastern Ethiopia. East Afr J Sci. 2016;10(1):1-4.
12. Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 1934;37:29-38.
13. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Washington (DC): United States Department of Agriculture; 1954. (USDA Circular No. 939).
14. Kebebew S, Bedadi B, Erkossa T, Yimer F, Wogi L. Effect of different land-use types on soil properties in Cheha District, South-Central Ethiopia. Sustainability. 2022;14(3):1323.
15. Black CA, editor. Methods of soil analysis. Part 2. Agronomy No. 9. Madison (WI): American Society of Agronomy; 1965. p. 891-901.
16. Bouyoucos GH. Reclamation of the hydrometer for making mechanical analysis of soil. Agron J. 1951;43:434-8.
17. Abuye F, Haile M, Haile W. Soil fertility status, fertilizer application and nutrient balance in SNNPR, southern Ethiopia in contrasting agro-ecological zones of Ethiopia. Afr J Agric Res. 2021;17(11):1433-52.

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