SVU-International Journal of Agricultural Sciences
Volume 6 Issue (2) pp.: 36-44, 2024
Print ISSN 2636-3801 | Online ISSN 2636-381X
Doi: 10.21608/svuijas.2024.265416.1336

RESEARCH ARTICLE

Spatial variability of soil fertility under different land use Types in Assosa District, Western Ethiopia

Gerbi, A.A.[1]*, M. Yli-Halla [2], L. Wogi [3] and A. Bekele [4]

[1] *Department of Soil resource and watershed management, University of Assosa, Ethiopia.*
[2] *Department of Agricultural Sciences, University of Helsinki, P.O. Box. 27, Finland.*
[3] *School of Natural Resources Management and Environmental Sciences, University of Haramaya, P.O. Box 138, Dire Dawa, Ethiopia.*
[4] *College of Agriculture and Environmental Sciences, Oda Bultum University, P.O. Box 226 Chiro, Ethiopia.*

Abstract

A study was conducted to evaluate the spatial variability of soil fertility under different land use types, in Assosa District, western Ethiopia. Three different land use types, namely; cultivated, grazing, and forestland considered for this study. Surface soil samples (0-20 cm depth) were collected from three kebeles (Amba 8, Abirhamo, and Amba 12) which are considered representative of the study sites. Total of 54 soil samples in triplicates (27 disturbed and 27 undisturbed) were collected from the three land use types. The obtained results indicated that the moisture contents of soil reduced from 17.89 to 14.58%, pH from 5.72 to 5.3. 1In addition, the same trend was observed for organic carbon that decreased from 3.52% to 1.42%, total nitrogen from 0.35% to 0.16%, available phosphorus from 5.16 to 3.36 mg kg^{-1}, extractable sulfur from 5.33 to 3.89 mg kg^{-1}, extractable zinc from 4.7 to 0.84 mg kg^{-1}, boron from 1.7 to 0.27 mg kg^{-1}. In contrast, there were increasing in soil bulk density from 1.15 to 1.25 g cm^{-3}, exchangeable acidity from 0.63 to 2.07 cmol+ kg^{-1}, exchangeable Al from 0.13 to 1.44 cmol+kg^{-1}. It was concluded that land use change has a significant effect on soil quality and crop productivity in the Assosa district. The conversion of forest land to cultivated and grazing; increases soil acidity, exchangeable acidity, and exchangeable Al and decreasing the amount and availability of Phosphorus, nitrogen, organic carbon, and deficiency problems of some micronutrient (B and Zn). As a result, soil fertility and crop productivity might decline. Therefore, attention should be given to correct soil nutrient status and site-specific management should be taken on cultivated lands by the concerned bodies and the farmers in the study area.

Keywords: Cultivated land; Grazing land; Forest land; Land use types; Soil fertility status.

1. Introduction

Agriculture in Ethiopia is threatened by soil nutrient removal, soil erosion, and depletion of organic matter (OM) due to land use change with increased population numbers (Elias, 2019). To meet the increased needs, more land is being put under intensive cultivation, and large areas of grazing land are being overgrazed and degraded in Ethiopia (Dereje, 2020). Weldemariam *et al.* (2020) indicated that nutrient mining increment and soil erosion, with minimum nutrient management have led to declining soil fertility and decreased soil productivity in Ethiopia. Also, they reported that knowledge of soil properties related to land use attributes is vital for establishing sustainable agricultural and site-specific management practices.

Conversion of forest land to cultivated land subjects it to degradation of soil physicochemical properties, thereby decreasing soil fertility. Soils

***Corresponding author: Abdisa Abebe**
Email: abdisaabebe3@gmail.com
Received: January25, 2024; Accepted: April 21, 2024; Published online: April 25, 2024.

in the cultivated land are more acidic when compared with adjacent forest and grazing lands, which might increase the toxicity of manganese and aluminum, and slower microbial conversion of NH_4^+ to nitrate (Assefa *et al*., 2023). Ekero *et al.* (2022) suggested that cultivated land had lower pH and minimum OC than adjacent grazing and forest land. The expansion of cultivated lands depleted soil organic carbon and total nitrogen, restricting crop growth and decreasing crop yield (Mengistu and Dereje, 2021). Studying the spatial variability of surface soil fertility under different land use types (cultivated, grazing, and forest) may support different stakeholders in designing proper land use planning to maintain soil fertility, protect forests, and restore degraded land through appropriate management practices. Therefore, this study was conducted to investigate the soil fertility spatial variability under different land uses in Assosa district, northwestern Ethiopia.

2. Materials and methods

The study was conducted in the Assosa district, Assosa Zone of Benshangul Gumuz Regional State, Western Ethiopia. The study site is located between 10º 01' 25" to 10º 02' 50" N latitude and 34º 33' 50" to 34º 34' 35" E longitude at an average altitude of about 1560 meters above sea level (masl).

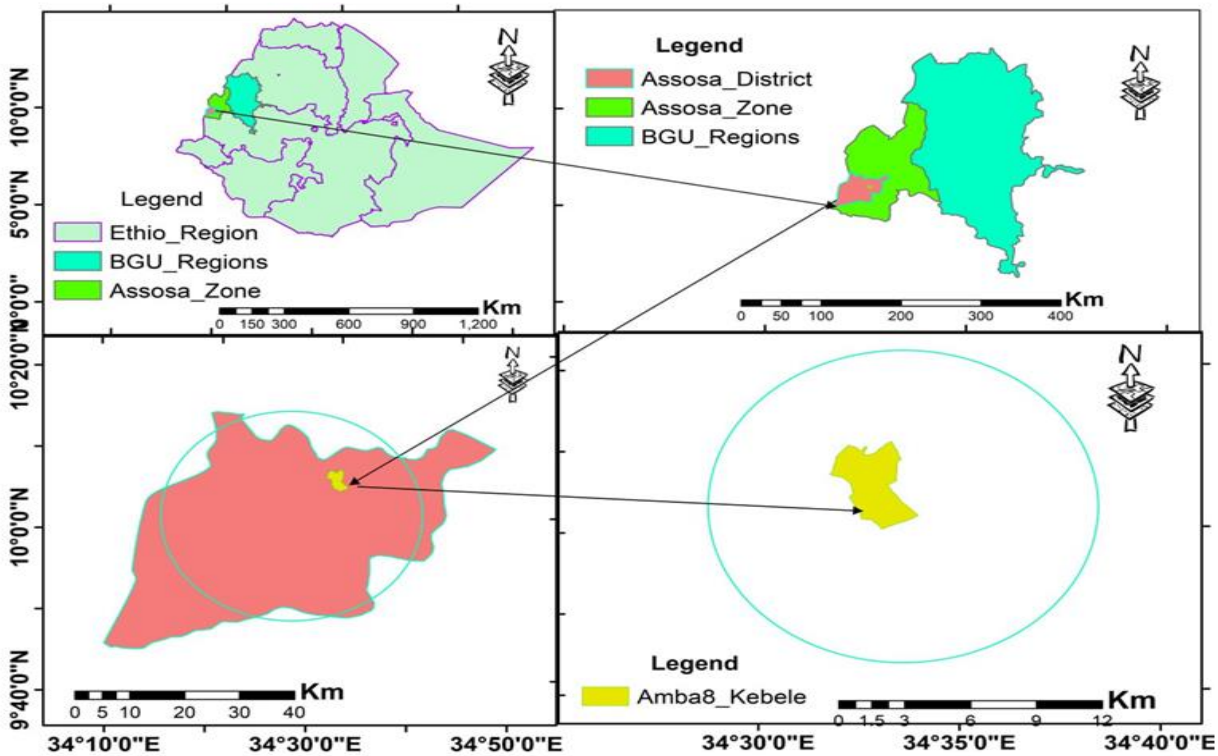

Figure 1. Location map of the experimental site.

2.1. Climate and Topography

Assosa district has two agroecological zones that are Kolla 90% and Weyna-dega 10% (MoA, 2000). The agro-climatic zones of Assosa Zone are hot to warm sub-humid. Based on 10 years of climatic data (2011–2020), the mean monthly minimum and maximum temperature in the study area are 12.8^{0}C and 32.4^{0}C, respectively while the mean monthly rainfall of 1346 mm mono-modal rainfall distribution (Fig. 2).

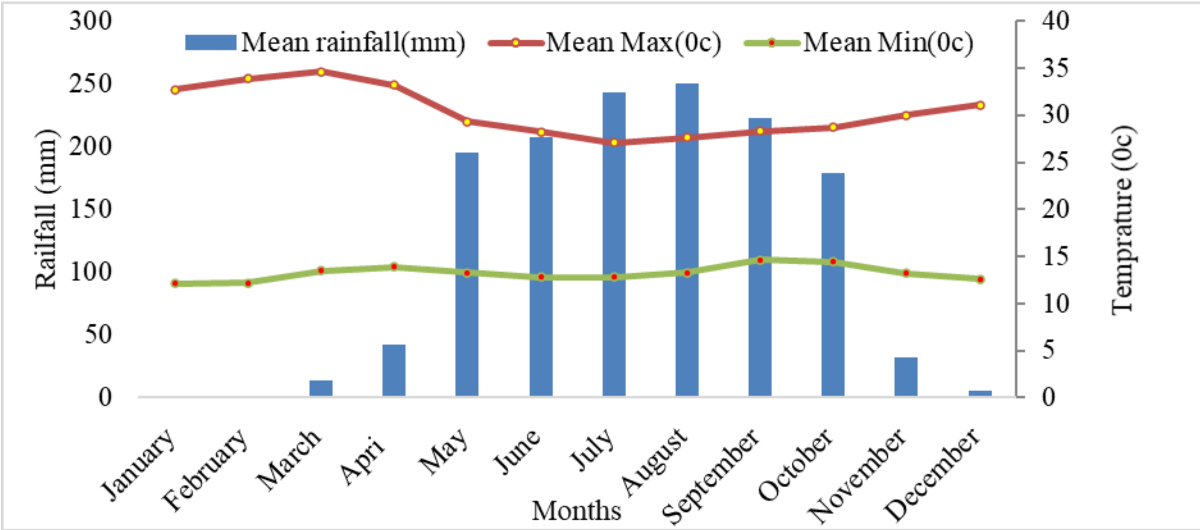

Figure 2. Agro climate of the study area from 2011 to 2020 (NMA, 2021)

2.2. Land Use Types Selection, Soil Sampling, and Analysis

The long-year land use history of the study area was collected from the local knowledgeable and elderly communities who have enough information about the area's land use history. Following the information obtained from the community, three kebeles namely Amba 8, Abirhamo, and Amba 12 were considered representative of the study sites and selected purposively. Cultivated, grazing, and natural forests that are adjacent to each other were selected for soil sampling sites. Composite soil samples from a depth of 0-20 cm were collected in plastic bags from representative sites of each land use type with three replications. Each composite soil sample was prepared from 10 sub-samples taken by using an auger to a depth of (0–20 cm) randomly in a zigzag pattern to provide a uniform distribution of sampling sites of each site. A total of 3*3*3 = 54 (27 disturbed and 27 undisturbed) composite soil samples were collected. The air-dried samples were ground, and sieved to pass through a 2 mm sieve and 0.5 mm for the analysis of the selected physical and chemical properties at Assosa University soil laboratory and Hawassa regional soil laboratory.

2.3. Soil Laboratory Analysis

Soil particle size was analyzed by the Bouyoucus hydrometer method (Bouyoucos, 1951). Soil BD was measured according to the Jamison *et al.* (1950) procedure while particle density PD was measured using a pycnometer (Barauah and Barthakulh, 1997) at Assosa University. Total porosity was calculated from the values of BD and PD while moisture content (MC) was calculated as follows:-

$$\mathrm{TP}(\%) = 1 - \frac{\text{Bulk density }(\mathrm{g\ cm^{-3}})}{\text{Particle density }(\mathrm{g\ cm^{-3}})} X100$$

$$\mathrm{MC}(\%) = \frac{100(\mathrm{FW(g)} - \mathrm{DW(g)})}{\mathrm{DW(g)}}$$

Where MC (%) = soil moisture content; FW= fresh weight and DW= dry weight

Soil pH was analyzed potentiometrically in 1:2.5 soils: H_2O solution using a combined glass electrode pH meter (Chopra and Kanwar, 1976). Exchangeable acidity was analyzed according to Rowell (1994) while the exchangeable Al was analyzed by applying 1M NaF on the extracted sample and back-titrated with a standard solution of 0.02 M HCl. The soil organic carbon was analyzed by the wet combustion procedure of Walkley and Black (1934). The soil's total nitrogen content was analyzed by the wet-oxidation procedure of the Kjeldahl method

(Bremner and Mulvaney, 1982). Available P was extracted by the Bray II method (Bray and Kurtz, 1945). Available S was determined by turbidimetric (William and Steinberg, 1959). Exchangeable basic cations (Ca, Mg, K, and Na) were determined by leaching the soil samples with 1M NH_4OAc solution at pH 7.0. Ca and Mg were determined by using atomic absorption spectrophotometry, while exchangeable Na and K were measured by flame photometers. The CEC of the soil was determined by the 1N-neutral normal ammonium acetate extraction method (Jackson, 1967). Extractable Fe, Zn, Mn, and Cu were extracted using 0.005 M di-ethylene triamine penta acetic acid solution having pH 7.3 as per Lindsay and Norvell (1978) and estimated in atomic absorption spectrophotometer (Perkin-Elmer Analyst 100, USA). Soil exchangeable B was extracted with hot water and estimated using the colorimetric Azomithene H method (Page *et al*., 1982).

3. Results and discussion

3.1. Soil Texture

The results of the analysis of variance showed that the particle size distribution was significantly affected by land use type (Table 1). The highest clay content (51%) was observed under the natural forest. This might be associated with the forest cover and minimum soil erosion intensity that reduced clay content reduction and depletion. Under all land uses there were lesser proportions of silt. A similar study also suggested the relative maximum clay content at the natural forest land due to the forest cover and minimum soil erosion intensity (Asmare *et al*., 2023). The higher sand content of the cultivated and gazing land indicates that the soil was highly eroded, with minimum water holding capacity, and higher BD when compared with cultivated and forest land. In line with this Dereje (2020) and Asmare *et al*. (2023) suggested the highest sand content at the surface soil of grazing land due to the removal of finer particles by erosion.

3.2. Soil Bulk Density, Particle Density, and Porosity

The relatively maximum bulk density was recorded for cultivated land (1.25 g cm^{-3}) and the lowest (1.15 g cm^{-3}) under forest land (Table 1). This might be due to the result of fewer disturbances of the soil and high plant residue input contributed from natural forest litter and high organic matter content than the other land use types. In line with this Dereje (2020) suggested the highest bulk density was recorded under cultivated land compared to the adjacent grazing and forest lands at a surface soil. Soil particle density showed a significant ($P \leq 0.05$) difference in land use types (Table 1). The relatively lowest (2.1 g cm^{-3}) particle density was recorded at the forest than in the adjacent cultivated and grazing lands (Table 1). This might be due to higher clay content at forest land. In agreement with this Asmare *et al.* (2023) reported relatively lower particle density in forest than the adjacent cultivated and grazing lands.

Table1. Effects of land use types on selected soil physical properties

Land use type	Clay	Silt	Sand	Textural Class	BD	PD	TP	SMC
	----------%---------				---g cm^{-3}----		---------%--------	
Cultivated land	44^c	27^a	29^b	Clay	1.25^a	2.3^b	55.0^a	14.6^c
Grazing land	46^b	24^b	35^a	Clay	1.24^a	2.4^a	53.2^b	16.5^b
Forest Land	51^a	22^c	27^c	Clay	1.15^b	2.1^c	55.7^a	17.9^a
CV (%)	2.12	4.1	3.29		1.17	0.74	1.55	1.23
LSD (0.05)	1.89	2.41	3.08		0.09	0.04	0.94	0.97

**Means within a column followed by the same letter are not significantly different at P = 0.05; BD= Bulk density; PD = Particle density; TP = Total porosity; SMC= soil moisture content; CV = Coefficient of variation; LSD = Least significant difference*

3.3. Effect of Land Use Types on Soil Acidity Related Properties

Soil pH showed a significant difference by land use type. Compared to the forest and grazing land, cultivated land has a lower (5.31) soil pH, highest exchangeable acidity (2.07 $cmol_+ \ kg^{-1}$) and exchangeable Al (1.44 $cmol_+ \ kg^{-1}$) (Table 2). The forest land showed a 0.41 unit difference in soil pH over cultivated land and 0.24 units over grazing land. This might be attributed to the ameliorating effect of the high accumulation of OM in surface soil. This might be related to intensive cultivation, depletion of basic cations in crop harvest, and continuous use of acid-forming mineral fertilizers which may produce strong inorganic acids when oxidized by soil microbes. Kebebew *et al*. (2022) and most recently Abadeye *et al*. (2023) reported the highest and lowest pH under forest and cultivated land respectively. Achalu and Dechassa (2021) investigated that exchangeable acidity and Al were lower in forest land and the highest under cultivated land.

Table 2. Effect of land use types on soil acidity-related properties

Land use type	pH - H_2O (1:2.5)	Exch. Acidity	Exch. Al^{3+}	AS (%)
		-------cmolc kg^{-1} -------		
Cultivated land	5.31^b	2.07a	1.44^a	10^a
Grazing land	5.48^b	1.38b	0.35^b	6^b
Forest Land	5.72^a	0.63c	0.13^c	3^c
CV (%)	2.17	8.49	13.26	9.21
LSD (0.05)	0.34	0.42	0.3	1.46

**Means within a column followed by the same letter are not significantly different at $P \leq 0.05$; Exch. Acidity = Exchangeable acidity; Exch. Al^{3+} = Exchangeable aluminum; AS = Acid saturation; CV = Coefficient of variation; LSD = Least of significant difference*

3.4. Effect of Land Use Types on Soil OC, TN, Available P, and S

Soil OC and TN were significantly affected by land use (Table 3). The relative highest (3.52 %) OC and (0.35%) TN were recorded under the natural forest while the lowest (1.42%) OC and (0.16 %) TN was recorded in cultivated land. This might be associated with the high biomass and plant litter fall returned to the soil, atmospheric carbon sequestration through photosynthesis, thus creating natural storage of carbon in forest land. Asmare *et al*. (2023) and Abadeye *et al*. (2023) reported that OC was found highest and lowest in forest and cultivated land respectively.

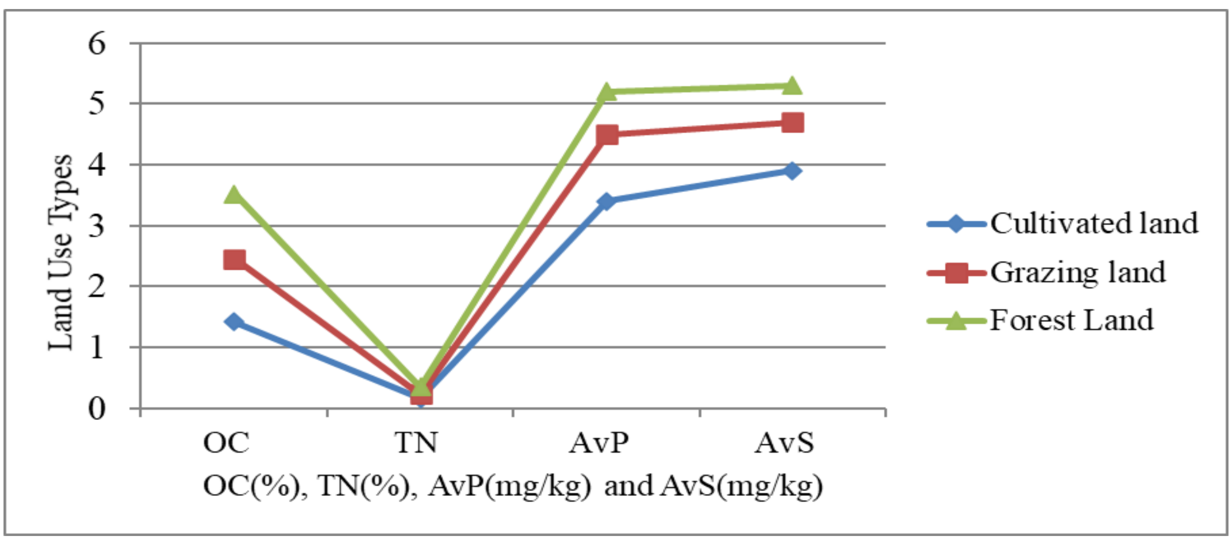

Figure 3. Soil OC (%), TN (%), AvP and AvS (mg/kg)

Available P under forest land was significantly higher (5.2 mg kg^{-1}) compared to cultivated (3.4 mg kg^{-1}) and grazing lands (4.5 mg kg^{-1}) (Fig. 3). This might be attributed to the high OM content and anion released from OM competing with P for fixation by Al^{3+} and H^{+} cations and release of P through mineralization of OM in the forest land. However, in the forest, P is more or less circulated within the area and not removed from there, and in grazing land, the dung of animals has an impact on available P. In line with this Weldemariam *et al*. (2020); Ekero *et al.* (2022) and most recently Abadeye *et al*. (2023) reported relatively higher and lower available P under forest and cultivated land respectively. Available S was also significantly affected by the difference in land use types. The relatively highest available S (5.3 mg kg^{-1}) and the lowest (3.9 mg kg^{-1}) amount were obtained under forest and cultivated land, respectively (Fig. 3). The relatively highest available S under forest land might be associated with OM which might increase soil available S by increasing the mineralization of sulfur from OM. This finding was consistent with the previous finding of Meseret *et al*. (2023) reported that soil-available S increases with an increase in soil OM content.

Table 3. Effect of land use types on soil OC, TN, and available P, and available S

Land use type	OC	TN	Bray II AvP	AvS
	--------%--------		---------mg kg^{-1} ----------	
Cultivated land	1.42^{c}	0.16c	3.4^{c}	3.9^{c}
Grazing land	2.45^{b}	0.23b	4.5^{b}	4.7^{b}
Forest Land	3.52^{a}	0.35a	5.2^{a}	5.3^{a}
CV (%)	4.2	4.45	4.05	2.0
LSD (0.05)	2.14	0.85	1.94	1.08

**Means within a column followed by the same letter are not significantly different at $P \leq 0.05$; OC = Organic Carbon; TN = Total nitrogen;* Bray II Av P = *Available phosphorus by Bray II method; AVS= Available Sulfur; CV = Coefficient of variation; LSD = Least significant difference*

3.5. Effect of Land Use Types on Soil Exchangeable Bases and CEC

The exchangeable bases showed significant differences among land uses. Exchangeable Ca^{2+} and Mg^{2+} was higher (3 $cmol_{+}$ kg^{-1}) and (2.1 $cmol_{+}$ kg^{-1}) in the forest land respectively than the adjacent cultivated and grazing lands (Table 4). This might be because of the higher OM content and high nutrient recycling in forest land as compared to cultivated and grazing lands where it may be lost on harvesting and grazing. On the other hand, the lowest exchangeable Ca^{2+} (2.7 $cmol_{+}$ kg^{-1}) and Mg^{2+} (1.8 $cmol_{+}$ kg^{-1}) was recorded in cultivated land due to its continuous removal through crop harvest with no or little organic matter input into the soil and high leaching losses when soil is disturbed with intensive cultivation. Dereje (2020); Ekero *et al.* (2022) and most recently Asmare *et al*. (2023) reported that relatively the highest and lowest level of exchangeable Ca^{2+} and Mg^{2+} was found under natural forest and cultivated land, respectively.

Exchangeable K^{+} and Na^{+} content was significantly affected by land use type. The relatively higher exchangeable K^{+} (0.53 $cmol_{+}$ kg^{-1}) and Na^{+} (0.21 $cmol_{+}$ kg^{-1}) was obtained in forest land. This may be attributed to the higher organic matter content of forest land than adjacent grazing and cultivation land. In agreement with this Dereje (2020) and Ekero *et al*. (2022) reported relatively higher exchangeable Na^{+} and K^{+} content in forest land than in the adjacent grazing and cultivated land. Cation exchange capacity was significantly lower (21.1 $cmol_{+}$ kg^{-1}) under cultivated land when compared with forest (22.9 $cmol_{+}$ kg^{-1}) and grazing (21.3$cmol_{c}$ kg^{-1}) lands (Table 4.). This might be associated with high pH, and depletion OM because of continuous cultivation and clay contents. Abadeye *et al*. (2023) and Ekero *et al.* (2022) reported that soil CEC is higher under forest land and lower in cultivated land.

Table 4. Effect of land use types on soil exchangeable bases, and CEC

Land use type	Exch. Ca	Exch. Mg	Exch. K	Exch. Na	CEC
	-------------------------cmolckg^{-1} ------------------------				
Cultivated land	2.73^{c}	1.77^{b}	0.18^{c}	0.14^{b}	21.1^{b}
Grazing land	2.85^{b}	1.84^{b}	0.29^{b}	0.16^{b}	21.3^{b}
Forest Land	3.03^{a}	2.10^{a}	0.53^{a}	0.21^{a}	22.9^{a}
CV (%)	2.09	4.45	12.77	10.53	3.27
LSD (0.05)	1.02	0.82	0.76	0.57	0.61

**Means within a column followed by the same letter are not significantly different at P = 0.05; Exch. Ca = Exchangeable calcium; Exch. Mg = Exchangeable magnesium; Exch. K = Exchangeable potassium; Exch. Na = Exchangeable sodium; CEC = Cation exchange capacity; CV = Coefficient of variation; LSD = Least significant difference*

3.6. Effect of Land Use Types on Soil Extractable Micronutrients

Micronutrients were highly affected by difference in land use type. Relatively the highest (35 mg kg^{-1}) extractable Fe and (29.4 mg kg^{-1}) Mn was recorded in cultivated land compared to grazing and forest land, while the relatively lowest was recorded in forest land (Table 5). This might be associated higher pH under cultivated land and lower in forest land. In consistent with this Mengistu and Dereje (2021) and Salwinder *et al. (*2023) reported that relative maximum and minimum soil Fe and Mn was recorded in cultivated and forest land respectively.

The comparatively highest Zn (4.7 mg kg^{-1}) and Cu (4.1 mg kg^{-1}) were recorded under forest land while the lowest Zn (0.84 mg kg^{-1}) and (2.9 mg kg^{-1}) were recorded under cultivated land, respectively (Table 5). Low Zn and Cu concentration in cultivated land might be associated with continuous harvesting of crops, organic matter oxidation, and losses of the topsoil through different forms of erosion that is occurred by tillage activities. In coupled to this Mengistu and Dereje (2021) and Kebebew *et al.* (2022) reported that lower available Zn and Cu in cultivated land compared to grazing and forest land. The comparatively highest (1.3 mg kg^{-1}) soil B was recorded in forest land while the relatively lowest was obtained at cultivated land. This might be associated to high OM which may increase soil B by mineralization of B from organic fertilizer. In agreement with this finding increase in boron availability under forest land with the increase in OM was reported by Mengistu and Dereje (2021).

Table 5. Effect of land use types on soil extractable micronutrients

Land use types	Extra. Fe	Extra. Mn	Extra. Zn	Extra. Cu	Extra. B
	----------------------------mg kg^{-1}----------------------------				
Cultivated land	35.0^{a}	29.4^{a}	0.84^{c}	2.9^{c}	0.27^{c}
Grazing land	32.5^{b}	28.8^{a}	2.6^{b}	3.2^{b}	0.81^{b}
Forest Land	30.0^{c}	25.2^{b}	4.7^{a}	4.1^{a}	1.3^{a}
CV (%)	2.96	3.02	11.82	4.16	6.60
LSD (0.05)	0.86	0.74	1.24	0.93	0.95

**Mean values within columns followed by the same letter(s) are not significantly different at P = 0.05; Extra. Fe= Extractable iron; Extra. Mn= Extractable manganese; Extra. Zn = extractable zinc; Extra*. Cu = *extractable copper; Extra. B = extractable boron; CV Coefficient of variation; LSD = Least significant difference.*

4. Conclusion

The study was conducted to investigate soil fertility spatial variability under different land uses in Assosa District, western Ethiopia. The result indicated when forest land is converted into cultivated and grazing land; there is an increase in soil acidity, exchangeable acidity, and exchangeable Al while available P, nitrogen, OC, and some micronutrient (B and Zn) deficiency problems were occurred. This contributed to the decline in soil fertility and crop productivity. Therefore, attention should be given to correct soil nutrient status and site-specific management should be taken on cultivated lands by the concerned bodies and the farmers in the study area.

Authors' Contributions
All authors are contributed in this research

Funding
There is no funding for this research.

Institutional Review Board Statement
All Institutional Review Board Statements are confirmed and approved.

Data Availability Statement
Data presented in this study are available on fair request from the respective author.

Ethics Approval and Consent to Participate
Not applicable

Consent for Publication
Not applicable.

Conflicts of Interest
The authors disclosed no conflict of interest.

5. References

Abadeye, T., Yitbarek, T., Zewide, I., Adimasu K. (2023). 'Assessing soil fertility influenced by land use in Moche, Gurage Zone, Ethiopia', *The Scientific Temper*, 14(1), pp. 80-92.

Achalu, C., Dcchessa, Y. (2021). 'Spatial variability and status of some physical-chemical properties of soil under different land use type: the case of Kiramu District east Wollega Zone, Oromia. *Journal of science and sustainable development*, 9(2), PP. 70-91.

Asmare, T., Befkadu, A., Melese, Y., Birhan, T., (2023). 'The effect of land use type on selected soil physicochemical properties in Shihatig watershed, Dabat district, Northwest Ethiopia' *Heliyon*, 9(5), PP. 1-10.

Assefa, B. (2023). '*Maize yield gaps and their mitigation in Ethiopia: an integrated assessment*. [Internal PhD, WU, Wageningen University]. Wageningen University. https://doi.org/10.18174/585728.

Barauah, T.C., Barthakulh, H.P. (1997). '*A Text Book of Soil Analysis*. Vikas Publishing House, New Delhi, India.

Bouyoucos, G.H. (1951) 'A recalibration of the hydrometer for making mechanical analysis of soils', *Agricultural Journals,* 43, PP. 434-438.

Bray, R.H., Kurtz, L.T. (1945). 'Determination of Total Organic and Available Forms of Phosphorus in Soils', *Soil Science*, 59, PP. 39-45.

Bremner, J.M., Mulvaney, C.S. (1982). '*Nitrogen total, In Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties*, 2^{Ed}. (Eds Page A.L, Miller R.H., and Keeney D.R.). Madison, WI: American Society of Agronomy, 595-624.

Chopra, S.H., Kanwar, J.S. (1976). '*Analytical Agricultural Chemistry*. Kalyani Publisher.

Dereje, G. (2020). 'Effect of land use types on selected soil physical and chemical properties at Sire Morose sub watershed, central highland of Ethiopia, *International Journal of Engineering Research and Technology,* 9 (5), PP. 770-779.

Ekero, D., Haile, W., Lelago, A., Bibiso, M. (2022). 'Effects of Different Land Use Types on Soil Physico-Chemical Properties in Wolaita Zone, Ethiopia., *Polish Journal of Soil Science*, 55(1), PP.19-35. DOI: 10.17951/pjss/2022.55.1.19.

Elias, E. (2019). 'Selected chemical properties of agricultural soils in the Ethiopian highlands: a rapid assessment' *South African Journal of Plant and Soil*, 36(2) PP. 153–156.

Jackson, M.L. (1967). '*Soil chemical analysis Printice Hall',. Ind*, Englewood, Chiffs N.J. USA.

Jamison, V.C., Weaver, H.H., Reed, I.F. (1950). 'A hammer-driven soil core sampler.', *Soil Science*, 69, PP. 487-496.

Kebebew, S., Bedadi, B., Erkossa, T., Yimer, F., Wogi, L. (2022). 'Effect of Different Land-Use Types on Soil Properties in Cheha District, South-Central Ethiopia', *Sustainability*, 14(3), PP. 13-23. https://doi.org/ 10.3390/su14031323.

Kedir, J. (2020). 'Effects of different land use systems on physicochemical properties of soil in Wudma sub-watershed district, southern Ethiopia' *Global Advanced Research Journal of Agricultural Science*, 9(6), PP. 151–159.

Lindsay, W.L., Norvell, W.A. (1978). 'Development of DTPA soil tests for Zn, Fe, Mn, and Cu', *Soil Science Society of America Journal*, 42(3), PP. 421-428.

Mengistu, T., Tesgaye, D. (2021). 'Impact of land use types and soil depths on selected soil physicochemical properties in Fasha District, Konso Zone, southern Ethiopia', *Journal of Soil Science and Environmental Management*, 12(1), PP. 10-16 http//doi.org/10.5897/JSSEM2020.0815.

Meseret, H., Eyasu, E., Mekuria, A., (2023). 'Effects of Integrated Soil Fertility Management Practices on Soil Properties under Wheat and Faba Bean Production in Dire and Legedadi Watersheds of Ethiopia', *Research Square*. DOI: https://doi.org/10.21203/rs.3.rs-3037266/v1.

MoA (Ministry of Agriculture). (2000). Agro-ecological Zonation of Ethiopia. Addis Ababa, Ethiopia.

NMA (National Meteorological Agency). (2021). Assosa district agroclimatic report.

Page, A.L., Miller R.H., Keeney, D.R. (1982). *Methods of Soil Analysis*, Part 2: *Chemical and Microbiological Properties*. 2nd Edition. ASA and SSSA, Madison, Wisconsin

Rowell, DL. 1994. Methods and application. Addison Wesley Longman, Limited, England, UK. *Soil science, 66:* 573-574.

Salwinder, S. D., Vivek, S., Arvind, K. S., Janpriya, K., Rajeev, K.G., Vibha, V., Manmeet, K., Vijay, K. S., Prabhjot, S. (2023). 'Interactive effect of land use systems on depth-wise soil properties and micronutrient minerals in North-Western India', *Heliyon*, 9(2), PP. 1-10.

Walkley, A., Black, I.A (1934). 'An examination of the Degtjareff method for determining soil organic matter and proposed modification of the titration method', *Soil Science,* 37, PP. 29-38.

Weldemariam, S, Eyasu, E., Girmay, G. (2020). 'The Effects of Land Use and Landscape Position on Soil Physicochemical Properties in a Semiarid Watershed, Northern Ethiopia', *Applied and Environmental Soil Science*, 2020, pp. 1-20. doi.org/10.1155/2020/8816248.

Williams, C.H., Steinberg, A. (1959). 'Soil sulphur fractions as chemical indices of available Sulphur in some Australian soils.', *Australian Journal of Agricultural Research*, 10, pp. 340-352.