Greener Journal of Soil Science and Plant Nutrition
Vol. 10(1), pp. 1-7, 2026
ISSN: 2384-6348

https://gjournals.org/GJSSPN
DOI: https://doi.org/10.15580/gjsspn.2026.1.080626132

Extent of Soil Acidity in Smallholder Farming Systems of the West and South West Shoa Highlands, Oromia, Ethiopia

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ABSTRACT

This study assessed soil acidity status in agricultural lands across twelve districts spanning in the West and South-West Shoa highlands, Ethiopia. A total of 610 soil samples were collected from farmers' fields at 0–20 cm depth: 375 from West Shoa, 120 from Southwest Shoa, 98 from two in Geferssa Guje, and 11 from Nedjo in West Wollega as reference. Laboratory analysis at Holeta Agricultural Research Centre confirmed widespread soil acidification, with mean pH values ranging from 4.03 to 4.71—well below the agronomic optimum of 6.0–7.5. Exchangeable acidity (EA), a key indicator of active acidity, varied across sites. Ale Ababa (Sadan Sodo), Haro Boki (Welmera), and Shukute (Jeldu) showed the highest EA levels at 62.17%, 62.07%, and 60.39%, respectively, identifying them as critical intervention hotspots. The findings reveal that soil acidity, once localized in western areas like Nedjo, is now almost similar to that to south Western and west Shoa highlands, posing risks to agricultural productivity and food security. Effective management such as liming and acid-tolerant crop varieties-is vital for restoring nutrient availability. The study emphasizes integrated soil fertility management and coordinated efforts among governments, NGOs, and communities to implement sustainable solutions including land rehabilitation and erosion control.

ARTICLE'S INFO

Article No.: *080626132*
Type*: *Research
Full Text: *PDF, PHP, HTML, EPUB, MP3*
DOI: ***10.15580/gjsspn.2026.1.080626132***

Accepted: *15/08/2026*
Published: *20/08/2026*

Keywords: *Central highlands, Exchangeable acidity, Lime, pH, Soil acidity*

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Article's QR code

INTRODUCTION

About 43% of the Ethiopian total land is affected by soil acidity; out of which, about 27.7 % are dominated by moderate to weak acid soils (pH in KCl of 4.5 -5.5), and around 13.2 % are strong acid soils (pH in KCl of <4.5) and nearly one-third have aluminum toxicity problem (Mesfin, 2007). As stated by Robarge, 2008 and Menzies, 2003; Aluminum toxicity becomes a management issue mainly when the pH in water is below 5.0. In humid and sub-humid area of Ethiopia, vast areas of land in the Western, South-Western and North-Western highlands of the country which receive high rainfall are thought to be affected by soil acidity (Mesfin, 2007). The problem of soil acidity in the country is apparently increasing recently both in extent of area coverage and severity of the problem.

Based on the pH scale; soil can be classified as acidic, neutral, or alkaline. Soil acidity refers to soils with a low pH level, typically less than 7 (Robarge, 2008). Soil pH is a key factor influencing ion exchange, dissolution, oxidation, reduction-adsorption, and complexation (Murray, 1994). The combined effects of these processes determine the quantity and form of nutrient ions in the soil solution, thereby affecting their availability for plant growth (Robarge, 2008).

Soil acidity can be influenced by various natural and human-induced factors. The major soil forming factors and management practices giving rise to the increase in soil acidity involve high rainfall and leaching, organic matter decomposition, acidic parent materials, removal of basic cations, application of ammonium fertilizers, and intense weathering (Hede et al., 2001; Sumner and Noble, 2003).

Soil acidity negatively impacts crop growth due to the toxic levels of aluminum and manganese present in acidic soils, as well as the deficiency of essential plant nutrients such as phosphorus, nitrogen, potassium, calcium, magnesium, and molybdenum (Wang et al., 2006). When the soil pH drops below 5, aluminum becomes soluble and dominant in the soil solution which is harmful to the root environment and inhibit root elongation (Sivaguru and Horst, 1998) in turn affects water and nutrient uptake though available in the root zone (Matsumoto, 2002; Langer et al., 2009). Consequently, the overall growth and yield of crops are diminished (Wang et al., 2006).

Ethiopia boasts a diverse array of agro-ecological zones and natural resources. The highlands, which constitute 43% of the nation's land area, are home to 88% of the human population and 86% of the livestock (Amsalu et al., 2007). Ninety-five percent of the total cultivated land area is also concentrated in the highlands (Sonneveld et al., 2003). In these areas, agriculture still remains the base of the national economy in the highlands of the country. Small holder farmers in different districts/zones of Shoa have faced yield stagnation and even yield decline of cereals and pulse crops and lack of response to application of diammonium phosphate (DAP) and urea fertilizers Yield decline and lack of response to fertilizers may be due to soil acidity, which results in deficiencies of essential nutrients and the toxicity of acidic cations in agricultural soil.

Based on soil chemical analysis mainly soil pH and exchangeable acidity, interventions were made through amending the soils with ag-lime and remarkable achievements recorded (Getachew et al, 2017, Geremew et al., 2020) leading to significant yield improvements, improvement of soil acidity over time and across various locations in the central highlands of Ethiopia. Some interventions and assessments have revealed that several areas in Central Shoa are affected by soil acidity. However, this issue has received little attention, mainly due to the assumption that the soils are not acidic enough to significantly reduce crop yields. The purpose of this paper is to present the trends and extent of soil acidity in the central highlands of Shoa.

MATERIALS AND METHODS

Description of Study Location

The study was conducted in two zones, West Shoa (Midakegni, Jeldu, Chobi, Ejere and Welmera), South West Shoa (Woliso, Wonchi and Sadan-Sodo) and Shager City (Geferssa Guje, Kolobo and Gudu). (Figure 1). The selected districts are representative of each zone and were selected purposively.

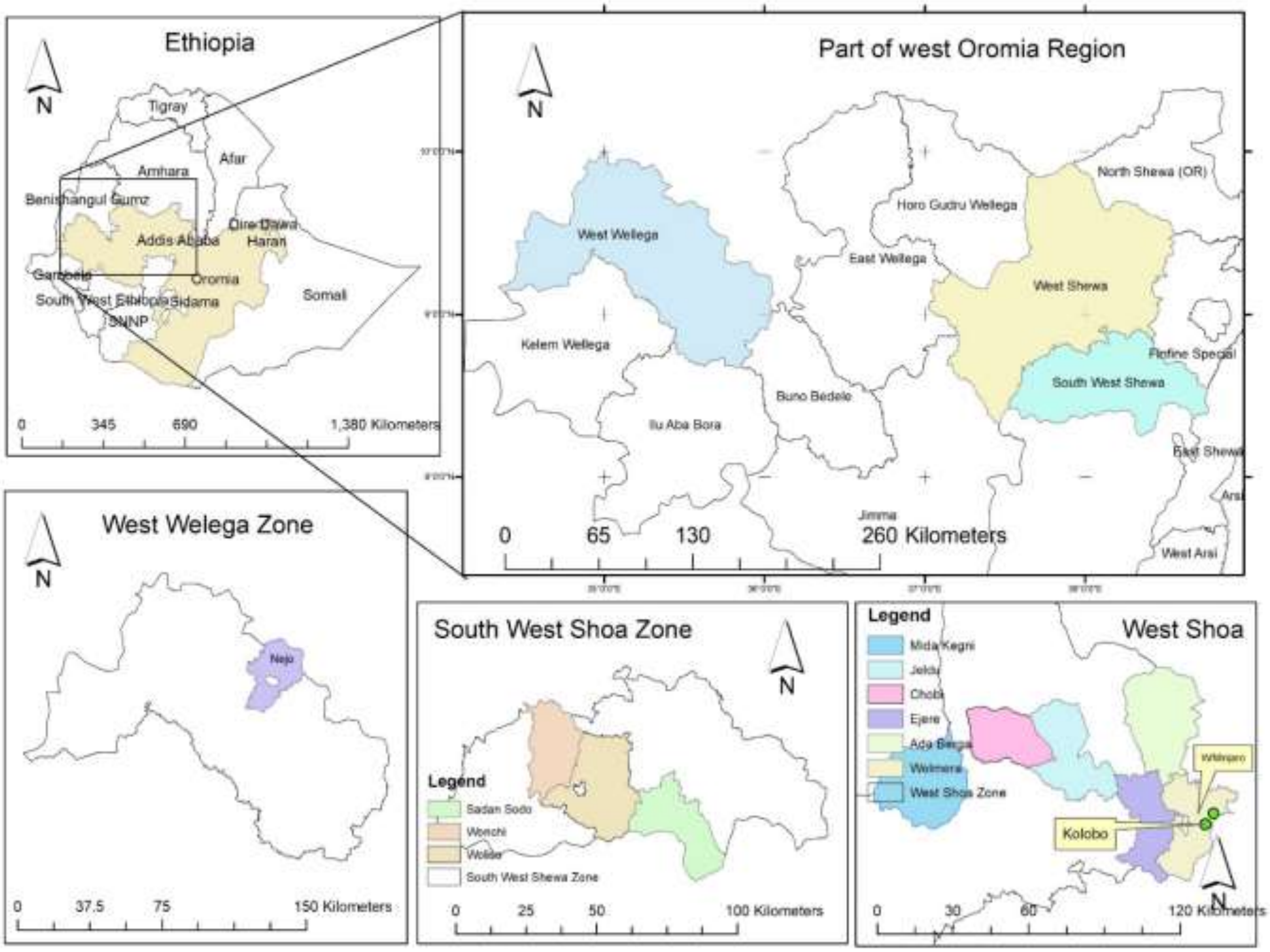

Figure 1. Study area Map of the Soil Acidity Assessment in the Highland of Shoa

Seven years of climatic data (2018/19–2023/24) were analyzed at the district level, specific to kebeles where soil samples were collected. The data include the average annual rainfall (in millimeters), as well as the annual mean minimum and maximum temperatures for each district, as summarized in Table 1. The topography of the study area is characterized by undulating feature. The livelihoods of the rural communities of the study districts depend mainly on crop production, animal husbandry and mixed farming system.

Table 1. GPS coordinate, average rainfall (mm) and mean min/max temperature of representative kebeles by district (2018/19–2023/24)

Zone	District	Kebeles	GPS			Average annual Rainfall (mm)	Mean mini temp (°C)	Mean Max temp (°C)
			Altitude (m)	Longitude (E°)	Latitude (N°)			
West Shoa	Mida-kegni	Baro-bidaro	2872	37.466695	9.145202	1507.4	12.0	22.9
	Jeldu	Shukute-wogide	2592	38.033026	9.372319	1367.1	11.5	22.2
	Chobi	Chobi	2537	37.941587	9.335076	1332.7	11.5	22.2
	Ejire	Damotu	2559	38.432463	9.093541	1314.8	16.4	21.7
	Welmera	Telecho	2735	38.453822	9.164850	1314.8	15.8	21.1
	Welmera	Haroboki	2784	38.530102	9.150683	1977.4	15.8	21.0
	Ada-berga	Ada-berga	2607	38.404162	9.271798	1385.5	15.8	21.1
South West Shoa	Woliso	Maru- babali	2522	38.030609	8.653219	1291.3	15.8	20.5
	Wonchi	Sonqole	2345	37.893332	8.668551	1371.5	15.8	20.5
	SadanSodo	Ale-Ababa	3106	38.308486	8.368850	1256.5	14.3	18.7
Geferssa Guje	Kolobo	Kolobo	2501	38.571779	9.056082	1252.7	16.4	21.7
	Gudu	Watabacha Minjaro	2694	38.625998	9.117992	1252.7	16.0	21.4
W/Wolloga	Nedjo*	Qoxe-Genase	1935	35.441350	9.541253	1826.5	16.2	26.4

CHIRPS Rainfall data and ERAS temperature data were retrieved from KNMI Climate Explorer.
* Used as reference/ for comparative purpose

Soil Sample and Analysis

A total of 610 soil samples were collected for the study purpose. From Midakegni district four locations (namely Baro bidaro, Tuye, Dire weni and Halelu gosu) 42 soil samples were collected in 2018/19. Likewise, 104 soil samples were collected from the Ejire district, specifically from three major clusters within Damotu kebele, during the 2019/20 season.

Moreover, 65 soil samples were collected from Shukute and Tulu bultum kebele from Jeldu district in 2020/21; while 12 samples were collected from Chobi districts. In the same year 51 and 79 samples were collected from Welmera (Dufa, Telecho and R/Gebeya) and Ada'a berga districts, respectively. In the same year from Woliso district (Maru Babali and Adami gotu kebele) 22 samples and from Wonchi district Sonkole kebele 7 soil samples were collected. In 2021/22 at Sadan sodo; Chewa-Qaxro-Fisaho and Ale-Ababa kebeles 52 and 39 soil samples were collected, respectively. Similarly, in 2022/23 at Welmera from Haro-boki kebele 28 soil samples were collected. In 2023/24 in Welmera at Tulu Harbu 9 samples were collected. While in 2023/24 in Geferssa Guje of Kolobo district kolobo and Gudu kebele, 98 soil samples were collected (Table 2).

11 samples were collected from Nedjo West Wollega, for comparative analysis. The severity of soil acidity in West Wollega**,** specialy Nedjo and Mana-sibu were well documented by multiple scientific studies and reports. The evidence consistently shows that soils in this zone are predominantly very strongly to strongly acidic with detrimental effects on soil fertility and crop productivity (Abdenna D.,2013; Achalu et al., 2012).

The samples were collected uniformly from farmers' fields at depth of 0-20cm using an auger. Composited and prepared, following standard sampling techniques and sample preparation procedures. The samples were transported to Holeta Agricultural Research Centre (HARC) Soil and Water Laboratory for analysis. Soil pH was determined in soil to water ratio of 1: 2.5 (w/v). as described by Chopra and Kanwar.1976. Exchangeable acidity (AL + H) was determined by saturating the samples with 1MKCL solution and titrated with sodium hydroxide as described by McLean (1965).

The pH and exchangeable acidity (EA) values were recorded from soil samples collected through Large-Scale Demonstrations (LSD) in the duration 2018 to 2025 form each kebele selected within the districts, the minimum and maximum values was taken to establish a reliable general understanding (Figure 2).

Table 2. Summary of Soil Samples by Zone, District, and Kebele with pH and Exchangeable Acidity Ranges (2018/19–2024/25)

Zone	District	Total soil samples collected	Kebele	pH (1:2.5)		EA (Cmol (+) kg-1 soil)	
				Min	Max	Min	Max
West Wollega	Nedjo*	11	Genasi	3.75	4.65	3.64	7.70
West shoa	Medakegn	8	Baro bidaro	4.07	4.82	1.42	4.15
		7	Tuye	4.13	4.50	1.72	3.88
		11	Dire weni	4.18	4.74	0.78	3.67
		16	Halelu gosu	4.10	4.70	1.09	3.53
	Jeldu	11	Wogide	4.24	4.85	2.55	3.95
		36	Shukute	4.08	4.89	1.74	3.64
		18	Tulu bultum	4.00	4.33	1.88	3.83
	Chobi	2	Tulu korma	4.26	4.36	0.80	2.32
		6	Beli	4.30	4.43	0.80	2.44
		2	Dandisa	4.16	4.25	0.80	3.11
		2	Sombo	4.18	4.25	0.80	3.11
	Ejiree	104	Damotu	4.29	4.96	0.62	3.75
	Welmera	8	Dufa	4.00	4.45	0.79	1.43
		11	Telecho	4.01	4.35	0.69	1.46
		26	R/Gebeya	4.13	4.23	0.73	1.50
		28	Haro Boki	4.30	4.72	2.71	4.28
		6	Tulu Harbu	4.32	4.93	0.85	1.52
	Ada barga	19	Etuu	4.03	4.70	0.70	0.95
		36	Roge 1ffa	4.09	4.78	1.07	1.45
		24	Ula ano	4.15	4.85	0.88	1.19
South West shoa	Woliso	17	Maru babali	4.03	4.53	0.73	1.35
		5	Adami gotu	4.40	4.60	0.31	0.95
	Wonch	7	Sonkole	3.97	4.08	1.02	1.94
	Sadan Sodo	39	C/Q/Fisaho	4.81	5.47	0.34	1.16
		52	Ale Ababa	4.40	4.59	2.71	4.28
Shager city	Geferssa Guje	89	Kolobo	3.95	4.80	1.70	5.06
		9	Bedi	4.04	4.64	2.28	4.17
	Total	610					

RESULT AND DISCUSSION

Trends in Soil Acidity Across Surveyed Areas

As indicated in (Table 2) the soils of West Shoa, Medakegn district (Baro bidaro and Tuye kebeles) showed consistently acidic conditions, with pH values ranging from 4.07 to 4.82 and EA reaching up to 4.15 Cmol (+) kg^{-1} soil. In Jeldu district (Shukute, Wogide kebeles and Tulu bultum) also exhibited notable acidity, with pH values below 4.10 and EA levels between 1.74 and 3.95 Cmol (+) kg^{-1} soil.

Recent assessments in Welmera district (2022–2025) (Haro Boki kebele) indicate the problem of soil acidity, where the pH is from 4.30 - 4.72, EA values reached up to 4.28 Cmol (+) kg^{-1} soil. Similarly, in Geferssa Guje of Shagar city (Kolobo and Bedi kebeles), soil acidity remains a serious concern, with EA values as high as 5.06 Cmol (+) kg^{-1} soil and pH levels as low as 3.95. Bedi has long been known for its vulnerability to acid soils, making these results in ongoing challenges faced by communities in the areas.

Notably, Ale Ababa kebele in South West Shoa also emerged as a hotspot, with EA values ranging from 2.71 to 4.28 Cmol (+) kg^{-1} soil despite moderately acidic pH readings (4.40-4.59), underscoring the progressive nature of soil acidity in the area and highlight the need for continued monitoring and targeted lime interventions. Nedjo (West Wollega), a site with historically severe acidity (pH 3.75 - 4.65; EA 3.64 -7.70 Cmol (+) kg-1 soil), was included as a standard reference.

The data reveals that considering the average value of minimum and maximum EA Nedjo exhibited the highest exchangeable acidity (5.63 Cmol (+) kg-1 soil), followed closely by Ale-Ababa (from Sadan-Sodo), Haroboki (from Welmera) and Shukute (from Jeldu) with exchangeable acidity (EA) 3.50 Cmol (+) kg-1 soil, 3.49 Cmol (+) kg-1 soil and 3.4 Cmol (+) kg-1 soil respectively. These districts fall into the top three acidity classes, indicating a need for immediate soil amendment interventions to reduce acidity and improve fertility. Midakegni, Kolobo, and Wetebecha-Minjaro (Bedi) also show elevated acidity levels, though slightly lower, emphasizing the widespread nature of soil acidity across the area. On the other hand, districts such as Woliso and Welmera (Dufa and Telecho) with much lower EA levels (13.29% and 20.01%, respectively), may require comparatively less intervention. These results underscore the variability in soil acidity levels across the studied locations, which is essential for prioritizing site-specific liming efforts (Figure 2).

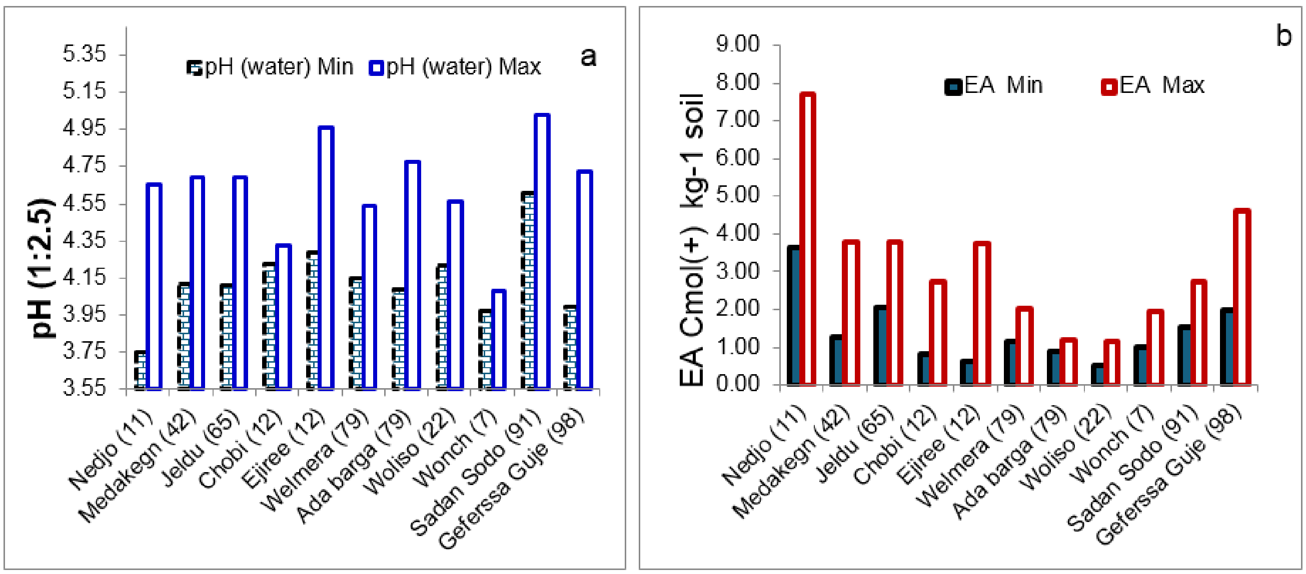

Figure 2. Mean Maximum and minimum pH (a) and exchangeable acidity (b) of the study district in west shoa, south west Shoa and Shager city; numbers in parenthesis next to District indicates number of samples.

Overall, the spatial distribution of soil pH and exchangeable acidity (EA) across the study area reveals persistent acidic hotspots and expanding zones of concern. The alignment of low pH with high EA patterns reinforces the urgency of implementing targeted lime-based interventions and adaptive soil fertility management strategies. Such measures are essential not only to mitigate the adverse effects of soil acidity on crop productivity and soil health, but also to control the further expansion of acid-affected soils and sustain agricultural productivity in the area.

CONCLUSION

The findings from soil acidity assessments conducted between 2018 and 2025 across the Central Highlands of Shoa reveal both persistent and emerging zones of concern. Districts in West Shoa such as Medakegn, Jeldu (Shukute), Welmera (Haro Boki), and South West Shoa (Ale Ababa) consistently exhibited critically low pH and elevated exchangeable acidity (EA), underscoring the long-standing nature of acidification in these areas. Similarly, in Geferssa Guje (Shagar city), soil acidity remains a serious concern in Kolobo and Bedi kebeles, with EA values as high as 5.06 Cmol (+) kg^{-1} soil and pH levels as low as 3.95.

Notably, Bedi has long been recognized as a hotspot for acid soil research, underscoring the persistence and intensity of the issue in these areas. These trends not only validate earlier concerns about the severity of acidity in central Ethiopia but also highlight the area's growing relevance for acid soil research-reducing the need to rely solely on already known acidic nature in western areas as benchmarks like Nedjo. The spatial variability and progression of acidity across districts reinforce the urgency of site-specific soil management strategies. Central Shoa is not less in soil acidity prevalence hence it requires serious intervention including lime and organic matter based integrated amendments and adaptive cropping systems, to mitigate acidification and sustain agricultural productivity.

ACKNOWLEDGEMENT

We express our heartfelt gratitude to Mr. Matiyas Dejene for crafting the districts map using Arc - GIS Maps. Our special thanks also go to Mr. Chala Idao from Holeta Research Meteorology Section for his valuable contribution in extrapolating seven years mean rainfall and minimum/maximum temperature data of each district by using CHIRPS Rainfall data and ERAS temperature data from KNMI Climate Explorer.

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Cite this Article: Fekadu, M; Geremew, T; Yohannis, H/Y; Getahun, D; Temesgen, D (2026). Extent of Soil Acidity in Smallholder Farming Systems of the West and South West Shoa Highlands, Oromia, Ethiopia. *Greener Journal of Soil Science and Plant Nutrition*, 10(1): 1-7, https://doi.org/10.15580/gjsspn.2026.1.080626132.