JOURNAL OF DEGRADED AND MINING LANDS MANAGEMENT
Volume 11, Number 4 (July 2024):6099-6105, doi:10.15243/jdmlm.2024.114.6099
ISSN: 2339-076X (p); 2502-2458 (e), www.jdmlm.ub.ac.id

Research Article

Soil fertility status under different land uses and its management practices in the Bure district of Illubabor zone, southwest Ethiopia

Solomon Tadesse[1*], Tekalign Assefa[2]

[1] Geography and Environmental Education Unit, Addis Ababa University, P.O. Box 1176, Addis Ababa, Ethiopia
[2] Department of Geography and Environmental Studies, Mattu University, Mattu, Ethiopia

[*]corresponding author: solomon.gtadesse@aau.edu.et

Article history:
Received 7 November 2023
Revised 5 April 2024
Accepted 18 April 2024

Keywords:
land use types
soil fertility management
soil properties

Abstract

The study examined soil fertility status under different land use types and its management practices in Bure district of Illubabor zone, southwest Ethiopia. A structured questionnaire survey of 546 randomly selected smallholder farmers was employed to collect data, along with focus group discussions, key informant interviews, and personal observations. In addition, thirty-two composite soil samples were taken at a depth of 0-30 cm from forest, grazing, and cultivated lands to determine soil fertility status. The data were analyzed using ANOVA and descriptive statistics. The findings of the soil analysis showed that the distribution of soil particle sizes, available phosphorus, total nitrogen, soil organic carbon, organic matter, and cation exchange capacity varied significantly ($p<0.05$) between forest, grazing, and cultivated lands. The findings also showed that when land use and cover shifted from forests to cultivated and grazing lands, soil fertility decreased. The pH of the soil under cultivated land was found to be highly acidic, while the soil under forest and grazing lands was found to be strongly acidic. The most widely used soil fertility management practices were the application of miner fertilizer, building of bunds, planting of vetiver grass, contour plowing, crop rotation, straw and mulching, and agroforestry practices. The findings of this study suggest that in highly acidic soils found in cultivated lands, applying an adequate amount of lime can help to enhance soil fertility and boost land productivity.

To cite this article: Tadesse, S. and Assefa, T. 2024. Soil fertility status under different land uses and its management practices in the Bure district of Illubabor zone, southwest Ethiopia. Journal of Degraded and Mining Lands Management 11(4):6099-6105, doi:10.15243/jdmlm.2024.114.6099.

Introduction

Land use and land cover (LULC) change is among the major environmental problems of the world, which lowers soil fertility (FAO, 2016). The conversion of forests to agricultural systems is the most common type of land use change (Siraw et al., 2018). Globally, 13 million ha of forestland has been converted to other land uses per annum (FAO, 2010). The loss of soil fertility due to changing land cover has been emphasized more significantly by research on development and the environment that addresses smallholder farming systems in Africa (FAO, 2014).

Ethiopian highland soils typically have low concentrations of organic matter and important plant nutrients (Siraw et al., 2018). The main factors contributing to the reduction in soil fertility are deforestation, high population density, ongoing cultivation on steep slopes, little vegetation cover, and insufficient soil management techniques (Girma, 2001). The nation's increasing land cover change is making food insecurity, crop yield declines, soil erosion, and reduced soil fertility worse (Gebremedhin and Swinton, 2003). Similarly, a study by Seyoum (2016) found that the primary causes of Ethiopia's low agricultural productivity, declining soil fertility, and food insecurity are converts in land uses, including settlement, open grazing, and the conversion of forest to farmland. Another study done by Campos et al. (2007) reported substantial alterations in soil parameters due to deforestation and the consequent transformation of the area to other land uses.

Several investigations have been conducted to examine how changes in land use affect the physio-chemical properties of soil. For example, Guteta and Abegaz (2016) found that the physical and chemical properties of soils that are consistently farmed can differ from those of land that is left uncultivated for a long period of time. A study by Habtamu et al. (2014) also reported that the cultivated land soils are poor in their fertility status as they have high bulk density, low total porosity, low pH, and very low organic matter and organic carbon content. Mebrate et al. (2022) also reported a decline in soil organic matter and total nitrogen content in central Ethiopia as a result of land use and cover change.

Lower cation exchange capacity (CEC) under croplands was noted in western Ethiopia in comparison to forest soils (Heluf and Wakene, 2006). Another investigation by Siraw et al. (2018) found that soil organic carbon decreased in crop lands as compared to forest and grazing lands. Numerous studies have identified different methods of managing soil fertility that smallholder farmers in Ethiopia use to counteract the decline in soil fertility. For example, agroforestry, crop residue, and organic fertilizer were utilized by farmers to maintain soil fertility, according to a study done in the southwest part of Ethiopia by Guteta and Abegaz (2016). In a related study conducted in southern Ethiopia by Mebrate et al. (2022) found that the most common methods for improving soil fertility and lowering soil erosion were mulching, composting, tillage, and application of mineral fertilizer and farmyard manure.

In Ethiopia's highlands, research on the effects of changing forest land to cultivated and grazing areas, along with an assessment of the soil fertility level beneath various land use types, is lacking despite the well-known consequences of this conversion (Seyoum, 2016). Furthermore, there is currently no scientific information in the study area that is relevant to the problem being investigated. To gain more insight into the condition of the soil under various land uses and the methods used to manage it, this research was undertaken in Bure district of Illubabor zone, southwest Ethiopia. The findings of this study may help policy makers by offering empirical evidence to enhance the productivity and soil acidity in the research site and other areas with comparable agroecological conditions.

Materials and Methods

Site description

This research was undertaken in the Bure district, which is found in the Illubabor zone of southwest Ethiopia (Figure 1). The study area falls within the elevation of 619 to 1,844 m. The landscape is characterized by a rough, uneven topography with a steep slope. The district area is predominantly characterized by mid-low land agroecology, as per Ethiopia's conventional classification of agroecological zones.

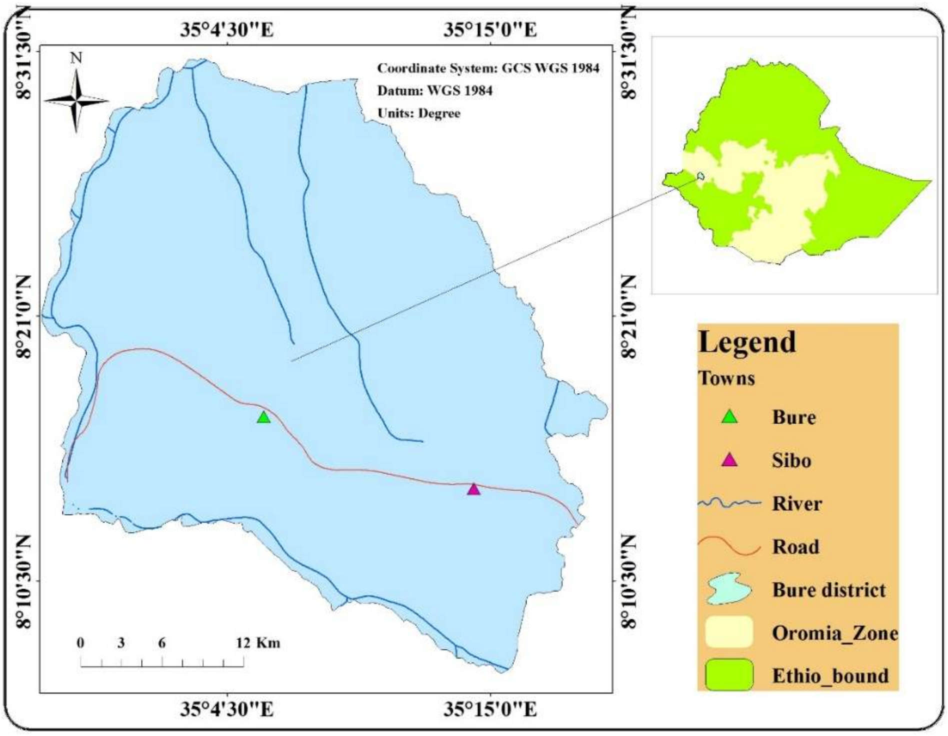

Figure 1. Study area map.

Based on the 2013 Central Statistics Agency population forecast, there are 31,062 women and 30,586 men living in the district, totaling 61,648 people. The area's vegetation is dominated by A*lbizia gummifera, Millittia ferruginea, Sapim ellipticum, Syzygium guineense*, *Acacia lahai* Steud, and *Eucalyptus* spp. The study district's primary soil types are Orthic Acrisols, Calcic Xerosoils, Dystric Nitisols, and Orthnic Solonckaks. Based on 38 years (1983-2021) of rainfall data obtained from Bure Station of the Ethiopian National Meteorology Agency, the area receives 1,450 mm of rain on average each year. The average yearly temperature is 22°C, with 19.7°C for maximum temperatures and 24°C for minimum temperatures, respectively. The main source of income for the community is mixed farming, which blends crop production with animal husbandry.

Sampling procedure and sample size

A two-stage sampling technique was used to select the study district and sample households. First, Bure district was purposely selected among the 14 districts found in Illubabor zone because there is a severe decline in soil fertility. Second, as recommended by Kumar (1999), the sample size was determined using the probability proportional to size technique, which corresponds to a 15% sampling intensity. As a result, 546 smallholder farmers were chosen at random to receive the survey questionnaire (see Table 1). A lottery method was employed for all these random selections.

Table 1. Sampled household distribution by rural *kebeles*.

Rural *kebeles*	Total households	Sample of households
Koture	545	82
Tolikorase	701	105
Doreni Dibi	573	86
Nebomiriga	884	133
Idgetfana	387	58
Megersa	551	83
Total	3,641	546

Socio-economic data collection and analysis

A household survey questionnaire, key informant interviews, focus group discussions, and first-hand observations were all employed to gather data. The survey questionnaire was asked about (a) demographic and socio-economic characteristics (sex, age, family size, education level, ownership of livestock, and farming experiences), as well as (b) techniques to manage soil fertility. The questionnaire underwent pretesting to check its reliability. The researcher selected and trained six enumerators (one from each sampled rural kebele) to help them understand its objective and become familiar with the questionnaire. Enumerators were chosen based on their educational background and prior involvement in relevant research. With an average of eight heads of household, three focus group discussions were conducted. Among the topics covered during focus group discussions were important soil fertility conservation methods and perceived trends in soil fertility decline. In addition, 28 knowledgeable farmers and experts from the district's agricultural office participated in key informant interviews. Experts were chosen on the basis of their prior work experiences. Data analysis was done using SPSS version 23, the Statistical Package for Social Sciences. Descriptive statistics such as percentages and means were employed to compute some demographic and socio-economic variables. The quantitative analysis was supplemented and supported by qualitative data obtained from focus group discussions and key informant interviews.

Soil sampling and analysis

A reconnaissance survey was conducted across the landscape to get an overview of the area and to select soil sampling sites. Soil sampling was taken from forestland, grassland, and cultivated land. In the topmost layer (0-30 cm), a total of 32 soil samples were taken using an auger and a core sampler. Following air drying, crushing, and sifting through a 2 mm sieve, 100 g of each composite sample was sent to the Bedelle Agricultural Research Center's laboratory for analysis. The most significant soil fertility indicator that has been extensively documented in the literature was utilized to assess the fertility of soil under each of the three types of land uses.

The Walkley and Black method (Black, 1965) was used to calculate bulk density. A pH meter was used to measure the pH using a 1:2.5 soil: water ratio, as per Van Reeuwijk's (2002) description. The Walkley and Black rapid titration method, described in Sakar and Haldar (2005), was used to calculate the SOC (soil organic carbon) concentration. Following the determination of organic carbon using the Walkley-Black rapid titration method, as outlined in Sakar and Haldar (2005), SOM (soil organic matter) was computed by multiplying SOC by 1.724. The Micro Kjeldhal method, as detailed in Landon (1984), was used to calculate TN (total nitrogen). Van Reeuwijk (2002) describes the Olsen extraction method that was used to determine the available phosphorus (av. P) content. The ammonium acetate method was used to determine the CEC (Sakar and Haldar 2005). The mean differences in soil parameters among various land uses were determined using Analysis of Variance (ANOVA).

Results and Discussion

Characteristics of the respondents

Table 2 summarizes the major socio-demographic variables for the surveyed households. Male heads accounted for 82.4% of the total respondents, while female heads made up 17.6%. This suggests that compared to female-headed households, male-headed households were more likely to practice soil fertility management. The respondents' ages ranged from 20 to 71 years old, with a mean age of 40.39 years. This suggests that the majority belonged to the age group that is productive. Regarding educational attainment, the majority of respondents (65.3%) were illiterate, meaning they had never attended school, while the remaining 34.7% were literate, meaning they had attended school.

Table 2. General characteristics of the respondents.

Variables	Values
Gender (%)	
Male	82.4
Female	17.6
Education level (%)	
Illiterate	65.3
Literate	34.7
Age (mean)	40.39
Family size (mean)	5.81
Landholding size (mean)	1.71
Farming experience (mean)	16.73
Livestock ownership (TLU) (mean)	6.72

The family size of the households ranged from two to thirteen, with a mean of 5.81, which is greater than the 5.4 regional average family size (CSA, 2016). This indicates that a large family had an excess labor force to move manure, compost, and crop residue from the farm yard to their farms, which may have benefited soil fertility management. This is in line with what Gebremedhin and Swinton (2003) found that adopting labor-intensive soil fertility management was favored in households with a higher number of working-age members. A mean land holding size of 1.71 hectares was determined, with a maximum and minimum of 5 ha and 0.25 ha, respectively. According to CSA (2016), this landholding value was greater than the average for the region, which was 1.45 ha, and the country, which was 1 ha. The average farming experience was 16.7 years. This suggests that farmers with sizable farms have a strong chance of making money by buying inorganic fertilizers, which could improve soil fertility. The average size of a livestock holding was 6.72 Tropical Livestock Units (TLU). This implies that by adding more manure inputs, farmers with larger livestock herds can maintain soil fertility and boost agricultural productivity. Guteta and Abegaz (2016) reported a similar result in southwestern Ethiopia.

Soil fertility status under different land uses

Soil fertility indicators under three various land use types (i.e., forestland, grassland, and cultivated land) considered for this study were presented in Table 3. Results revealed that the proportion of sand particles was higher in the forestland (67.64%) than in grassland (37.67%) and cultivated land (35.64%). On the contrary, the proportion of clay particle size was relatively higher in the grassland (42.36%) than in the grazing and forested lands. The soil of the agricultural land had the highest silt content (42%), while the soil of the forest had the lowest silt content (16%). The difference in sand, clay, and silt soil contents among the three land uses was significant at ($p<0.05$). This is consistent with the results of Siraw et al. (2018), who found a significant difference in soil particles in the northwestern highlands of Ethiopia. Similar results have been reported by Seyoum (2016) in the North Shoa zone of Ethiopia. With regard to textural class, the soil of cultivated land was dominantly loam, whereas grassland and forested land were clay and sandy loam, respectively. In contrast to grazing and forest areas, the pH of the soil was highest in cultivated lands. This indicates that pH in the soil was extremely acidic under cultivated land, whereas it was strongly acidic under forest and grazing lands. Coinciding with the hypothesized assumption, the variations in soil pH values between the three distinct land use types in the soil pH values were notably different at ($p<0.05$). The sub-humid climate and heavy precipitation in the area may be contributing factors to the soil's acidity.

Table 3. One-way ANOVA results of soil properties under various land use types.

Soil properties	Land Use Types			F	p-value
	Forestland	Grassland	Cultivated land		
Sand content (%)	67.64	37.64	35.64	2.19	0.000*
Clay content (%)	16.36	42.36	22.36	2.99	0.000*
Silt content (%)	16	20	42	3.12	0.000*
Textural class	Sandy Loam	Clay	Loam		
Soil pH	5.2	5.1	4.3	2.03	0.000*
Bulk Density (g cm^{-3})	1.03	1.35	1.14	3.26	0.061
Available Phosphorus (ppm)	1.43	0.29	0.27	9.42	0.000*
Soil Organic Carbon (%)	6.88	4.65	2.99	2.11	0.000*
Soil Organic Matter (%)	11.86	8.01	5.15	7.69	0.000*
Total Nitrogen (%)	0.59	0.40	0.26	5.68	0.000*
CEC (cmol(+) kg^{-1})	18.68	17.38	14.28	2.88	0.000*

Note: *indicates significance at $p<0.05$ probability level.

Abdenna et al. (2013) reported a similar outcome in the southwest Ethiopian Highlands. Osman (2013) asserts that areas that receive more rainfall have more acidic soil than areas that are arid or semi-arid. Statistically significant differences in available phosphorous were also found across the three categories of land use. The mean soil organic carbon value varied significantly ($p<0.05$) among the three land use types, with forestland having a higher value of soil organic carbon.

Forestland had higher (11.86%) soil organic matter in comparison to grassland (8.01%) and cultivated land (5.15%), respectively. The increased litter falling from the forest or plantation canopy may be the cause of the higher soil organic matter content beneath forest land. ANOVA analysis revealed that the three land uses soil organic matter content differed significantly at ($p<0.05$). This finding is consistent with Liang et al. (2016), who found greater organic matter content under forest land than other land uses. The findings of this study supported those of Li et al. (2014) and Liu et al. (2021), who found that the soil organic carbon content in forests and grasslands was higher than in cultivated areas. A similar pattern in significant differences was observed among forest, grazing, and cultivated lands for measured total nitrogen content. This result is consistent with the findings of Habtamu et al. (2014), who found that land use had a significant impact on total nitrogen. They found that the mean amount of nitrogen was highest under forestland and lowest under cultivated land, possibly as a result of the high organic matter content under forestland.

In comparison to grassland (17.38 cmol(+) kg^{-1}) and cultivated land (14.28 cmol(+) kg^{-1}), the average cation exchange capacity (CEC) of the soil in forestland (18.68 cmol(+) kg^{-1}) was higher, and this difference was significant at ($p<0.05$). This difference was attributed to biomass cover in the forestland in contrast to other forms of land use. The variations in bulk density among the three different land use types were not statistically significant (Table 3).

Major soil fertility management practices

Farmers use a variety of soil fertility management strategies to boost agricultural productivity, minimize soil erosion, improve soil fertility, and ensure food security. Figure 2 presents the main soil management strategies that have been implemented in the study district. The results of descriptive statistics indicated that most farmers have taken various measures to enhance soil fertility in their farmland. For instance, a significant number (75.5%) of the respondents have practiced planting vetiver grass as soil fertility management.

Discussions with extension agents revealed to address the issue of soil erosion, some non-governmental organizations like the Menschen für Menschen Foundation in the early 1990s and the Ethio-Wetland and Natural Resources Association (EWNRA) since 2005, have been introducing vetiver grass as a solution to reduce soil erosion. Field observations also confirmed that the majority of the farmers planted vetiver grass in their farmland to improve soil fertility and minimize soil erosion.

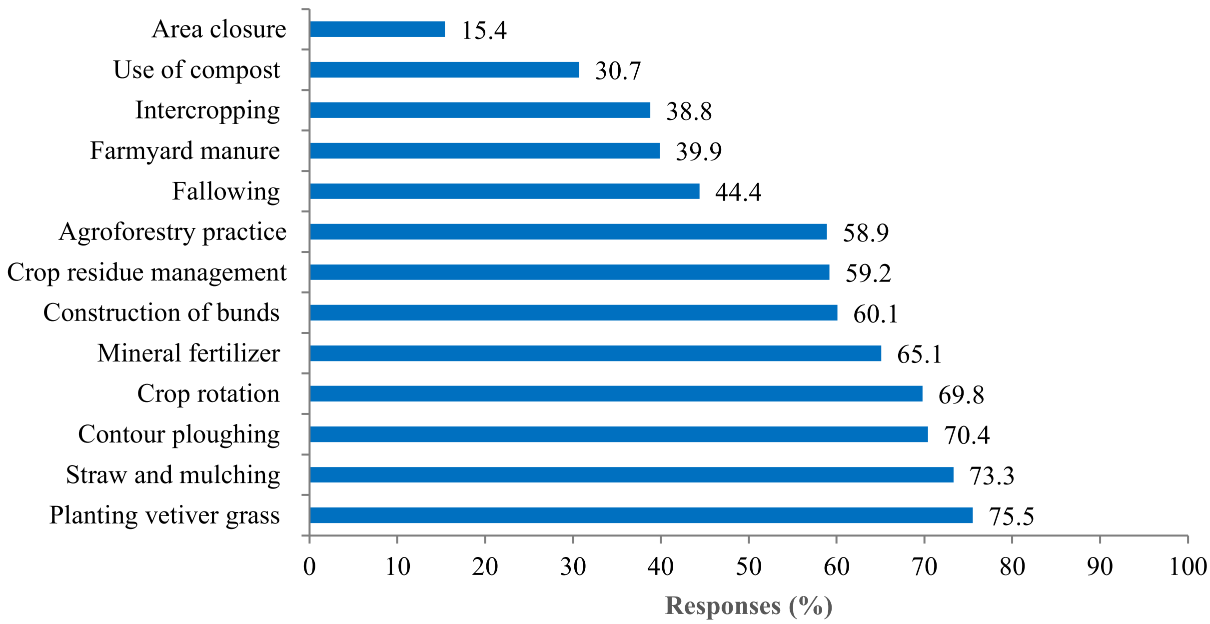

Figure 2. Methods used to manage soil fertility.

Similarly, the majority of farmers (73.3%) increased the soil's fertility by using mulching and straw. Results of focus group discussions and key informant interviews also confirmed that straw and mulching practices are crucial to enhancing soil fertility because soil erosion is one of the main causes of soil nutrient loss and affects soil moisture availability. Discussion with extension agents also revealed that the availability of mulching materials (i.e., vetiver grass, tree leaves, grain straw, and cover crops) in the study area made mulching as one of the most widely practiced to maintain soil fertility. According to a related study by Junge et al. (2009), mulching techniques generally have low labor requirements and are very cost-effective, compatible, simple, and inexpensive to implement. The survey results also revealed that while roughly 60.1% of respondents reported building bunds as a method of managing soil fertility, over 70% of respondents reported using contour plowing.

The results also showed that the majority (69.8%) of respondents managed soil fertility through crop rotation. Sorghum is grown in the study area in rotation with maize, as reported by key informants, which supports this finding. Mineral fertilizer is also widely used in the area by the highest proportion of farmers (65.1%) for improving soil fertility and agricultural productivity. Discussion with key informants and focus group discussants proved that the increase in fertilizer usage was due to a decline in soil fertility in the study area. In the contrary, nearly 39.9% of the respondents tended to use farmyard manure for the enhancement of soil fertility. The use of manure was extremely limited, according to key informants and focus group discussions, as farmers instead used animal dung as a source of fuel rather than fertilizer. Relatively few farmers (15.4%) typically used area closure as a management strategy for soil fertility. According to information acquired from participants, smallholder farmers showed a lower preference for area enclosure because they were unaware of the advantages of uncontrolled livestock grazing practices. Discussions with extension agents also confirmed that farmers have less experience using area enclosures.

Conclusion and Policy Implications

The present study aimed to examine soil fertility status under three different land uses and the methods used for management in Bure district of Illubabor zone, southwest Ethiopia. In addition to soil sampling, key informant interviews, personal observations, focus group discussions, and a structured household questionnaire were employed to gather data. The results of the soil analysis demonstrated that, with the exception of bulk density, the selected soil parameters for this study varied significantly among three different land uses, including forestland, grassland, and cultivated lands. The soil pH value showed that it was extremely acidic under cultivated land while strongly acidic under forest and grazing lands, respectively. Soil organic matter and carbon contents were also very high under forestland; high under grassland but medium under cultivated land.

The results further revealed that the main methods of managing soil fertility that smallholder farmers in the study area used were application of mineral fertilizer, farmyard manure, straw and mulching, fallowing, crop residue management, contour plowing, intercropping, crop rotation, planting vetiver grass, compost, agroforestry practice, building of bunds, and area closure. The following policy implications are forwarded in light of the study's main findings. First, applying calcium carbonates can help to maintain and enhance the fertility of cultivated lands by reducing strong soil acidity, which may be the main barrier to agricultural productivity and production. Second, farmers will be aware of the advantages of integrated management of soil fertility and have encouraged to implement on their own farmlands in order to minimize acidic soils and enhance land productivity. Third, it is highly recommended to incorporate the results of a simple experiment aimed at improving soil fertility within the research area.

Acknowledgments

The authors acknowledge Mattu University for its support in funding this study. We also thank the enumerators and participants for their cooperation. Bedelle Agricultural Research Center also deserves special appreciation for soil laboratory analysis.

References

Abdenna, D., Bikila, B. and Hirpa, L. 2013. Evaluation of soil cations in agricultural soils of East Wollega Zone in Southwestern Ethiopia. *Star Journal* 2(1):10-17, doi:10.4314/star.v2i1.98836.

Black, C.A. 1965. Methods of soil analysis. Part 1 and 2. Retrieved from http://14.139.56.90/handle/1/2061845.

Campos, A., Klaudia, O.L. and Jorge, E.B. 2007. Exploring the effect of changes in land use on soil quality on eastern slope of the cotre de perote volcano (Mexico). *Forest Ecology and Management* 248:174-182, doi:10.1016/j.foreco.2007.05.004.

CSA (Central Statistical Agency of Ethiopia). 2016. Agricultural sample survey report for the year 2015/2016 (Report on land use utilization for private peasant holdings, meher season). Vol. 4. Addis Ababa, Ethiopia.

FAO. 2010. Global forest resources assessment 2010. FAO Forestry Paper 163. FAO, Rome.

FAO. 2014. Status of the World's Soil Resources (SWSR)-Main Report. Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy.

FAO. 2016. Forests and agriculture: land-use challenges and opportunities. Food and Agriculture Organization of the United Nations, Rome.

Gebremedhin, B.G. and Swinton, S.M. 2003. Investment in soil conservation in northern Ethiopia: the role of land tenure security and public programs. *Agricultural Economics* 29: 69-84, doi:10.1111/j.1574-0862.2003.tb00148.x.

Girma, T. 2001. Land degradation: A challenge to Ethiopia. *Environmental Management* 27(6):815-824, doi:10.1007/s002670010190.

Guteta, D. and Abegaz, A. 2016. Determinants of integrated soil fertility management adoption under annual cropping system in Arsamma watershed, southwestern Ethiopian Highlands. *African Geographical Review* 35(2):95-116, doi:10.1080/19376812.2015.1088390.

Habtamu A., Heluf, G., Bobe B. and Enyew, A. 2014. Fertility status of soils under different land uses at Wujiraba Watershed, North-Western Highlands of Ethiopia. *Agriculture, Forestry and Fisheries* 3(5):410-419, doi:10.11648/j.aff.20140305.24.

Heluf, G. and Wakene, N. 2006. Impact of land use and management practices on chemical properties of some soils of Bako area, Western Ethiopia. *Ethiopian Journal of Natural Resources* 8(2):177-197.

Junge, B., Deji, O., Abaidoo, R., Chikoye, D. and Stahr, K. 2009. Farmers' adoption of soil conservation technologies: a case study from Osun State, Nigeria. *Journal of Agricultural Education and Extension* 15(3):257-274, doi:10.1080/13892240903069769.

Kumar, R. 1999. *Research Methodology: A Step-by-Step Guide for Beginners*. SAGE publications Ltd, London.

Landon, J. 1984. Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in The Tropics and Subtropics. John Wiley and Sons.

Li, Y., Han, J., Wang, S., Brandle, J., Lian, J., Luo, Y. and Zhang, F. 2014. Soil organic carbon and total nitrogen storage under different land uses in the Naiman Banner, a semi-arid degraded region of Northern China. *Canadian Journal of Soil Science* 94:9-20, doi:10.4141/cjss2013-074.

Liang, J., Reynolds, T., Wassie, A., Collins, C. and Wubalem, A. 2016. Effects of exotic *Eucalyptus* spp. plantations on soil properties in and around sacred natural sites in the northern Ethiopian Highlands. *AIMS Agriculture and Food* 1(2):175-193, doi:10.3934/agrfood.2016.2.175.

Liu, Z., Shao, M. and Wang, Y. 2011. Effect of environmental factors on regional soil organic carbon stocks across the Loess Plateau region, China. *Agriculture, Ecosystems & Environment* 142(3-4):184-194, doi:10.1016/j.agee.2011.05.002.

Mebrate, A., Zeray, N., Kippie, T. and Haile, G. 2022. Determinants of soil fertility management practices in Gedeo Zone, Southern Ethiopia: logistic regression approach. *Heliyon* 8:e08820, doi:10.1016/j.heliyon.2022.e08820.

Osman, K.T. 2013. *Soils: Principles, Properties and Management*. Springer, Dordrecht, doi:10.1007/978-94-007-5663-2.

Sakar, D. and Haldar, A. 2005. *Physical and Chemical Method in Soil Analysis: Fundamental Concepts of Analytical Chemistry and Instrumental Techniques*. New Age International (P) Ltd Publisher, New Delhi.

Seyoum, B. 2016. Assessment of soil fertility status of Vertisols under selected three land uses in Girar Jarso District of North Shoa Zone, Oromia National Regional State, Ethiopia. *Environmental Systems Research* 5:18, doi:10.1186/s40068-016-0069-y.

Siraw, Z., Bewket, W. and Adnew, M. 2018. Effects of community-based watershed development on soil properties in the Northwestern Highlands of Ethiopia. *Malaysian Journal of Soil Science* 22:19-33.

Van Reeuwijk, L. 2002. *Procedures for Soil Analysis*, Six edition, Technical paper 9. Wageningen, The Netherlands.