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Original Research

# Soil Erosion Hazards and its Implication on Selected Soil Properties at Chancho Watershed of Diga District, Western Ethiopia

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## Abstract

*This study aimed to assess soil erosion dangers and their impact on specific soil qualities in Chancho Watershed, Diga District, and Western Ethiopia. Surface soil samples were collected and analyzed using SAS software. The findings revealed that soil characteristics in the tested areas differed, with clay and clay loam textures present. The study aimed to examine the effects of soil erosion threats on these soil qualities. The soil's amount of organic carbon (SOC) varied from low (2.979%) to moderate (3.121%). The range of the soil reactivity was 5.19 to 5.32 (very acidic). The range of the soil's accessible phosphorus (P) concentrations was low (3.311 ppm) to moderate (10.771 ppm). There was a low (2.157 ppm) to moderate (2.625 ppm) range in available potassium. The soils exhibited a range of catalytic ion exchange capacities, from moderate (28.943 cmol kg1) to high (30.236 cmol kg1). Improper farming practices and soil erosion can negatively impact soil quality. To boost productivity, appropriate reclamation techniques should be employed on low nutrient, CEC, SOC, and acidic soils. To ensure sustainable future generations, appropriate land uses and physical soil and water conservation structures should be implemented based on the land's slope positions.*

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## INTRODUCTION

Transportation of soil particles from one place to another is referred to as soil erosion. The gradient (slope), discharge, and channel geometry affect the erosion and sediment deposition in streams as well as their velocity. Due to both natural and man-made forces, a large portion of the planet has been experiencing progressively severe soil erosion of varying degrees, along with the ensuing environmental degradation. According to Pimentel (2006), a significant worldwide danger to food security and the environment is the decrease in water availability brought on by soil erosion and land degradation. In the highlands of Ethiopia, Kenya, Tanzania, and Uganda in East Africa, there is particularly severe land degradation, particularly in the form of soil erosion, nutrient depletion, and soil moisture stress (Johnes, 2002).

Estimates of soil erosion in Ethiopia's highlands show that approximately 1.5 billion tonnes of topsoil are lost to erosion each year from 2 million hectares of highly degraded land (Jagger and Pender, 2003). (Girma, 2001). The degradation of agricultural land poses a severe threat to both current and future food production, especially in Ethiopia's highlands.

Approximately 45.5% of Ethiopia's GDP, 85% of jobs, and 94% of exports are derived from the country's agricultural sector (NBE, 2002). The main issues confronting the nation are low agricultural productivity and production, rapid population increase, and environmental deterioration. The extreme soil erosion in particular played a major role in the soil's sterility. A decrease in soil fertility is thought to be a major factor in many soils' low production.

A considerable amount of land has been lost in Ethiopia due to soil degradation, which is mostly caused by a number of factors including population pressure, overgrazing and cultivation, deforestation, unsustainable agricultural production, erosive rainfall, and rugged terrain features (EHRS, 1984). In Diga District, farmers cultivate their land without first examining the soil's qualities, and as a result, the area is constantly under stress from overgrazing, deforestation, and continuous agricultural use, all of which cause soil erosion and a decline in soil fertility. The hydrology of many watersheds is significantly altered by soil erosion, and these changes are further exacerbated by social, economic, and political developments (Pimentel, 2000). In order to close the research gap, the relevant data regarding the state of soil erosion dangers and their impact on particular soil qualities at Chancho Watershed, Diga District, and Western Ethiopia were obtained.

In order to make conclusions that will support future biological and physical land management practices in improving erosion control and soil for better productivity and sustainable use of the resources available in the study area, the study set out to investigate the hazards associated with soil erosion and a subset of soil properties.

## METHODS AND MATERIALS

### Description of the study area

Diga District, East Wollega Zone, Oromia Regional State, and Western Ethiopia were the study's locations. The study area is 12 km from Nekemte Town and 340 km from Addis Ababa. Diga District is situated geographically between 8090'3'' and 8061'3 N Latitude and 36030'2 and 36004'6 E Longitude. The district covered an area of roughly 60.131 km^ (59545.413 hectares). There are two biological zones in the study area: lowland, which makes up about 51.4% of the climatic conditions with an annual rainfall range of 1200 to 2100 mm, and mid-land (medium temperate), which makes up about 48.6%. The region's average annual lowest temperature was 180°C, while its average annual high temperature was 32°C. Diga District's soil is classified into three categories according to the global soil classification system. Approximately 54,744.7ha of the Diga District are covered by dystric nitosols, which are among the most fertile soil types. The remaining agricultural portion of the district is made up of orthic acrisols and dystric gleysols. In the midlands, the predominant soil colour was red, whereas in the lowlands, it was black. The Diga District's primary terrain type is almost a slope, with 0–55% of it sloping rather steeply and undulating. The district has excellent agricultural potential due to its abundance of sandy loam, sandy clay, and sandy loam, with percentages of 40%, 30%, 20%, and 10%, respectively (Figure 1).

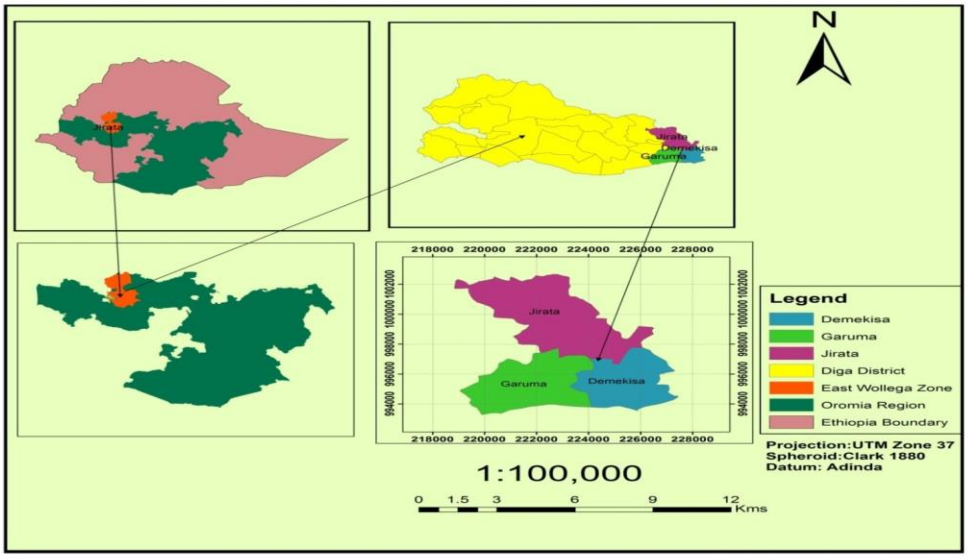

**Figure 1** *Location map of Diga District*

The territory is generally between 1200 and 2220 m above sea level, and it is divided into two agro-ecological zones: the lowlands, which make up 51.4% of the area, and the midlands, which make up 48.6%. The community in Diga district benefits from the abundance of rivers and streams for drinking, irrigation, and other uses. The Didessa River is being used as a recreation area; the Maka and Dimtu Rivers are utilised for small-scale irrigation and provide sand to Nekemte town; and the Chancho River provides drinking water to Nekemte town. Other rivers include Bareda, Sororo, Kiki, Gulufa, and others. The Didessa River receives water from each of these rivers.

The research area's land cover and land use types include built-up areas, grasslands, eucalyptus plantations, water bodies, and barren or degraded terrain. Livestock grazing pastures are located on the steep mountain slopes and streambeds beneath the eucalyptus plantation. These units are naturally covered in grassy shrubs and sporadic trees. The catchment region is dispersed throughout with cultivated land, which makes up the majority of land uses (Figure 2).

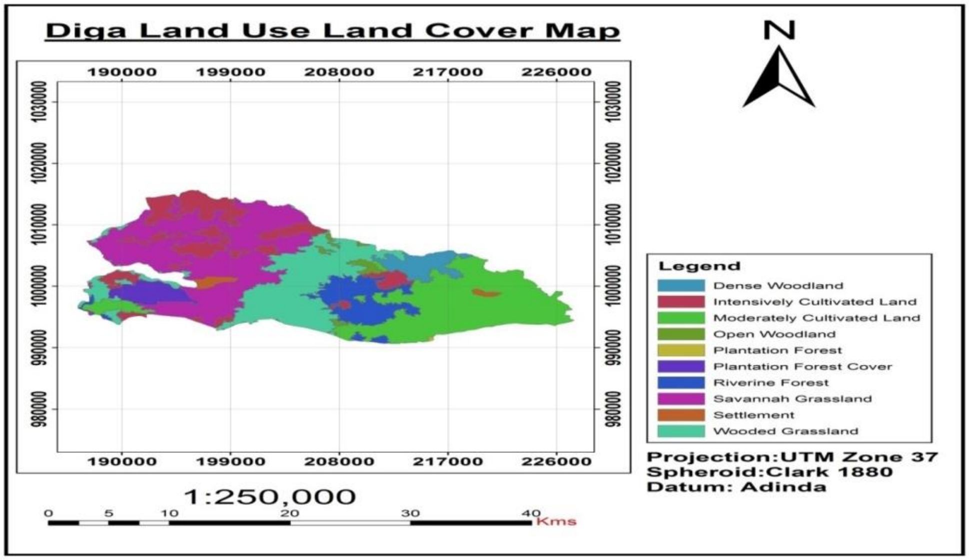

**Figure 2** *Diga District LULC Map*

The three primary agro-ecological zones of Diga District are high land, midland, and lowland, each having a unique proportion. The topography of the Diga District is made up of hills, mountains, and sloping terrain. The midland region grows a variety of significant crops, including barley, wheat, beans, peas, onions, and potatoes. Corn, sorghum, oil crops, bananas, sugar cane, tomatoes, almonds, avocados and mangos are all produced in the lowland region. Cattle, goats, sheep, mules, donkeys, and fouls are the main animals raised in the region (Figure 3).

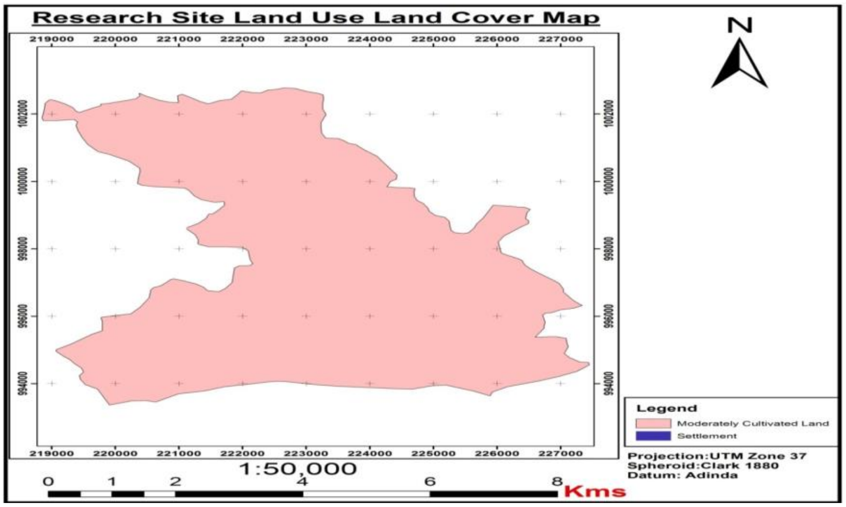

**Figure 3** LULC Map of the study area

## Soil data analysis

For the purpose of analysing the soil's physicochemical properties, the soil samples were air dried, ground with a mortar and pestle, well mixed, and run through a 2 mm screen. The properties that were examined were the organic matter content, soil pH

($H_2O$), CEC, soil texture, and bulk density. The organic matter content was calculated using the black and Walkly titration techniques.

An empirical factor was used in the process of converting carbon to organic matter. After converting organic nitrogen to easily estimated ammonium-nitrogen using the walkly and black titration methods, total nitrogen was ascertained. A spectrophotometer was used to measure absorbance in order to quantify the available phosphorous content of soil samples. A flame photometer measurement was used to find the available potassium. One gramme of dirt and 2.5 distilled water was used to generate a soil suspension solution from which the PH ($H_2O$) of soil samples was measured. ratios of soil to water using a traditional glass electrode metre. Using the ammonium extract method at PH 7.0, CEC was calculated (Mocek et al., 1997).

The mass of a unit volume of soil bulk, including pore space, was used to calculate the bulk density of the soil. Using undisturbed soil cores taken from the soil's surface and a metal cylinder/core sampler (Black, 1965) with a 5 cm diameter and 5 cm height, the bulk density of the soil samples was calculated.

### Statistical Data Analysis

For the purpose of calculating the mean difference for each variable, descriptive statistical analysis was applied to the data gathered from the laboratory test and study of the physical and chemical characteristics of each soil on the upper and lower slopes. After calculating and drawing conclusions, the mean difference between the two variables was determined. Utilising Arc GIS software and one-way analyses of variance, a statistical analysis would be conducted to determine the impact of erosion hazards on soil productivity. Using SAS software, investigations were carried out to find if there was a significant difference in the physicochemical parameters of the soil between the two slopes. In words, figures, and tables, the analysis's ultimate product was interpreted.

## RESULTS AND DISCUSSIONS

### Physical Properties of the Studied Soil Sample

Based on the upper and lower slope gradients, the sample soil's physical characteristics were bulk density, particle size distribution, and texture class (Table 1).

**Table 1**

*Mean values of Bulk density and particle size distribution*

| Land Topography type | BD(g/cm$^3$) | Particle size distribution | | | Textural Class |
|---|---|---|---|---|---|
| | | Sand % | Silt % | Clay % | |
| *Upper slope* | 1.073 | 39 | 23 | 38 | Clay Clay Loam |
| Lower slope | 1.145 | 37 | 25 | 38 | Clay Clay Loam |

The soil samples in the studied areas comprised two different textural classes, as shown in Table 2. These include clay loam (CL) and clay (C) for both the upper and lower slopes of the studied soil. The texture of the soil influenced the root nodulation of the legumes. The finer texture of the soil sample was due to a higher proportion of clay content.

## Bulky Density

The study's findings demonstrate that the interaction between land use and slope had a substantial impact on bulk density; the maximum value (1.145 g/cm3) was found on the surface layer of lower sloped land, and the lowest value (1.073 g/cm3) on the surface layer of upper sloped land (Table 2). The higher OM and lower clay content on the upper slope land may be the cause of the comparatively low soil bulk density on that area. Compaction raises bulky density, whereas an increase in SOM decreases it. Soils with low and high bulky densities have favourable and unfavourable soil physical characteristics. For optimal air and water flow through the soil, low BD dirt (<1.5 g/cm3) is often preferred.

## Chemical properties of the Studied soil Samples

### Carbon (OC) and Total Nitrogen (N)

Table 2 displayed the soils under study's OC, total N, and C:N values. The recommended rating (Tekalign et al., 1991) placed the soil OC contents between low and moderate (2.884%) and 3.215%. The reason for low organic carbon (OC) on the higher slopes may be attributed to intense farming practices and erosion, which greatly reduced the OC content of the soil. In a similar vein, all of the soils in the locations under study had total N levels that ranged from 0.249 to 0.277%, which is low to medium. According to Barber (1984), if soil is categorised according to its total nitrogen content (%), then 0.3–0.4 = high, 0.2–0.3 = medium, 0.1–0.2 = low, and <0.1 = extremely low. The total nitrogen concentration of the soil under study was low and medium. This may be explained by the combination of constant cultivation and intense erosion, which exacerbated OC oxidation and decreased total N. The outcomes support Wakene and Heluf's (2003) findings, which said that constant cultivation and intense erosion pushed OC oxidation and, as a result, decreased total N.

**Table 2**

*Mean Values of Organic carbon (OC) and total nitrogen (N) of the Studied Soils*

| Land Topography type | OC( %) | TN (%) | C:N |
|---|---|---|---|
| Upper Slope | 2.884 | 0.249 | 11.58 |
| Lower Slope | 3.215 | 0.277 | 11.61 |

Soil productivity is probably going to be impacted by a persistent decrease in soil OC content. The soils' C:N ranged from 11.58 to 11.61 as well. In the area under study, the C:N exceeded 10. Gavlak et al. (2003) classified the soils in the areas under study as medium. This suggests that in the locations under study, there is an ideal spectrum for microbial processes including humification and mineralization of organic material.

### Soil Reaction (pH ($H_2O$))

Table 3 shows that the pH (H2O) ranged from 5.19 to 5.32. Jones (2003) states that the soils in the locations under study had severely acidic pH values. The soil is highly acidic if the PH value and related soil reaction are between 5.0 and 5.5.According to Iwara, I., B.S. Gani, J.A. Adeyemi, and E.E. Ewa (2013), the leaching of certain basic cations was the primary cause of the soils' increased acidity. Other likely causes included improper fertiliser application, improper farming practices, and accelerated erosions, which suggested a decline in soil quality (Nega & Heluf, 2013).

There are a lot of exchangeable hydrogen ions present in the soil, as evidenced by the low pH after KCl determination. In comparison to the corresponding pH values measured in KCl solution, the soil pH measured in water was approximately 1.6–1.7 units higher (Table 3). Anon (1993) reported that the presence of weathered minerals and high potential acidity was indicated by high soil acidity as determined by KCl solution.

The pH (pH (KCl) - pH (H2O) values were negative and ranged from -1.6 to -1.7 in every site. A negative pH value, according to Uehara and Gilman (1981), indicates that soils contain net negative charges. Almost all crops will have significant germination problems when EC values are higher than this advised threshold. This has an impact on the crop's growth and yield, which is significantly decreased.

**Table 3**

*Mean Values of Soil pH of the Studied Soils*

| Land topography type | pH($H_2O$) | pH($CaCl_2$) | pH(KCl) | ∇pH($CaCl_2$) | ∇pH(KCl) |
|---|---|---|---|---|---|
| Upper Slope | *5.19* | *3.953* | *3.596* | *-1.2* | *-1.6* |
| Lower Slope | *5.32* | *4.013* | *3.650* | *-1.3* | *-1.7* |

### Available Phosphorus, Available Potassium, SOM and Cat ion Exchange Capacity

Enhancing soil structure and raising the soil's ability to hold water and nutrients are two advantages of having organic matter in the soil. Soil biology also receives nourishment from organic materials.According to the examination of the soil organic matter content, soil samples from the field with the lower slope had a higher mean value (5.543%) for soil organic matter, indicating that these samples had a substantial influence on preserving and enhancing the soil organic matter content (Table 4). The results corroborated those of (Black 1965, Pimentel, 2000, Onemli, 2004), who noted that enhanced soil organic matter (SOM) is crucial for enhancing soil physical characteristics, preserving water, and augmenting nutrient availability. The mean amount of organic matter (4.971%) was much lower in the fields with higher slopes (Table 4).

**Table 4**

*Mean Values of Available phosphorus, Available potassium, SOM and cat ion exchange capacity*

| Land Topography type | P (ppm ) | K (ppm) | SOM(%) | CEC (cmol kg -1) |
|---|---|---|---|---|
| Upper Slope | 3.626 | 2.468 | 4.971 | 28.943 |
| Lower Slope | 10.456 | 2.313 | 5.543 | 30.236 |

The higher mean percentage of SOM content on lower slopes may be caused by extensive runoff from upper slope lands to lower slopes, which adds organic matter to the gentle and level slope soil, as well as the lack of soil physical structure conservation. The results corroborated those of Gardner & Miller (2004), who said that organic matter in soil refers to plant and animal remains at different stages of decomposition. OM tends to stabilise and be retained more in soils with a relatively higher clay content than in soils with a lower clay content (Ladd, 1990).

However, there are a number of practices that degrade soil quality, including burning crop leftovers, clearing crop residue after harvest, cultivating on steep slopes that increase erosion, and continuously tilling the soil, which makes it more loose and vulnerable to erosion. Because SWC techniques increase and preserve the amount of organic matter in the soil, they consequently contribute significantly to better soil quality. Along with boosting soil organic matter and soil structure, greater infiltration also enhances ground water recharge, which raises well supplies. These factors all work together to promote soil drainage, aeration, water holding capacity, and soil infiltration of water. Greater biomass and agricultural productivity should result from these advancements in the end (Black 1965, Pimentel, 2000, Onemli, 2004).

For the higher slope, the available P mean value varied from 3.626 ppm to 10.456 ppm. The accessible P levels of the soils varied from low to high, according to Cottenie (1980). Because of the high soil organic matter (OM) level, the lowest slope likely has the maximum accessible phosphorus. By desorbing P from the adsorption site through a ligand exchange process with the organic ligands, the OM affects P in the soil solution.

In the top slope, the lowest mean value of P that was available was noted. This might be the result of the soil's natural P shortage and the advantageous acidic soil reaction that fixes P with Fe and Al. Similar to this, in acidic soil conditions, P easily forms insoluble complexes with cations like iron (Fe) and aluminium (Al), which accounts for its limited availability. Stone, C.U., D. Allan, and C.P. Vance (2003).

The analysed sites differed in terms of available K (Table 4). The site's lower slope had the lowest available K, whereas the higher slope had the greatest possible K. Tekalign et al. (1991) recommended ratings, which ranged from low to extremely high status for the exchangeable K. The findings went against the widely held notion that Ethiopian soils are high in K for arable land. Since weathering, intense farming, and the use of acid-forming inorganic fertilisers on acid soils change the distribution of K in the soil systems and enhance its depletion, previous research results support the findings (Saikh, 1998). The application of home wastes such as ash and livestock dung was found to be responsible for the highest concentration of accessible potassium under the higher slope soil. since this location is a cultivated place for food crops.

Table 4 displays the mean value of cation exchange capacity (CEC), which varied between 28.943 and 30.236 cmol kg-1 of soil. The values increased with decreasing slope. As to Hazelton and Murphy's (2007) findings, the CEC of the soils in the locations under investigation varied from low to high. The lowest percentage of clay (38%) and largest percentage of sand (39%) in the soil may be the cause of the upper slope's low CEC. Their low level of organic matter (OM) may be the secondary cause, if this is the primary one. Consequently, the CEC has decreased due to OM depletion brought on by intensive farming, which is consistent with earlier research (Chimdi et al., 2012).

## CONCLUSION

The risks of soil erosion on particular soil qualities within the research region were examined in this investigation. Variations in soil qualities may be caused by changes in the soil's acidity, alkalinity, availability of nutrients, and management techniques. The findings also demonstrated the high acidity of the soils in the investigated sites. Low levels of total nitrogen, SOM, and percent organic carbon were found in soil samples from the higher slopes. The erodibility of nutrient-rich soil from upper sloped lands to lower sloped lands (flat sloped fields) is the reason of this variance. As a result, the study suggests that severe soil erosion affects soil qualities in addition to other ways. Applying organic wastes to agricultural areas as a significant source of nutrients is beneficial. Applying fertilisers rich in phosphorus when needed by a particular crop can enhance soils ranging from low to high in phosphorus. For sustainable agriculture, more research must be done on the microbial activity, plant nutrition, and chemical characteristics of the soil.

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## DECLARATION

The authors declare that there is no conflict of interest.

## DATA AVAILABILITY STATEMENT

All are available from the corresponding author upon request.

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