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International Soil and Water Conservation Research ∎ (∎∎∎∎) ∎∎∎–∎∎∎

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International Soil and Water Conservation Research

journal homepage: www.elsevier.com/locate/iswcr

Original Research Article

Soil and water conservation effects on soil properties in the Middle Silluh Valley, northern Ethiopia

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ARTICLE INFO

Article history:
Received 16 March 2017
Received in revised form
22 June 2017
Accepted 29 June 2017

Keywords:
Land degradation
Soil and water conservation
Soil properties
Middle Silluh Valley
Ethiopia

ABSTRACT

Community-based Soil and Water Conservation (SWC) practices have been adopted in the Tigray region since 1991 for restoration of the degraded landscape. The effects of those conservation measures on physico-chemical properties of soil were limitedly studied. Thus, this study evaluated the effects of SWC on selected soil properties in the Middle Silluh Valley, Tigray region, Northern Ethiopia. The study considered conserved landscapes (terraced hillside, terraced farmland and exclosure area) and non-conserved landscapes (non-terraced hillside, non-terraced farmland and open grazing land) for comparison using a one-way analysis of variance (ANOVA). A total of 24 samples were collected from each landscape at a depth of 10–30 cm. The results indicated that mean bulk density (BD) was low on terraced hillside, non-terraced hillside and exclosure area. Sand and clay content were significantly different at $P < 0.05$ for the six landscape categories. Higher mean organic matter was observed in the conserved landscape, as compared with the corresponding non-conserved landscape. Pearson's correlation between Soil Organic Matter (SOM) and clay content, SOM and Total Nitrogen (TN) showed strong positive relationships. Overall, the results show that SWC had significantly positive effects on soil's physical and chemical properties in the study area.

1. Introduction

Land degradation is a major problem in Ethiopia. It has a negative impact on agricultural economy and the natural environment Taddese (2001) clearly explained that the major causes of land degradation in Ethiopia are the rapid population increase, soil erosion, deforestation, low vegetative cover and unbalanced crop and livestock production.

Similar idea was also reported by Bishaw (2001), Negusse, Yazew, and Tadesse (2013) that the rapid population growth, improper land resource management and utilization are the principal causes of increased runoff and soil erosion in the country which resulted in declining agricultural productivity, water scarcity and continuing food insecurity. The fertility of soil could be diminished through time due to land degradation. Moreover, Damene, Tamene, and Vlek (2013) addressed that the inappropriate agricultural practices and conversion of marginal land into cultivation and grazing land have led to severe land degradation in the Ethiopian highlands.

Land degradation increases vulnerability of people to the adverse effects of climate variability and change, by reducing Soil Organic Carbon (SOC) concentration and water holding capacity, which in turn reduces agricultural productivity and local resource assets (Mengistu, Bewket,& Lal, 2015; Damene et al., 2013; Pender, Ringler, Magalhaes, & Place, 2012). In order to solve such degradation problem, the Regional Government of Tigray in collaboration with some other non-governmental organizations like Gesellschaft Für Internationale Zusammenarbeit (GIZ), World Food Pprogramme (WFP), Relief Society of Tigray (ReST), Adigrat Diocesan Catholic Secretariat (ADCS) have developed strategies to work hand in hand with local communities on many SWC measures such as, construction of soil bund, stone bund, runoff control, and water harvesting structures, setting aside exclosure areas and nutrient management.

It has been addressed by many researchers such as Gebreegziabher et al. (2009), Gebremichael et al. (2005), Nyssen et al.

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Peer review under responsibility of International Research and Training Center on Erosion and Sedimentation and China Water and Power Press.

http://dx.doi.org/10.1016/j.iswcr.2017.06.005
2095-6339/

Please cite this article as: Hishe, S., et al. *International Soil and Water Conservation Research* (2017), http://dx.doi.org/10.1016/j.iswcr.2017.06.005

(2007) that in order to minimize land degradation and restore degraded landscapes, a lot of efforts have been done in Ethiopia through SWC measures. It has been addressed by Bewket and Stroosnijder (2003) that local level investigation is essential to design area-specific and appropriate rehabilitation and management interventions. Within a broader context of understanding land degradation and SWC, the specific objectives of the present research paper are: (1) to evaluate the physico-chemical properties of soil; (2) to compare the two situations of conserved and non-conserved landscapes impacted by SWC measures. Hence, the effectiveness of such intervention on improving the fertility of soil biophysical and chemical properties shall be studied for better recommendation to policy makers.

2. Materials and methods

2.1. Study area description

The study was carried out in the Middle Silluh Valley (MSV), northern highlands of Ethiopia with an area coverage of 490 km^2. According to the local agro-ecological classification system which mainly relies on altitude and temperature, the study area is characterized by *Woynadega* (midland) and *Dega* (highland) (Mengistu, 2006). The River Sulluh flows in the middle of the study area in a north-south direction. The Middle Silluh Valley has an altitudinal range of 1818–2744 m.a.s.l. Within the study area, 28 lower administrative units, locally called "*Tabia*" were situated from Kilte_Awulaelo, Saesie Tsaeda Emba and Hawzen districts. Out of the 28 *tabias*, only 15 *tabias* are fully situated within the basin and the remaining have 50% or more of their territory. Mean annual rainfall from three stations for the period 2006–2015 is 536 mm and the minimum and maximum mean annual temperature are is 10.7 °C and 26.6 °C respectively. The dominant soils are Cambisols (moderately developed soils); Luvisols (evidence with accumulation of clay/organic matter); and Leptosols (highly calcareous material). The slope gradient of the study area also ranges from flat ($<0.2\%$) to very steep ($>60\%$). The study area is characterized by semi-arid environment where farmers dominantly produce wheat, barely, *kerkaeta* (mixed of barley and wheat), *Eragrostis tef,* millet and beans. The predominant economic activity of the inhabitant is subsistence agriculture.

Monthly rainfall is high in the months of July and August in all the three stations. On the other hand, January and February are driest months. May and June are the hottest months (Fig. 2).

2.2. Soil Sampling and data collection

Soil samples were collected from 24 sample sites in August 2016 (Fig. 1). Different soil sampling method have their own advantages and drawbacks Landon (1984). suggests judgment sampling for selection of typical sites is feasible to represent large areas. Accordingly, we used judgment sampling to take representative soil samples from conserved and non-conserved sites. The sites were four each from terraced hillside, non-terraced hillside, terraced farmland, non-terraced farmland, open grazing land and exclosure area. After removing the first 10 cm topsoil to exclude the presence of nematodes. Soil samples were taken using augur from 10 to 30 cm depth. One kg of soil from each sample site was packed in a plastic bag for laboratory analysis. In order to determine soil moisture content later in the lab, 200 g soils were collected from each sample site and measured on scale in-situ. Moreover, for determination of bulk density, 24 undisturbed soil samples were collected using core samplers. In characterizing the sample sites, we followed a similar approach as in Abegaz, Winowiecki, Vågen, Langan, and Smith (2016); Winowiecki (2015) and recorded information about land use, average gradient, human influence and types of SWC structures.

2.3. Laboratory analysis

The soil samples were air dried, crushed and sieved through a 2 mm mesh sieve for analysis. The soil properties considered in this study were Soil Organic carbon (SOC), Soil Organic matter (SOM), total nitrogen (TN), pH, texture, bulk density, exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}), available phosphorus (av. P), percentage base saturation (PBS), and cation exchange capacity (CEC). The analysis for exchangeable cations, CEC and avail. P were done at Department of Earth Sciences whereas the remaining parameters were analyzed at the Department of Land Resources and Environmental Protection (LaRMEP) soil laboratory unit, both at Mekelle University.

Bulk density was determined using the Walkley and Black method (Black, 1965) method. Soil pH and texture were determined using the glass electrode and hydrometer method as suggested by Van Reeuwijk (2002), Haldar and Sakar (2005), respectively. Soil Organic Matter (SOM) was calculated by multiplying SOC with a factor of 1.724 after determining the organic carbon using Walkley-Black rapid titration method as described in Haldar and Sakar (2005). Total Nitrogen (TN) was determined by the Micro Kjeldhal process as described in Landon (1984). The determination of available Phosphorus (P) was made using the Oslen et al. (1954) method as described in Van Reeuwijk (2002). The measurement of individual exchangeable cations (Na^{+}, K^{+} Ca^{++}, and Mg^{++}) and Cation Exchange Capacity (CEC) was done by adding 1 M ammonium ethanoate (acetate) solution at pH 7 as suggested by Haldar and Sakar (2005), Rowell (1994).

2.4. Data analysis

The different physical and chemical properties of soil samples mentioned as a dependent variables and landscape category as independent variable were statistically tested. From each six landscape function, four samples were taken for the computation. Analysis of variance (ANOVA) using the Statistical Package for Social Scientists (SPSS 20) to evaluate whether significant difference exists among the landscape categories or not as the data contains more than two factors. Therefore, the ANOVA test using Post Hoc Test of Least Significance Difference (LSD) at alpha value of 5% was applied in the analysis. The mean difference is calculated by subtracting the mean of one landscape category from the mean of other respective landscape categories under a given dependent variable.

3. Results and discussion

3.1. Soil physical properties

The soil physical properties were different under different landscape categories (Table 1). Mean bulk density (BD) was low in the terraced hillside, non-terraced hillside and exclosure area. SMC, BD, sand, silt and clay contents were significantly different under different landscape categories.

A one-way analysis of variance (ANOVA) was conducted to explore the impact of different landscape category (conserved and non-conserved types) on soil physical property parameters (Bulk density fertility, soil moisture content, sand, silt and clay content) status. For the sand content, there is statistically significance difference at $P < 0.05$ level for the six landscape groups: $F(5, 23) = 4.179$, $P < 0.05$. Similarly, for the clay content, there is statistically significance difference at $P < 0.05$ level for the six landscape