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Evaluation of different soil moisture conservation structures in selected moisture stressed dry lands areas of Halaba, Southern Ethiopia

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Abstract

Land degradation is serious global environmental problem affect land productivity. The decline of land productivity posed a negative impact on the individual and the economy of the Ethiopia as a whole. Land degradation had a serious impact on farmer's livelihood of wera district due to inappropriate land use and land management practices. Construction of physical SWC structures is crucial option to improve soil moisture status and other soil properties that increase land productivity. The experiment was conducted for three consecutive years in moisture conservation structures in moisture stressed dry area of Southern Ethiopia. The evaluation were made on four treatments physical SWC structures; micro basin, eyebrow basin, micro-trench and traditional pit. The treatments are replicated three times. Soil samples before and after the trial, soil moisture conservation and test tree data were collected for analysis. Except pH and soil texture some soil properties like; TN, P, OM, OC showed an improvement due to the SWC structures implementation. In the first year of trial there was no significant difference was observed soil moisture, plant height and collar diameter. In the second year of the trial highly significant variation at ($p<0.05$) was observed in soil moisture conservation percent. Micro-trench conserved the higher percent of moisture than other structures. In the third year only plant height show significant difference, but the others were not statistically significant. The result depicts that implementation of physical SWC structures are very important to conserve soil moisture at dry areas. Therefore, all stake holders should practice construction physical structure integrated with tree for land rehabilitation and alleviate soil moisture stress.

Keywords: Land degradation; SWC structures; Soil moisture stress; Soil moisture conservation

Introduction

Globally, one-third of agricultural soils were reported as being affected by soil degradation of which water and wind erosion account 56 and 28% of the observed damage, respectively [1]. Land degradation due to erosion processes incurs substantial costs both for individual farmers and society as a whole. Land degradation process occurs slowly, causing long lasting impacts on rural population who become increasing vulnerable [2]. Estimates showed that about 85% of land attenuation globally is because of soil erosion reducing crop productivity by about 17%, affecting the soil fertility initially and in the long term resulting in land desertification [3].

Land degradation can occur due to intensive crop cultivation, deforestation, excessive tillage for land preparation, overstocking and overgrazing both pasture and cropland, shifting cultivation without adequate fallow periods, absence of soil conservation practices and overuse of certain cattle routes and watering points [4]. The immediate impact of land degradation has reduced crop yield and productivity [5].

Soil moisture is one of the determining factors of the stress or health on land surface ecosystems and managed systems such as those in agriculture. Plant growth and crop yield are closely related to the amount of moisture available during the growing season.

The variation in soil water content is influenced by a number of factors; such as soil properties (soil texture, structure, organic matter, depth, density and salinity), climate (precipitation, solar radiation, temperature, etc.), topography and land cover [6]. These influencing parameters can regulate permeability, infiltration, water holding capacity and moisture loss rates. Currently, the practices like; crop type choice, agronomic practices, input fertilizers application and irrigation management practices are expected to vary the dynamics of soil moisture [7] due to their impacts on the physical and bio-geochemical interactions within ecosystems [8].

To alleviate moisture stress and land degradation problem, soil and water conservation practices were initiated in Ethiopia during the 1970s and 1980s [9]. The basic need of the initiatives was to minimize soil erosion risk, restore soil fertility status, reclaim degraded land, and increase agricultural productivity (Mekuria et al., 2007).

Wera district is characterized as moisture stressed dry land area, due to its high temperature, erratic rainfall pattern and low soil water holding capacity. The is also characterized by intensive and frequent tillage practice, overgrazing, deforestation, limited number of enclosures and less SWC (soil and water conservation) practice that exacerbate soil moisture deficiency and cause land degradation (Wera, district, 2020).

Many research findings by different authors argue that SWC measures are effective for soil management [10]. Some of them argue that SWC contributes for runoff reduction and sediment deposit [11] and increased soil moisture conservation [12,13]. So, this study was done to with the objectives; to compare and select best physical moisture conservation technique, to show the effect of different conservation structures on moisture conservation and tree growth.

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Materials and Methods

Study area description

The experiment was laid out at Wera district located in Halaba Zone. The district is located in 86 km far away from Hawassa Town, Southern nation's nationalities and peoples region (SNNPR) capital and 310 Km far from Addis Ababa, Capital of Ethiopia. Geographically the district is located in 37 0 58'0''E to 38 0 13'30''E and 7 0 14'30''N to 7 0 26'30''N. The elevation ranges from 1700 to 2150 m above sea level. The income for majority of the people in the area comes from agricultural practice. The major growing crops on the area includes pepper, teff, sorghum, wheat, maize and common bean.

Treatments and experimental design

Treatments the treatments evaluated were

1. Micro basins with tree planting holes.

2. Eye-brow basins with tree planting holes.

3. Micro trenches with tree planting holes.

4. Only traditional tree planting without any supportive structure. Gravillea robusta seedling was planted behind each structure to evaluate impacts of structures on tree growth.

Experimental design

The treatments were arranged in RCBD (completely randomized block design) with four replications. Each treatment had three structures arranged in staggered manner. The diameters and foundation of the structures excluding traditional pit were 2m and 20cm respectively. The width and depth for traditional planting pit were 40cm and 50cm respectively. The trenches had length of 2m, width of 0.5 and depth of 0.5m. The inter space between blocks were 1.5m.

Data collection and analysis

Data collection

Sixteen (16) soil samples were collected before and after the trial to evaluate the impact of the moisture conservation structures on soil physico-chemical properties. The soil moisture content data were collected within each tree month's interval. The tree data; like tree height, above ground biomass, collar diameter of seedling, seedling survival and performance were collected with four months interval. The structures construction work and soil samples collection were done during dry season. But, tree planting were undertaken during wet season. In other way, soil moisture data were collected after rainfall event within three months interval.

Statistical data analysis

The collected soil sample before and after the trial were analyzed at Hawassa Agricultural Research Center Soil laboratory. Soil moisture was determined by removing soil moisture by oven-drying a soil sample until the weight remains constant. The soil moisture content (%) was calculated from sample weight measured before and after oven drying for each sample. This was done to know and compare soil moisture conservation between treatments. The tree height, above ground biomass, collar diameter of seedling, seedling survival and performance were analyzed to evaluate the performance and growth status between the treatments. Finally, all data were analyzed using R-Software package. LSD (least significant difference) was used to depict data mean difference between treatments and the statistical analysis process was employed following standard procedures applicable for RCBD (Randomized complete block design).

Result and Discussion

Soil properties of soil before and after the experiment The average pH, OC (%), OM (%), TN (%), P (ppm) of the study area before the trial was; 7.47, 1.42, 2.97, 0.13 and 16.43 respectively as shown on table 1. The average composition of clay, silt and sand were 17.33%, 24% and 58.67% respectively. According to USG soil textural class classification, the experimental site was dominantly categorized under Sandy loam textural class.

According to the table 2 shown below the average soil property values of OC, OM, TN and P after the trial were 2.0 %, 3.5 %, 0.21 % and 23.12 ppm respectively. This result conveys that physical soil and water conservation structures poses an impact for the improvement of above listed soil properties like; organic carbon, organic matter, total nitrogen and phosphorus contents of the soil compared with the analysis result before the structures establishment. But, the percent composition of texture and pH value cannot show any change due to the structures construction. This is because the impact of physical soil and water conservation structures requires long time to show improvement on soil texture and pH value.

Where: SMC = Soil moisture content dry base (%)

Ww = Weight of the wet soil (gm)

W d = Weight of the dry soil (gm)

In 2 nd experimental year there was no significant variation of plant height, soil moisture content and collar diameter data between replications. Similarly, there was no significant difference of plant height and collar diameter data between treatments. But, highly significant variation was observed in soil moisture content between treatments as shown on table 4.

According to 3 rd year data shown in table 5, there was no significant variation between replications. Except collar diameter data, the significant variation was observed on both plant height and soil moisture content data between treatments.

Soil moisture conservation level and tree growth data between physical structures (treatments)

In the first year of the trial there was no statistical significance difference between treatments for soil moisture, plant height and collar diameter. This is because physical structures cannot show immediate effect on the soil as well as the test tree in their construction year.

In the second year of the trial statistically significant difference was observed between treatments for soil moisture content, but test tree

Table 1: Soil properties before the experiment.

Samples						Soil texture			
	pH(1:2.5) in H2O	OC (%)	OM (%)	TN (%)	P (ppm)	% clay	% silt	% sand	Textural class
Sample one	7.51	1.05	3.5	0.09	17.0	14	28	58	Sandy loam
Sample two	7.55	1.58	3.3	0.14	15.9	10	32	58	Sandy loam
Sample three	7.35	1.63	2.1	0.15	16.12	28	12	60	Sandy clay loam
Average	7.47	1.42	2.97	0.13	16.34	17.33	24.0	58.67	

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Table 2: Soil properties after the experiment.

Samples						Soil texture			
	pH(1:2.5) in H2O	OC (%)	OM (%)	TN (%)	P(ppm)	% clay	% silt	% sand	Textural class
Sample one	7.51	2.25	3.9	0.2	21.25	14	28	58	Sandy loam
Sample two	7.55	2.25	3.9	0.25	24.65	10	32	58	Sandy loam
Sample three	7.35	1.5	2.59	0.18	23.45	28	12	60	Sandy clay loam
Average	7.47	2.0	3.5	0.21	23.12	17.33	24.0	58.67	

Table 3: Mean square of plant height moisture content and collar diameter variation between replications ant treatments of experiment at Wera district in 1st experimental year.

Source	DF	Plant height	Moisture content	Collar diameter
Replication	2	0.05561 ns	0.0053 ns	0.00000863 ns
Treatments	3	0.02533 ns	50.5***	0.00000506*
Error	6	0.00664	1.0356	0.00000064
Total	11			
CV		13.07	6.51	14.96

CV= Coefficient of variation; DF= degree of freedom; ***= highly significant variation; *= depicts significant variation.

Table 4: Mean square of plant height soil moisture and collar diameter at Wera district in 2nd year.

Source	DF	Plant height	Moisture content	Collar diameter
Replication	2	0.02257 ns	2.527ns	0.000001726 ns
Treatments	3	0.57063 ns	168.008***	0.000001726 ns
Error	6	0.1663	0.157	0.000001726 ns
Total	11			
CV		21.16	1.03	23.76

CV= Coefficient of variation; DF= degree of freedom; ***= highly significant variation.

Table 5: Mean square of plant height soil moisture and collar diameter at Wera district in 3rd year.

Source	DF	Plant height	Moisture content	Collar diameter
Replication	2	0.03626ns	18.5984ns	0.000001067ns
Treatments	3	0.33736***	99.2672***	0.000002530ns
Error	6	0.00131	0.5242	0.000001463
Total	11			
CV		1.52	1.64	

CV= Coefficient of variation; DF= degree of freedom; ***= highly significant variation.

Table 6: Average soil moisture and test tree data of the trial at Wera district in 1st experimental year.

Treatments	Soil moisture (%)	Plant height(m)	Collar diameter(mm)
Micro basin	19.733 a	0.5433	b
Eyebrow basin	18.31 a	0.55 b	4.5 b
Micro-trench	13.667 b	0.67 ab	7.17 a
Traditional pit	10.863 c	0.73 a	4.33 b
$LSD_{(0.05)}$	ns	ns	ns

Note: values followed by the same letter are not significantly different at p<0.05. LSD= Least significant difference.

data couldn't show significant difference as shown on table 7. Micro-trench conserved high percent of soil moisture compared with other treatments. But, the lowest soil moisture was conserved by traditional pit.

In the third year of the trial statistically significant difference was observed between treatments for only plant height and for the insignificant difference was observed as shown on table 8. Accordingly,

Table 7: Average soil moisture and test tree data of the trial at Wera district in 2nd experimental year.

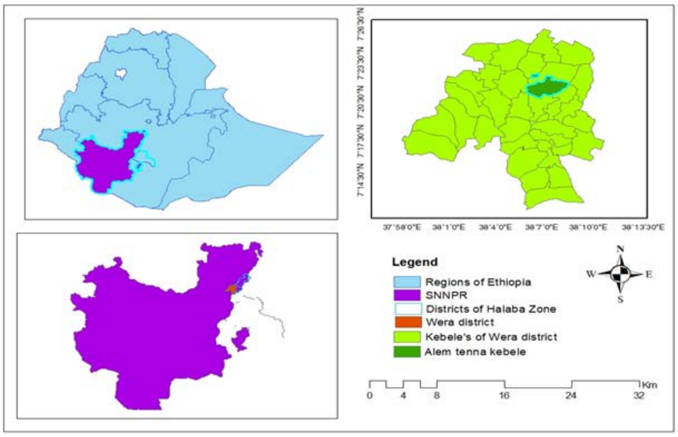
Treatments	Soil moisture (%)	Plant height(m)	Collar diameter(mm)
Micro basin	39.43 b	2.0667 a	8.67 a
Eyebrow basin	34.57 c	1.9 ab	8 a
Micro-trench	48.427a	2.3933a	6.93 a
Traditional pit	31.207d	1.35 b	5.47 a
$LSD_{(0.05)}$	6.81*	ns	ns

Note: values followed by the same letter are not significantly different at p<0.05. LSD= Least significant difference.

Table 8: Average soil moisture and test tree data of the trial at Wera district in 3rd experimental year.

Treatments	Soil moisture (%)	Plant height(m)	Collar diameter(mm)
Micro basin	42.25 b	2.5767 b	8.9 a
Eyebrow basin	41.213 bc	2.32 c	9.1 a
Micro-trench	52.633a	2.7033a	10.7 a
Traditional pit	40.267c	1.9433 d	8.6 a
$LSD_{(0.05)}$	ns	7.035125	ns

Note: values followed by the same letter are not significantly different at p<0.05. LSD= Least significant difference.



the test tree got highest height on micro-trench, but the lowest plant height was observed on traditional pit. This is because micro trench conserved highest percent of moisture content, but the traditional pit conserved the lowest moisture content even though the variation is not significant.

The available data of three years data were not analyzed combined in combined form. This is because there was significant variation of data between years, due to rainfall pattern variability and temperature difference between experimental years.

Conclusion and Recommendation

Construction of small physical SWC (soil and water conservation) structures is an important option to improve soil moisture and better tree growth, through harvesting runoff water. This study showed that the four evaluated physical soil and water conservation structures were important for soil moisture conservation, tree growth and degraded area rehabilitation as a whole. In addition to improving soil moisture the measures had a positive impact on improving other soil physic-chemical properties. The highest percent of soil moisture was conserved by micro-trench, followed by micro basin and eyebrow basin. But, the lowest percent was observed on traditional pit. In this study the researchers recommend that construction of physical SWC structures are the best options to rehabilitate degraded land and improve soil moisture content of soils at dry and moisture stressed areas. So, communities and stake holders of the study area should practice construction of those physical structures to alleviate moisture stress problem of the area.

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