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# Evaluation of selected multipurpose tree species and moisture conservation structures for degraded dryland rehabilitation in Dugda Dawa District, Southern Ethiopia

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**Land degradation affecting the livelihoods of people living in dryland areas, particularly the Sub-Saharan Africa countries like Ethiopia. Degraded land rehabilitation in dryland is a challenging task due to moisture limitation. This study was conducted to evaluate the effects of soil and water conservation structures on growth of planted tree and rehabilitation of indigenous plant species in West Guji Zone, Dugda Dawa District. Four multipurpose tree species (MPTs) namely *Faidherbia albida, Melia azedarach, Moringa stenopetala*, and *Sesbania sesban* were planted in four soil and moisture conservation structures (soil level bund, half-moon, trench and normal pit). Data of survival rate, height and diameter growth of planted tree species and, diversity and species richness of indigenous plant species were collected. The survival rate of all planted MPTs species were declining along the study years; however, the survival rate was better under soil level bund and half-moon. Under control treatments, all planted MPTs died at the end of the study period. The height and stem diameter of *F. albida, M. azedarach* and *M. stenopetala* were best in soil level bund and half-moon and followed by the trench. Whereas, the growth performance of Sesbania sesban was not significantly different among the three moisture conservation structures. Furthermore, soil moisture conservation structures significantly increased the indigenous plant species regeneration after the intervention. The mean indigenous plant species diversity and richness were significantly highest in half-moon and soil level bund followed by trench and, lowest in Control (normal pit). Thus, the results a potential for alternative forest and soil restoration in arid areas.**

**Key words**: Rehabilitation, Land degradation, survival rate,Trees growth, Indigenous plant species diversity, Moisture conservation structures.

## INTRODUCTION

Land degradation is the process by which ecosystem goods and services associated with primary productivity are declines compared with their provider under human pressures (Olsson et al., 2019; MA, 2005). Common land

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degradation processes are vegetation degradation, water and wind erosion, salinization, soil compaction and crusting and soil nutrient depletion, pollution, acidification, alkalization, and waterlogging are often important locally. Land degradation is widespread and is a serious threat affecting the livelihoods of 1.5 billion people worldwide of which one-sixth of people reside in drylands (Yirdaw et al., 2017). Globally, it is estimated that 10-20% of drylands are already degraded and about 12 million ha are degraded each year.

Ethiopia is one of the countries in Sub-Saharan Africa most seriously affected by land degradation (Simachew, 2020; UNCCD, 2015). The severely degraded lands are typically characterized by heavily eroded or nutrient-deficient soils, hydrological instability, reduced primary productivity and low biological diversity (Verma et al., 1999) and these are common phenomena in the dry areas of Ethiopia especially in southern parts of the country. Thus, land degradation is a major cause of the country’s low and declining agricultural productivity, persistent food insecurity, and rural poverty and associated adverse economic and social consequences. The minimum estimated annual costs of land degradation in Ethiopia range from 2 to 3% of agricultural Gross Domestic Product (GDP) which is a significant loss for a country where agriculture accounts for nearly 50% of GDP, 90 percent of export revenue and is a source of livelihood for more than 85% of the country’s 90 million peoples. Generally, Environmental degradation is proceeding at an unprecedented rate in many tropical regions, jeopardizing prospects for conservation of biological diversity and sustainable economic development of agricultural and forest resources (Mahari and Giday, 2014). Rangelands of Borana and lowland parts of west Guji are some of the areas affected by land degradation in southern Ethiopia.

Afforestation is the common approach of restoration on degraded land and biodiversity conservation, and eco-environmental improvement (Shixiong, 2011). Dryland restoration activities may go beyond simply planting trees because they often play a central role in the provision of benefits for both people and biodiversity. The vegetative maintenance of degraded land by using multipurpose trees principally consists of different essential benefits: (i) mitigation of surface runoff and erosion by reducing the kinetic energy of rain droplets when they strike the soil, (ii) reducing wind erosion, (iii) add organic matter to soils which enhancing fertility and reducing soil erosion, and (v) increase soil microfauna (FAO, 2015). A report by Sharma and Sunderraj (2005) also stated that establishing multipurpose tree species on degraded land can play a key role in rehabilitation or restoration goals through afforestation or/and reforestation. However, Tree and shrubs planting efforts should focus on species performing a wide range of functions. The information needs to be pooled for selection of multi-purpose species are species-specific ecological ranges, characteristics and a set of potentially valuable functions of the species (Reubens et al., 2011).

The vegetation establishment on degraded land is constrained by many factors of which the insufficient moisture availability is listed as the top constraint (Li et al., 2008). Successful tree seedling survival and growth depend on the soil condition and stored soil moisture available to ensure tree seedling survival dry season (Warren et al., 2005). In the degraded lands of Borana rangeland, pastoralists have been planting many tree seedlings species year after year (Demisachew et al., 2018). However, the survival of those seedlings is poor and variable as the area is mainly affected by moisture stress problems. This shows plant moisture and the onset of plant water stress caused by soil water deficits are recognized as the principal limiting factors controlling the growth and survival of forest trees (Mahari and Giday, 2014). These gap hinders further adoption of degraded land rehabilitation practices and thereby limits the potential benefits. Thus, selected multipurpose tree species were used for rehabilitation of degraded lands of the study area to evaluate the performance of the selected tree/shrub species in different moisture conservation structures and to assess changes in species diversity before and after rehabilitation. Hence, best performing multipurpose tree species and moisture conservation structures are used for future rehabilitations purposes of the degraded areas.

## MATERIALS AND METHODS

### Description of the study areas

The study was conducted in a recently established west Guji zone, Dugda Dawa distric, Jigessa Kebele for five consecutive years. The district is found at 38°43'7.663"E 5°4'12.396"N and 37°57'29.306"E 5°39'36.02"N. The environmental conditions of Dugda Dawa district are mid-altitude (30%) and lowland (70%). The altitude of the district ranged from 1100 to 1750 masl. The rainfall pattern of the district is bimodal with erratic annual rainfall ranging 500 mm in the south to 750 mm. The main growing season is from March to June “*Gana*” season and short growing season is from August to October “*Hagaya*” season. The mean minimum and maximum temperature of the district is 17 and 27°respectively.

The major land use and land cover of Dugdadewa District are grass land, cultivated land, woodland, Forest land, shrub land and exposed soil surface with scattered trees/shrubs (area with no or very few cover surface). The exposed soil surface area of the district is very huge (OWWDSE, 2010). The majority vegetation of the area is characterized as Acacia-Commiphora woodland and bush land (Friis et al., 2011). The major soil types of the area are Vertisols, Luvisols, Cambisols, Andosols, Fluvisols, Calcisols, Nitisols and Leptosols.

### Site selection

Discussions and interviews with natural resource experts from the Zonal level to Districts, NGOs working in the area and, key

**Figure 1.** Bare and compacted land that was selected for the study.

**Figure 2.** Constructed moisture conservation structures in the selected site.

informants from Pastoralists and Agro-pastoralist as well as a reconnaissance survey were conducted to identify and select the degraded land area. Finally, the study area was selected purposively based on the degree of degradation. Based on this Dugda Dawa district, Kilkile specific site was selected. The site was almost bare, compacted, and did not provide any required social and environmental goods and services for long years. Hence, the term 'Kilkile' in the local language is bare and compacted land (Figure 1).

### Moisture conservation structure and tree species selection

Four multipurpose tree/shrub species and four soil and moisture conservation structures were selected for this study. The selected soil and moisture conservation structures ware soil level bund, Half-moon, Trench and Control (plant pit only). The selected tree/shrub species were *Faidherbia albida*, *Melia azedarach, Moringa stenopetala,* and *Sesbania sesban*. The species were selected based on their adaptability in the study area, growth performance and their multi-functional functional benefits. *F. albida* is one of multi-purpose species obtained highest scores for functional benefit under different scenarios (Reubens et al., 2011). *S. sesban* and *M. stenopetala* are the superior fodder tree/shrub species in terms of growth performances and nutrient composition respectively (Asmelash et al., 2020).

### Experimental layout and design

The selected moisture conservation structures were prepared in a randomized complete block design (RCBD) with three blocks/ replications and, each block contains four experimental plots, representing the four structures and the selected four tree species. Replications were used to reduce only the variation among treatments. The spacing between blocks was 5 m and the spacing between plots was 3 m, plots sizes were 30 m × 30 m. The depth, width and length of soil level bunds were 50, 50 and 10 cm respectively. The diameter size of half-moons was 2 m and planting pits were prepared at the three corners of the half-moons. The depth, width and length of trenches were 50, 50 and 3 cm respectively. At the center of the trenches, pits were dug and seedlings were planted in the pits. On the control plots, normal pits were dug at 2 m interval and each selected species were planted in the pits. The soil and moisture conservation structures were prepared before the onset of the main rainy season.

Seeds of the selected tree species were collected from Ethiopian Environment and Forest Research Institute, Addis Ababa, and their seedlings were raised in polythene tubes in Yaballo Pastoral and Dryland Agricultural Research Centre nursery site. The seedlings in nursery have been watering every day early in the morning and evening. Vigor seedlings with similar sizes (greater than 30 cm height) were selected for the field planting and then transplanted at the beginning of the main rain season. The seedling were planted at 2 m interval in all plots. The seedlings were planted on the lower slope side of the bund at 2 m intervals and, in the case of half-moons, seedlings were planted in the three corners of the half-moons. After planting, the site was protected from grazing and human interference for the duration of the study. Plantation plots were neither irrigated nor fertilized (Figure 2).

### Survival and growth performance data collection for planted trees

Number of planted trees species surviving dry seasons, height of trees (from ground level to the tip of the plant) and root collar diameter (RCD) were recorded each year of the study time at the

**Figure 3.** Change made after the intervention.

end of the main rainy seasons and, diameter at breast height (DBH) data collection was started after two years (after height growth of planted tree species exceed breast height). The survival percentage of each species was calculated as the number of trees survived dry seasons divided by the initial tree number multiplied 100. The height was measured using a measuring stick, and diameter was measured using a caliper. Trees root collar diameter was measured at the ankle (5 to 10 cm aboveground) and, DBH was measured at breast height (1.3 m above the ground)(Figure 3).

### Indigenous plant species sampling and diversity data analysis before and after intervention

To estimate the abundance, analyze indigenous plant diversity and species richness of plant species found in the study area, a complete plant species inventory was conducted both before and after the intervention. Before the intervention, the existing herbaceous, shrubs, and tree species were collected using a nested vegetation sampling plot. Within the selected study site three linear transect lines were systematically placed along a geographic gradient (elevation). Along with each transect line nested square-shaped sampling plots having a size 20 m x 20 m, 10 m x 10 m and 1 m x 1 m were systematically placed along transect lines. As a study by Mueller-Dumbois and Ellenberg (1974) indicated such nested plots are of considerable importance in the description of vegetation changes. The nested square-shaped plot was divided into subplots. The largest plots (20 m x 20 m) were used for collecting tree species data and, within main, sub-plot (10 m x 10 m) placed at the center of the largest plots were used for sampling shrub species; while the 1 m x 1m plots placed at the four corners and center of the main plot were used for sampling seedlings, herbaceous species.

After rehabilitation (after five years), the vegetation data collections were conducted to evaluate the changes in species composition. Plant species composition (trees, shrub, herb, forb and grasses) data were collected from all experimental plots. A total of 24 nested square-shaped quadrant sample plots were used both before and after experiment intervention as mentioned above. Identification of the species was made in the field with the help of field identification keys and plates and Flora of Ethiopia books (Edwards et al., 1995, 1997, 2000) based on herbarium specimens collected from the sample plots. Likewise, during the vegetation survey the local people, particularly the elders who are more likely to know plant local names were interviewed. The names of plant species were cross-checked with previous studies conducted in the study areas (Gemedo et al., 2005).

Plant species diversity was analyzed using the Shannon-Weiner index (H') which takes into account plant species abundance, evenness and richness. The similarity of woody species among different habitats/study area/plant communities was calculated by employing Sorensen's similarity coefficient (Kent and Coker, 1992). The H' is calculated using the Shannon-Weiner index (H') (Shannon and Weaver, 1948) as:

$$H' = -\sum_{i=1}^{s} Pi \ln Pi \qquad (1)$$

Where, H'= Shannon-Wiener diversity index, Pi = the proportion of individuals or the abundance of the $i^{th}$ species expressed as a proportion of the total and ln = the natural logarithm of a base n (log $\text{base}_n$).

The values of the index (H') usually lie between 1.5 and 3.5, although in exceptional cases, the value can exceed 4.5 (Kent and Coker, 1992). Usually, the Shannon diversity index places the most weight on the rare species in the sample and it is also moderately sensitive to sample sizes. The species evenness (E) was calculated as:

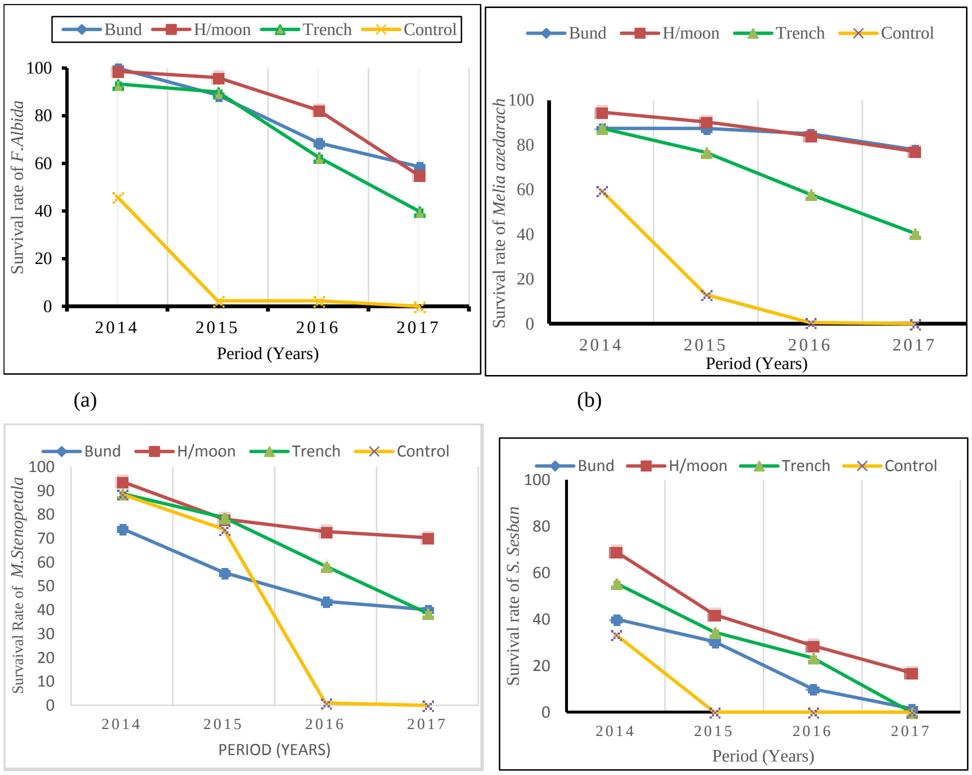
$$E = \frac{H'}{H\max} = -\frac{\sum_{i=1}^{s} Pi \ln Pi}{\ln S} \qquad (2)$$

Where, E = Shannon-Wiener Evenness Index, H' = Shannon-Wiener diversity, and Hmax=lnS [species diversity under maximum equitability conditions] and S= Stands for the total species in the study sites.

Measurement of similarity was conducted using the Sorensen coefficient of similarity (Ss) is given by the formula:

$$Ss = \frac{2a}{(2a+b+c)} \qquad (3)$$

Where, Ss = Sorensen similarity coefficient; a = number of species common to both communities (before and after intervention); b = number of species recorded in the first communities (before intervention) and absent in the second (after intervention) and c = number of species recorded in the second communities (after intervention) and absent in the first (before intervention Similarity indices measure the degree to which the species composition of the communities is alike. Many measures exist for the assessment of



(a) (b)

(c) (d)

**Figure 4.** Survival (%) for (a) *Faidherbia albida,* (b) *Melia azedarach* (c) *Moringa stenopetala* and (d) *Sesbania sesban* under soil level bund(bund), half-moon (H/moon), trench and control (pit only) treatments through sequential periods from June 2014 to June 2017.

similarity or dissimilarity between vegetation samples or quadrats. Its coefficient values range from 0, complete dissimilarity to 1, total similarity (Kent and Coker, 1992). The coefficient of the community is the percentage of the total species that the two communities have in common.

### Statistical analysis

Plant diversity was analyzed using Paleontological Statistical (PAST) software, version 3.10 (Hammer et al., 2001). Before analysis, the data were tested for normal distribution using SPSS version 20 following Shapiro-Wilk methods. Diversity results with other vegetation attributes were analyzed using General Linear Model (GLM) procedures of the statistical analysis system with IBM SPSS version 20. One-way analysis of variance (ANOVA) was used to test the growth data of the selected tree species and mean comparisons were made using the Tukey Honest Significant Difference (HSD) test at 0.05 significant levels.

## RESULTS AND DISCUSSION

### Effects of soil and moisture conservation structures on the survival rate of planted species

The moisture conservation structures provided considerable effects on the survival rate of all planted multipurpose tree/shrub species in the study area. Our results confirm that the survival rate of planted tree species in moisture conservation structures were significantly different and declining trend along the study years.

The survival rate of planted species ((a) *F. albida*, (b) *M. azedarach,* (c) *M. stenopetala* and (d) *S. sesban*) significantly varied in all the moisture conservation structures along study years. The survival trend of the species in all moisture conservation structures showed a declining trend along the study years. Under normal pits the survival rates of all planted species were too low, even all of them have died at the end of the study time. The result agrees with the report from West Hararghe Zone by Desalegn et al. (2016) which showed the survival rate of different multipurpose tree species planted in moisture conservation structures declined each year after transplanting (Figure 4a to d)

The survival rate of planted species was not significantly different among the moisture conservation structures except for *M. azedarach*. The survival rate of *M. azedarach* among the treatments was significantly

**Table 1.** Mean (± standard error) of % Survival of *F. albida*, *M. azedarach*, *M. stenopetala* and *S.sesban* under different moisture conservation structures at the age of four years.

| Structures (planting methods) | Parameter | | | |
|---|---|---|---|---|
| | ***F. albida*** | ***M. azedarach*** | ***M. stenopetala*** | ***S. sesban*** |
| Soil level Bund | 58.67 ± 5.01 | $77.87\pm4.73^{a}$ | 38.62±13.98 | 28.61±6.01 |
| Half moon | 55.00 ± 5.01 | $77.12\pm4.73^{a}$ | 70.30±13.98 | 10.01±6.01 |
| Trench | 40.00 ± 5.01 | $40.53\pm4.73^{b}$ | 40.11±13.98 | 23.33±6.01 |
| Control (Normal pit) | 0.00 | 0.00 | 0.00 | 0.00 |
| CV | 25.67 | 12.58 | 48.75 | 50.39 |
| P-value | 0.25 | 0.002 | 0.27 | 0.16 |

Means with the same superscripts in the same columns are not significantly different.

different ($p$ = 0.002). The highest survival percentages at the end of the fourth year were recorded in soil level bund and followed by half-moon, whereas under trench performed the least (Table 1). Even the survival rates of planted tree species were not statistically significantly different, it was more survived under soil level bund, followed by half-moon soil and moisture conservation structures and the survival rate was 40% in the trench (Figure 3a). In the control treatment (normal pit) almost all tree seedlings planted failed to survive after four years of establishment (Figure 3). The result indicated that the survival rates of all the species were highest under soil level bund, followed by semicircular bund moisture conservation structures. The result contrasts with the study in dry areas of East Shoa zone where the survival percentages of four types of promising multipurpose trees that is, *Azadirachta indica*, *Schinus molle*, *Acacia saligna* and *Parkinsonia aculeata* were highest in semicircular bund and contour-bench and, least performed in infiltration pits (Abera and Fitih, 2015). *In-situ* rainwater harvesting devices are important in facilitating favorable conditions for plant growth as well as tree seedling survival in moisture-stress areas (Demisachew et al., 2018).

## Height and diameter growth of the planted trees species

Height and diameter growth of *F. albida* were evaluated at the end of the study year (2017). The height and diameter growth of planted *F. albida* trees were not significantly different under the three moisture conservation structures (planting methods), however, it was better under soil level bund and half-moon. The average DBH and height of planted *F. albida* trees in soil level bund were 2.27 and 3.48 cm respectively at the 4th year of study years, whereas that of half-moon was 2.16 and 3.2cm respectively (Table 2).

The height and diameter growth performance of *M. azedarach* planted in different planting methods (moisture conservation structures) is presented in (Table 2). The analysis of variance revealed that the height and diameter growth of *M. azedarach* was significantly different under the three moisture conservation structures (planting methods). The height growth of the species was best in soil level bund (5.59 m) at the age of four years followed by half-moon (4.96 m) and trench (4.11 m). The average diameter at breast height (DBH) of *M. azedarach* at the four years after planting was also best in soil level bund (2.95 cm) followed by half-moon (2.41 cm) and trench (2.18 cm) and, root color diameter (RCD) showed similar trends as shown in (Table 2).

Analysis of variance revealed that the DBH ($p < 0.001$) and height growth ($p < 0.01$) of *M. stenopetala* have significantly different under the three evaluated planting methods after four years. The mean DBH growth of the species was best in half-moon (2.46 cm) followed by soil level bund (2.35 cm) and least in the trench (1.56 cm). The RCD growth was also showed a similar trend (Table 2). The height growth of *M. stenopetala* planted in half-moon was 4.56 m four years after establishments and under soil level bund it was 4.4 m. Under the trench planting method, the species was not well performed in terms of height growth (2.78 m after four years). Generally, the height and diameter growth of *M. stenopetala* was best in half-moon and soil level bund and least in trench soil and moisture conservation structures.

The height and RCD growth of *S. sesban* planted under different moisture conservation structures were not statistically different ($p$ = 0.6 and $p$ = 0.69 respectively). However, the height and diameter growth of the species after three years was best under soil level bund compared to others (Table 2).

This study provides empirical shreds of evidence that affects moisture conservation structures on the height and diameter growth of selected multipurpose tree species. The height and diameter growth of all planted tree species were best under soil level bund and semi-

**Table 2.** Mean (± standard error) of root color diameter (RCD), diameter at breast height (DBH) and height of *F. albida*, *M. azedarach*, *M. stenopetala* and *S. sesban* under different moisture conservation structures at the age of four years.

| Tree species | Parameter | Structures (planting methods) | | | | P-value | CV |
|---|---|---|---|---|---|---|---|
| | | Soil level bund | Half moon | Trench | Control (Normal pit) | | |
| *Faidherbia albida* (Delile) A.Chev. | RCD(in cm) | $6.92 \pm 0.38^{a}$ | $6.77 \pm 0.38^{a}$ | $5.62 \pm 0.38^{a}$ | 0 | 0.16 | 11.95 |
| | DBH(in cm) | $2.27 \pm 0.25^{a}$ | $2.16 \pm 0.25^{a}$ | $1.69 \pm 0.25^{a}$ | 0 | 0.38 | 24.78 |
| | Height(in M) | $3.48 \pm 0.26^{a}$ | $3.20 \pm 0.26^{a}$ | $2.78 \pm 0.26^{a}$ | 0 | 0.32 | 16.46 |
| *Melia azedarach L.* | RCD (in cm) | $14.72 \pm 0.97^{a}$ | $11.08 \pm 0.97^{b}$ | $8.20 \pm 0.97^{b}$ | 0 | 0.009 | 14.76 |
| | DBH (in cm) | $2.95 \pm 0.11^{a}$ | $2.41 \pm 0.11^{b}$ | $2.18 \pm 0.11^{b}$ | 0 | 0.006 | 7.56 |
| | Height (in M) | $5.79 \pm 0.29^{a}$ | $4.96 \pm 0.29^{ab}$ | $4.11 \pm 0.29^{b}$ | 0 | 0.016 | 9.96 |
| *Moringa stenopetala (Bak.) Cuf* | RCD(in cm) | $14.21 \pm 1.14^{a}$ | $10.94 \pm 1.14^{ab}$ | $7.94 \pm 1.14^{b}$ | 0 | 0.022 | 17.88 |
| | DBH(in cm) | $2.46 \pm 0.1^{a}$ | $2.35 \pm 0.1^{a}$ | $1.56 \pm 0.1^{b}$ | 0 | 0.0008 | 7.92 |
| | Height(in M) | $4.56 \pm 0.3^{a}$ | $4.40 \pm 0.3^{a}$ | $2.78 \pm 0.3^{b}$ | 0 | 0.009 | 13.06 |
| **Sesbania sesban (L.) Merr.* | RCD (in cm) | 2.96±0.66 | 2.29±0.66 | 2.20±0.66 | 0 | 0.6 | 45.89 |
| | Height (in M) | 2.3±0.46 | 1.74±0.46 | 1.96±0.46 | 0 | 0.69 | 39.99 |

Means with the same superscripts in the same columns are not significantly different.
(*Three years after panted for *S. sesban*)

circular bund. A study by Desalegn et al. (2016) in West Hararghe Zone showed that *M. azedarach* planted in half-moon relatively higher DBH and plant height followed by trench micro catchment. Other study in Eastern Oromia, Ethiopia indicated the height and root color diameter growth parameters of the tree species planted in the soil level bund were better than that of planted in trench and, tree species planted in trench were also more surviving than tree species planted in normal pit (Bira et al., 2021). The findings also in line with the study conducted in Southern Tigray indicated that seedlings grown on Moisture harvesting structures were significantly thicker, taller, and more survived than those grown on the normal pits (Gebru et al., 2019). The other study in Southern Ethiopia by Shiferaw et al. (2020) also showed that tree species planted in moisture harvesting structures (trench) had higher growth and biomass production than the trees planted in normal pits. Soil moisture conservation structures reduce runoff and improve the infiltration of rainwater during the rainy season. This infiltrated rainwater then available for plants during the dry period, which vigorously enhances plant growth and increases plant biomass compared with that of trees planted without moisture harvesting structures, that is, planting pit only (Sumbali et al., 2012; Panigrahi et al., 2007).

## Indigenous plant species regeneration

A total of 87 indigenous plant species belonging to 31 families were recorded across the study site. There was a significant difference in terms of plant species richness, Shannon index (H`) and, the number of Individual plants per plot before and after intervention (p < 0.0001 for all). Similarly, a significant difference was observed before and after rehabilitation of degraded land in terms of plant species evenness (p = 0.04). The average

**Table 3.** Means (±standard error) of species richness, Shannon index (H`) and evenness of SWC plots after the 5-year intervention, Control plots protected for 5 years and the study site before intervention.

| Factors | Species richness | Shannon index (H`) | No of Individual plants | Evenness |
|---|---|---|---|---|
| SWC plots after intervention | 27.67±1.27 $^{a}$ | 2.41±0.09 $^{a}$ | 269.33 ± 25.93$^{a}$ | 0.49 ± 0.05$^{a}$ |
| Control plots after intervention | 14.67±1.27$^{b}$ | 1.66±0.09 $^{b}$ | 76.00 ± 25.93$^{b}$ | 0.34 ± 0.05$^{ab}$ |
| Before intervention | 14.00±1.27$^{b}$ | 1.62±0.09 $^{b}$ | 72.83 ± 25.93$^{b}$ | 0.28 ± 0.05$^{b}$ |
| CV | 16.53 | 11.31 | 45.55 | 34.71 |
| P-value | < 0.0001 | < 0.0001 | < 0.0001 | 0.04 |

SWC = soil and water conservation.

**Table 4.** Mean value of species richness, diversity and evenness in four different SWC structures at Dugda Dawa site after rehabilitation.

| Treatment | Species richness | No of Individual plants | Shannon index (H`) | Sp. Evenness |
|---|---|---|---|---|
| Half-moon | 30.33±1.96$^{a}$ | 353.83±29.81$^{a}$ | 2.69±0.08 $^{a}$ | 0.59± 0.06$^{a}$ |
| Soil level bund | 29.17±1.96$^{ab}$ | 317.17±29.81$^{a}$ | 2.53±0.08 $^{a}$ | 0.49± 0.06$^{ab}$ |
| Trench | 23.83±1.96$^{b}$ | 138.00±29.81$^{b}$ | 2.02±0.08$^{b}$ | 0.39±0.06$^{bc}$ |
| Control (normal pit) | 14.67±1.96$^{c}$ | 76.00±29.81$^{b}$ | 1.66±0.08 $^{c}$ | 0.28±0.06$^{c}$ |

Means with the same superscripts in the same columns are not significantly different

species richness per plot before the innervation was 14 and, it was increased to 27.67 after the innervation. Whereas, the number of individual plants per plot increased from 72.82 to 269.33 (Table 3). The Shannon diversity index was also significantly raised from 1.62 to 2.41 after rehabilitations. The findings of this study are consistent with those of Ombega et al. (2017) who is working in Southwest of Kenya on the rangeland rehabilitated through the establishment of soil and water conservation structures, reported the rehabilitated area had a higher herbaceous species diversity, species richness, relative abundance, composition and biomass production compared to the degraded area. Likewise, Singh et al. (2011) who is working in the degraded Aravalli hills in Western India found a higher species diversity in areas with soil and water conservation structures. A study in northern Ethiopia indicted the species diversity and richness in watershed based rehabilitated area using SWC structures are significantly greater than of untreated areas (Gerbremariam et al., 2018).

The establishment of soil and water conservation structures in the study area reduced runoff and erosion and, trapped seeds of different plant species came from other areas by runoff. Soil and water conservation structures also facilitated soil seed bank regeneration and sprout from root cutting during the establishment of the structures. Which in turn improved indigenous plant species richness, relative abundance, and diversity. Rehabilitation of degraded areas supporting the soil and water conservation structures has been found to reduce soil erosion which in turn enhances soil fertility, vegetation recovery, and plant biodiversity (Singh et al., 2011; Tongway and Ludwig, 2012) (Table 4).

The Shannon diversity index of the study site was low for both before and after rehabilitation. This may be because of the dominance of a few plant species on the site. Shannon diversity index (H) rises with increasing species richness, as well as increasing equal distribution of species and, decrease with the dominance of few species (unequal distribution of species) and reducing in species richness (Mühlenberg, 1993). Dominance affects ecosystem functions and influences the temporal and spatial variability of aggregate community properties and compositional stability (Helmut et al., 2008). Both before and after intervention *Dodonea angustifolia* was the dominant plant species recorded in the study area which, was considered by the local community as an encroached tree species affecting the growth of other herbaceous plant species under it. *D. angustifolia* was one of the most dominant indigenous species found in the study area and accounted for 13.18% of the total plant species recorded in the study area before the intervention in the area followed by *Eragrostis capitulifera* accounted 12.79% of the total plant species recorded in the study area. Following the above two woody species, *Aristida kenyensis* was the third plant species with high abundance (9.69%) in the study sites. The least density was recorded for species like *Senna occidentalis, Cenchrus ciliaris and Melinis repens* (Table 5).

Similarly, after intervention *D. angustifolia* was the most dominant indigenous species accounted 44.79% relative density of the total plant species recorded in the study area. *Aristida adoensis* was the next plant species with

**Table 5.** The ten most abundant species and their relative proportions before intervention.

| Scientific name | Local name | Abundance before intervention | Relative density (%) |
|---|---|---|---|
| *Dodonea angustifolia* L. f. | Dhittacha | 34 | 13.18 |
| *Eragrostis capitulifera* Chiov. | Marga mataa furdaa | 33 | 12.79 |
| *Aristida kenyensis* Henr. | Marga biilaa | 25 | 9.69 |
| *Sporobolus pyramidalis* P. Beauv. | Biilaa | 22 | 8.53 |
| *Heteropogon contortus* (L.) Roem. & Schult | Seericha | 22 | 8.53 |
| *Leptothrium senegalense* (Kunth) Clayton | biilaa diidaa | 16 | 6.20 |
| *Harpachne schimperi* Hochst. ex A. Rich. | Biilaa Seericha | 14 | 5.43 |
| *Dalbergia microphylla* Chiov. | Walchaamala | 12 | 4.65 |
| *Balanites aegyptiaca* (L.) Del. | Baddana | 9 | 3.49 |
| *Cyperus amauropus* Steud. | Saattuu | 8 | 3.10 |
| Other 15 species | | 63 | 24.42 |

**Table 6.** The ten most proportions after abundant species and their relative density after intervention.

| Scientific name | Local name | Abundance | Relative density (%) |
|---|---|---|---|
| *Dodonea angustifolia* L. f. | Dhittacha | 2597 | 44.79 |
| *Aristida adoensis* Hochst. | Buushee/Saattuu biilaa | 291 | 5.02 |
| *Ormocarpum trichocarpum* (Taub.) Engl | Buutiyyee | 244 | 4.21 |
| *Tephrosia pentaphylla* (Roxb.) G. Don. | Darguu | 242 | 4.17 |
| *Aristida kenyensis* Henr. | Marga biilaa | 229 | 3.95 |
| *Otostegia erlangeri* Gurke | Bulee luqqa'aa/Harcaa | 153 | 2.64 |
| *Harpachne schimperi* Hochst. ex A. Rich. | Biilaa Seericha | 148 | 2.55 |
| *Heteropogon contortus* (L.) Roem. & Schult. | Seericha | 135 | 2.33 |
| Other 74 plant species | - | 1466 | 25.28 |

the highest abundance (291 individuals) and accounted for 5.02% relative density of the total plant species recorded in the study area. Following the above two woody species, *Ormocarpum trichocarpum* was the third with high abundant plant species in the study sites. The least density was recorded for species like *Capparis cartilaginea*, *Cordia africana*, *Crabbea velutina* and many other plant species with one individual respectively (Table 6).

The similarity in indigenous plant species composition of the study area before and after the rehabilitation is expected. However, out of 87 plant species belonging to 31 families recorded across the study site, about 22 plant species belonging to 9 families were found to be common to both study sites. The Sorensen coefficients of similarity showed the lowest similarity of plant species composition before and after rehabilitation, which accounts for about 40.37% combinations among the assessment. This showed that the plant species compositions assessed before and after interventions were different and the plant species diversity of the study area was increased due to the intervention made. A study in Southern Ethiopia by Dessale et al. (2020) found that woody cover increased due to the implementation of integrated SWC practices after ten years intervention. Similarly other study indicated that vegetation cover and plant species diversity are higher in plot areas treated SWC measures comparted to non-treated plot areas after ten years intervention (Mengistu et al., 2021)

## CONCLUSION AND RECOMMENDATIONS

Soil and moisture conservation structures have significant effects on the rehabilitation of indigenes plants and, survival and growth performance of planted tree species. Our study found that tree species planted in soil level bund and half-moon moisture conservation structures were well survived and high growth performance followed by trench. Whereas, all tree species planted in control treatments (normal pits) were died three years after planting. Furthermore, degraded land rehabilitation intervention using soil moisture conservation structures increased the regenerations of indigenous plant species.

The indigenous plant species diversity, richness, and the number of individual plants were significantly increased after the intervention. The mean indigenous plant species diversity, richness and number of individual plants were significantly highest in half-moon and soil level bund followed by trench and, lowest in Control (normal pit). This might because the structures reduced runoff and erosion and, trapped seeds of different plant species came from other areas by runoff. Soil and water conservation structures also facilitated soil seed bank regeneration and sprout from root cutting during the establishment of the structures. This in turn improved indigenous plant species richness and diversity. In general, *this* study confirmed that half-moon and soil level bund soil and moisture conservation structures are more suitable than the conventional method of tree planting and habilitation of indigenous plant species. Thus, the best performing multipurpose tree species and soil and moisture conservation structures were recommended for the rehabilitation of degraded land. Moreover, the results of this study represent a potentially valuable alternative for forest restoration and soil conservation in arid areas.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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