#### **Socioeconomic drivers influencing performance of Soil and Water Conservation Measures** **in Tigray, Northern Ethiopia**

# *Abstract*

*Diverse soil and water conservation (SWC) interventions were implemented in Tigray region to retard and stop soil loss due to water erosion problem. The aim of study was to evaluate the biophysical and socioeconomic drivers for the performance of implemented SWC structures under different landforms at Adi-Kimbro Watershed found in the midland agro-climatic zone of North Western Tigray. Slope, soil sample and length of destructed SWC structures were collected from plot sample size of 2500 m2 along upper, middle, foot and bottom landforms of the Watershed from different land uses. socioeconomic drivers were collected from 113 households through semi-structured questionnaires. Descriptive statistics, Pearson correlation, logistic model and independent t-test, analysis were developed. The major SWC structures implemented in both exclosures and grazing land were hillside terraces, hillside terraces with trenches, loose stone check dams and trenches. Stone bunds, check dams (cement, gabion) and 'daget' were constructed at cultivated land. Check dams at the bottom part of the watershed were comparatively effective in, rehabilitating degraded area and soil grasp.* *The farm size, sex household head, availability of labor and training were positive and significantly influenced the performance of SWC structures. Home distance to farm land, age and livestock holding number negatively affected to the success of the implemented SWC structures. Emphasis should be given to community participation during planning, designing, implementation and monitoring and evaluation phases by considering the* household head age, labor availability, farm size, level of training, household sex and *to increase the performance of SWC structures.*

***Keywords: destruction; biophysical and socioeconomic drivers; landforms; land uses; soil and water conservation, success.***

# Introduction

Soil and water conservation (SWC) program was encouraged in Ethiopia starting 1970s with the support of organizations to reduce soil degradation, improve agricultural production, enhance food security and reduce poverty [1]. Currently, SWC mass-community program are promoted to ensure sustainable watershed development and socioeconomic development [2]. These practices able to reduce soil erosion in highlands of Ethiopia; for example soil bunds reduce erosion by 30.5%, improve infiltration, reduce surface runoff and soil loss, improves soil characteristics (pH, CEC, OC etc.) and increases crop yields ([3, 4, 5].

#### SWC technologies are not equally successful or effective in many parts of Ethiopia [6]. The effectiveness of SWC measures implemented in the Tigray region controverting where some studies reveal success while other indicate failure. Success or failure of SWC intervention was the degree to which farmers adopt the technologies promoted [7]. For instance, the stone bund was effective in sloping area [8]. Mean measured of sediment accumulation behind the stone bunds was 119 kgm-1 yr-1 or 59 t ha-1 yr-1 in degu`a Temben, Tigray [9]. The reason for the failure of many SWC measures rely mainly on the fact that planners and implementing agencies ignored local level biophysical and socio-economic realities [10, 11]. The government has been reporting success stories in terms of the area of land covered, lengths of SWC structures, and numbers of tree seedlings planted. However, a study that comprehensively assesses outcomes of the community-based watershed management program was not available, as the existing empirical evidence on Ethiopia generally focuses on outcomes of project-based interventions that are carried out through food-for-work payments or incentives [12,50,51]. This study aimed to determine the socio-economic factors affecting the performance of implemented Physical SWC structures in Tigray, Northern Ethiopia.

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# Materials and Methods

## **2.1. Study area description**

The study conducted in Adi-kimbro watershed located in north western zone of Tigray, Ethiopia (140 06' 53'' to 140 08' 06'' North and 380 19' 13'' to 380 19' 40'' East) (Figure 1). It is situated at distance of about 320 km of Mekelle, the North West capital city of Tigray Region.

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Figure 1: Location of Ethiopia (A), Tigray (B), Tahtay Koraro district (C) and Adi-Kimbro Watershed (D)

The watershed situated at an altitude ranges 1913 to 2228 meter above sea level covering an area of 4.92 km2. The slope gradient of the watershed ranges from flat to very steep slopes and the dominant soils are Lithosol and chromic Cambisols. Mean annual rainfall based on 21 years (1996-2017) obtained from the Tigray meteorological service center is 1040 mm and high in the months of July and August. The minimum and maximum mean annual temperature are 13.9 0C and 27.7 0C respectively. The study area characterized by Weina-dega agro-ecology with the dominant, cultivated land, grazing land and bush land uses.

#### **2.2.** **Sampling techniques and sample size**

A single watershed that represents implemented major physical SWC structures in the district was selected in consultation with the experts and development agents having similar year of implementation. T ASTER digital elevation model (DEM) 30m by 30m spatial resolution was imported to Arc GIS 10.3 for boundary delineation and to develop slope class. Following the recommendation landform classification system proposed by [13] on the position of the topography and slope boundary of Adi-kimbro Watershed divided into four landforms of upper slope, middle /sloping land, lower slope /foot slope and bottom /flat.

Four parallel transects were made along the landforms with the sample plot size of 50m by 50m similar with the method of [14] for measuring status of the physical SWC structures. Grazing, exclosures and cultivated areas were taken to assess status of SWC structures and total 35 sample plot were taken to measure destructed length of the structures of hillside terraces, hillside terraces with trenches, loose stone check dams, trenches and stone bunds found along all landforms. The sampled SWC structures for each plot vary based on the types of implemented SWC structures. Composite soil sample (35) were taken from 0-30cm depth for particle size analysis [15, 16].

Sample household farmers from the study watershed were selected by using simple random sampling technique. Total 113 sample household heads (HHs) were determined by [17] (equation 1) as used for the sample size household survey by [18, 19, 20].

$n\_{0}=\frac{z^{2}pq}{d^{2}}$ , $n=\frac{n\_{0}}{1+\frac{n\_{0-1}}{N}}$ …………………… Equation1

Where, no = the desired sample size when the population is > 10,000. N = sample size when the population is < 10,000.

Z = 95% confidence limit, i.e. 1.96, p = 0.1 (proportion of the population to be included in the sample i.e. 10%). q = 1 – p i.e. (0.9), N = total households; d = degree of accuracy desired (0.05).

All the respondents who participated in the survey have knowhow about the impact of SWC structures. The questionnaires were related to the status, challenges, erosion level, drivers for the performance of SWC structures, and impact of SWC structures. Pre-tested on ten household heads was taken before running the detailed household survey.

#### **2.3. Data sources**

Primary data were collected on soil texture, slope, stone quality used for structures through field observation. Socio-economic factors (age, education level, management, distance of structures from home, farm size and livestock number) through focus group discussions, semi-structured interviews. Secondary data were collected from published materials such as journals, annual reports, manuals or guidelines, project reports, review papers, research papers and web pages.

#### **2.3.1. Data collection**

Direct preliminary observation with the help of key informants conducted to observe SWC measures, topography, soil erosion, land use types and status of SWC practices of the study watershed. During the preliminary survey each SWC structures and their appropriate placement in the slope was identified to evaluate its current status. Group discussions were held with farmers who had better knowledge on the status of the study watershed so as to triangulate and validate the information collected through individual farmer`s interview. For the purpose, three group discussions (female headed households, male headed households and both female and male headed households) were held from each residence of landforms [20].

### **2.3.2. Method of data Analysis**

Interview data were analyzed using descriptive statistics, Pearson correlation method and logistic model using SPSS version 20. The study utilized probability model specified with the performance of SWC measures as a function of series of socioeconomic and characteristics of households. The dependent variable is a dummy variable, which takes a value of zero or one depending on whether or not SWC structure is successful (i.e. success SWC structures is l, failed of SWC structures is 0). Logit model was used to estimate dependent dichotomous variables by following [21] and the functional form of logistic model is specified as follows:

$ln\left[\frac{p}{\left(1-p\right)}\right]=β0+β1X1+β2X2+…+βkXk $ ***……Equation1***

Where: *P/(1-P)* is the odds (likelihoods); *β0* is the intercept; *β1, β2 …* and *βk* are coefficients of the associated independent variables of *X1, X2…*and *Xk.* The effect of the independent variables (e.g., *β1*) is interpreted as the odds (possibilities) of the outcome increases or decreases by a factor of *eβ1*. The quantity *eβ1* is called the odds ratio. The estimated coefficients reflect the effect of individual explanatory variables on its log of odds {Ln [P/ (1- P)]}. The positive coefficient means that the log odds increase as the corresponding independent variable increases and the inverse is true for negative coefficients [21].

# 3. Results and Discussion

## **3.1. Soil and water conservation practices in the study area**

Trenches, hillside terraces (HTs), hillside terraces with trenches (HTTs), half-moon, stone bunds (SB) and loose stone check dams (LSCD), cement check dams (CCD), gabion stone check dams and '*armo' were* common physical SWC structures implemented in the watershed. Farmers used agronomic practices of organic manure, agroforestry, crop rotation, contour flowing, waterway making and fallowing. [22] Stated that farmers of Konso practiced indigenous mechanisms of mixing cropping, terracing, crop rotation, fallowing, and contour ploughing to conserve soil. Planting every year by mass community is common action in the upper and middle part of the watershed and naturally grown trees, shrubs and bushes also found throughout the watershed (Appendix 2). But from field observation and per group discussion the survival rate was low due to improper pits and absence of management after planting, absence strong keeper to the exclosure areas. Two group discussions explained that, plants planted in the form of seed were best survived than the seedlings but the seed plant types were selective like *gemero (Acacia polyacantha)* and *lihay* (*Acacia lahai*).

## **3.2. Perception of households on the status of the implemented SWC structures**

Farmers evaluate performance of physical SWC by observing on soil erosion effect, deposition of soil above bund or upstream check dam and its effectiveness for surviving of biological measures as explained by key informants. The respondents characterized the current status of physical SWC in study area, as poor by 69.2% of the respondents, medium (24.6%) and good (6.2%) (Table 1).

|  |  |  |
| --- | --- | --- |
| Status of structures  | Frequency | Percent (%) |
|  Good (well performed or strong)Medium (require some maintenance)Poor (damaged and require reconstruction)Total | 82778113 | 6.224.669.2100.0 |

 Table 1: Household evaluation of the current status of the implemented physical SWC in the study watershed

The destruction of trenches, hillside terraces, hillside terraces with trenches were higher in middle part of the watershed as comparing to upper part of the study area as stated by about 61.3 % of the respondents. Livestock trampling, runoff, less integrated SWC and less maintenance were the reasons as indicated by per group discussion. [20] Stated effectiveness of implemented soil bund was least due to

The surveyed gabion check dams in the bottom transect walk in the study watershed were eight in total; three (37.5%) of them were damaged (Table 2). Survey on check dams showed that 39% of sampled had been destroyed [24]. Siltation in the reservoir of the concrete check dams, absence of retaining wall, shallow foundation depth and higher horizontal distance were the reasons for the destruction of the structures in the bottom slope of the watershed.

From the group discussion the check dams constructed in the gulley were more effective to conserve soil and rehabilitate the gulley in a short period of time compared to the other physical SWC structures. However, half of the surveyed check dams reservoirs were filled with sediment and some of them had started to collapse. The failures of these check dams were due to absence of top-down catchment treatment during intervention. Absence of maintenance and biological measures were additional causes for poor performance of the check dams. [23] Finding stated that free grazing destroyed both the physical and biological SWC measures.

|  |  |  |  |
| --- | --- | --- | --- |
| Type structure  | Total structure | non effective | % of non-effective |
| Gabion check dam |  8 |  3 | 37.5 |
| Concrete check dam |  4 |  2 | 50 |

Table 2: Assessment the status of the sampled implemented gabion stone check dam and gabion concrete check dam in the bottom slope.

**3.3. Physical factors determine design of SWC structures**

**3.3.1. Slope:** Most structures in all slope of the watershed were constructed in the recommended of slope (Figure 2) but the main problem was the implemented design of structures were not considered for that slope. The physical SWC structures of half-moon and loose stone check dams which were implemented in the slope of 20% and 15-30 % respectively but the recommended slope for both structures was < 5% slope.

Figure 2: Comparisons of existed and recommended slope for SWC structures in the slopes of (a) steep (b) sloping (c) gentle (d) flat part of the Watershed.

**3.3.2. Soil depth and texture:** bio-physical features (soil depth, soil texture and slope) and management method (arrangement of stone and sequence of treatment) had their own difficulties to constructed stable physical SWC structure as described by household respondents. Field excavation during field survey showed depth of the soil ranges from 0.25 to 0.5 m in the upper, 0.5 and greater in middle and foot, and greater 2m in the bottom slope, technically accepted for the implemented SWC structures except in some plots of the upper part of the watershed because minimum depth required for physical SWC is 30cm for the stable soil [25]. The soil texture (Table 3) of the study watershed was classed based on the sampled soil depth (30cm). Most SWC structures are suitable in the deep and well drained soils [25] thus the soil texture of study watershed fulfilled this requirement because most sample soils in the upper, middle and foot were with sandy class. Textural class of Adi-kimbro watershed from laboratory (Table 3).

Table 3: Soil textural class for the upper, middle, foot and bottom landforms of the study Watershed for the depth of 30 cm.

|  |
| --- |
|  |
| **Upper** | **Middle** | **Foot** | **Bottom** |
| Sandy clay loam |  Sandy loam | Sandy clay loam | Silt loam  |
| Clay loam |  | loam | Clay loam |
|  |  | Sandy loam | Clay |

 Source: Own soil sample analysis in the Shire Agricultural Research center, soil laboratory

### **3.4. Socioeconomic drivers for performance SWC structures**

The results of model output presented in (Table 5) indicated that explanatory variables such as: level of education, household head sex, income level, level of training, farm size, participation and maintenance had positively influence on the performance of physical SWC structures. But the age of the household, number of livestock owned by the households and the distance to farmland negatively affected for the performance of the physical SWC structures. The negative sign indicates as the age, total number of livestock and home distance of farmers from farmland increases the performance of physical SWC decreased.

#### **3.4.1. Level of education**

The survey indicated variation in level of education among sampled household heads. Out of the sampled households, about 51% can read and write because about 39. 4% of them had got formal education and the 11.6 % of them through experience and religious education (Table 4). About 47. 8% households got knowledge due to school and non-formal action (sharing from another and adaptation) [26]. Education is an important mechanism to increase the perception of people on soil erosion and conservation technologies via acquired knowledge and information [27, 28].

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  Education | illiterate | Adult | Religious education | 1-4 grade | 5-8 grade | 9-12 grade | diploma  | Total |
| Frequency | 34 | 7 |  5 | 40 | 19 | 7 | 1 | 113 |
| Percent (%) | 30 | 6.2 | 4.4 | 35.4 | 17 | 6.2 | 0.88 | 100 |

 Table 4: Education level of the household in Adi-Kimbro watershed

 Source: own field survey, 2017/2018

Educational status of household heads correlated positively with the performance of SWC structures at p≤ 0.005 level of significance as shown in Table 5. The Ward statistics (9.78) revealed its significant association with the success of SWC practices (Table 5). This showed that relatively better educated farmers were engaged in the managing of the implemented SWC structures. The odds ratio in favor of the success of implemented SWC structures increased by factor of 5.22 for an increase in education level which implies that structures in farmers who were more educated have good performance by 5.22 times than the SWC structures on farms of the non-educated household. Similarly, [29, 30, 31, 32] reported that better education level of household heads having a strong and positive relationship with farmers’ adoption and maintenance of SWC structure. Contrary to this, [33, 34, 35] elaborated that illiterate farmers are better to be involved in the management of the SWC structure than educated farmers who were usually engaged and spend their time in the off-farm activity and they had less willingness to apply SWC measures on their farm lands.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Explanatory variables | Coe(β) | SE | Ward | sig | Exp (B) |
| Level of education (leveldu) | 1.66 | 0.53 | 9.78 | 0.002 | 5.22 |
| Household head age (HHage) | -0.602 | 0.197 | 9.35 | 0.002 | 0.54 |
| Household head of sex (HHsex) | 0.928 | 0.209 | 19.78 | 0.000 | 2.53 |
| Training related SWC technology (traiSWC) | 1.85 | 0.57 | 10.01 | 0.002 | 6.23 |
| Farm size (farmsize) | 2.74 | 0.96 | 8.1 | 0.004 | 15.5 |
| Participation (partiwsp) | 2.28 | 0.538 | 18.05 | 0.000 | 9.84 |
| Home distance to upper farmland (homdisupp)  | -0.328 | 0.232 | 2.01 | 0.154 | 0.72 |
| Home distance to middle farmland (homdismid) | -0.94 | 0.485 | 3.8 | 0.05 | 0.389 |
| Home distance to foot farmland (homdisfo) | -2.98 | 0.67 | 19.37 | 0.000 | 0.05 |
| Home distance to bottom farmland (homdisva) | -1.4 | 0.46 | 9.01 | 0.003 | 0.246 |
| Maintenance and SWC implement (nomain) | 0.125 | 0.059 | 4.4 | 0.036 | 1.13 |
| Livestock holding number (livholno) | -1.769 | 0.872 | 4.11 | 0.043 | 0.17 |

Table 5: Analysis of explanatory variables (factors) for the success or failure of physical SWC structures using binary logistic model output, the coefficient (β) expresses the association of the independent variable and the performance of SWC structure

**3.4.2. Farm and grazing land size**

The average farm size of households (0.74 ha) in the study area was 0.73 ha while the average personal grazing land size was 0.035 ha. Farm size affected positively and significantly (β=2.74; p≤ 0.05) for success of SWC investment in the study area (Table 5). The odds ratio of farm size (Table 5) indicates that, other things being constant, the odds ratio in favor of performance of SWC practices increases by a factor of 15.5 as the farm size increases by one hectare. Similarly [36, 30] found that the farm size positively and significantly associated with the continued use of SWC. [28, 37] indicated that farmers having larger land size (>1.5 ha) practiced in maintenance and spend their time in investing conservation structures. About 26% of the respondents in the study area were landless. Landless and people with small land size were not active in the SWC investment and maintenance since their income, mostly depend by cultivating others land to gain half of its product and daily laborer. The same result was achieved by [35, 38] that described farmers with small farms do not tend to spend money on conservation practices. These authors also revealed that own plots are more managed than sharecropper plots.

#### **3.4.3. Home distance to farmland**

Home distance to farmland negatively and statistically influenced on performance of implemented SWC measures in the foot and the bottom part of the watershed (Table 5). As home distance decreases from the farmland the number of physical SWC structures increased. This was because high settlement of farmers was populated in the foot slope. The odds ratios indicate that keeping the influences of other factors constant, the performance of SWC measures decreased by the rate of 0.72, 0.389, 0.05 and 0.246 in the upper, middle, foot and bottom slope respectively as distance of the farmland increased by one kilometer. This agrees with the findings of [29, 36, 30] who stated that distance of farmland from the homestead was negatively correlated. Farmers having farmland far from their home do not visit to their cultivation field except during planting and harvesting season.

#### **3.4.4. Sex of household head**

The Households in the study watershed were characterized by 31 (27.4 %) and 82(72.6%) female and male headed. Household head sex (1=male, o=female) positively correlated with good performance of SWC structures at significant level 0.01 (β=0.928, p≤ 0.001) (Table 5). This indicated that male headed households were more likely to engage in maintenance and enhancing the performance of the SWC structures than the SWC structures owned by the female headed households. The odds ratio of logistic regression showed SWC structures constructed in the personal lands of the male headed were good performed by a factor of 2.05 than that the SWC owned by the female headed households. In line with this [29] reported that sex of household head was positively and statistically significantly correlated with the adoption of introduced SWC practices. [39] Suggested household head sex significantly and positively associated with watershed management. Women were the most affected by environmental hardships such as; fetching water, firewood, animal dung and attending livestock [39]. Because physical SWC activities were more labor intensive, which are difficult to be performed by female in the female headed household [26].

#### **3.4.5. Household heads’ age**

The age of the households surveyed in Adi-kimbro Watershed were under classes 18-30 (14%), 31-45 (48%), 46-60 (42%) and >60 (9%) respectively. Age of household was negatively related to performance of SWC structures (Table 5). The odds ratio suggests holding all independent variables constant one year increase in the age of household head decreased the performance of introduced SWC practices by a factor of 0.54 (Table 5). [29, 30, 40, 41] indicated that household age had a negative influence on farmers willingness to manage land and water conservation activities. As age of farmer increases, the willingness to manage SWC measures decreases. Thus, old farmers unable to give care for their farm land. [26, 27, 40,] stated that farmers over 60 years faced labor shortages for implementing and maintenance of structures.

#### **3.4.6. Training on SWC technology**

Assessment results of training on the technology of SWC measures were given to 23% household by experts on layout and technical design of the SWC structures. [36] Found 25.3% of respondents get frequent training on SWC organized by government and non-government organizations. The provision of training helps farmers to implement structures easily on their farmland and supports their neighboring. Training on SWC technologies was positively significant (β=1.85, p≤ 0.005) on the success of SWC structures (Table 5). The results of the odds ratio showed that the performance of SWC structures increased by factor of 6.23 for unit increased in training on SWC structures. This corresponds with the findings of [19, 40, 42, 43] stated that training positively and significantly affected the longevity of SWC structures.

#### **3.4.7. Maintenance**

The logistic model also showed maintenance of SWC positively and significantly (β=0.125, P≤0.05) associated with the success of implemented SWC structures (Table 5). Similarly [29] suggested that distance from home to homestead was negatively influenced the maintenance of the SWC structures in the farm land. The upper and middle landforms were implemented and maintained by community mobilization because it was communal land. But the foot and bottom landforms of the watersheds were mostly maintained by the individual beneficiaries and correlated at 0.01 and 0.05 significance level as shown in (Table 6).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Explanatory variables | Upper | Middle  | foot | bottom |
| Home distance to farm land  | -0.086 | -0.02 | -0.56\*\* | - 0.2\* |
| Availability of labor | 0.085 | 0.23\* | 0.057\*\* | 0.38 |

Table 6: Relationship of home distance to farmland and availability labour with the SWC structurer’s management and maintenance at different part Adi-kimbro watershed.

 Note: \*\* and \* indicates correlation is significant at 0.01 and 0.05 level (2-tailed).

#### **3.4.8. Livestock roaming**

The livestock holding number negatively and significantly correlated with the success or stability of SWC Table 6. The Pearson correlation result of the research showed that, the number of livestock holding was positive and significant at (p≤ 0.001) correlated to destruction of SWC structure as indicated in Table 6. Similarly [26, 36] found out that livestock holding was negatively associated with the use of SWC structures. The number livestock holdings negatively correlated with the management practices since households having a high number of livestock invested their time in raring and keeping of livestock than investing in SWC structures. [27] that stated farmers live in upper landforms were more involved in livestock keeping than other due to their grazing area near the forest. Free grazing was a common practice in the middle, foot and some part of the upper slopes of the watershed (Appendex1). When the field crops harvested, cultivated area was used for free grazing. [19] revealed that field crops were free after harvest farmers let their livestock for free grazing which have serious negative impact on SWC and natural resource. Another study by [23, 44] suggested that free grazing of livestock was among the major limitations to sustainable management of SWC measures. On contrary to the above findings, [39, 40] suggested that increased livestock holdings by farmers in the downstream increased the chance for improved land and SWC structures.

### **3.5. Other drivers of poor performance SWC**

Other drivers described by the group discussion and household survey for the poor performance of the physical SWC were destroying of the implemented SWC structures during maintenance and during implementation of new structures.

Absence of community participation: mostly participated in implementation stage as stated by 79.3% of HH, only few farmers participated in planning, designing and monitoring included in all stages of watershed development, thus leads on farmers less ownership. Indigenous knowledge was not considered and effectiveness of SWC purpose decreased accordingly. The main reasons for the failure of introduced SWC techniques were poor record of indigenous knowledge attributed to lack of appreciation for indigenous SWC practices and traditional SWC techniques of the farmers were not integrated to improved SWC in each stage of planning and implementation [45]. Quality material (poor arrangements of stones, rolling shape and quality of stone) decreased the design and life span of SWC structures in the study watershed especially in the foot slope.

## **3.5. Challenges of the implemented physical SWC structures**

Participants of free-labor in the implementation of SWC structures lack short-term benefits. Correspondingly, stone terracing is labor intensive and the costs are usually not repaid by short-term [46]. Particularly, the landless peoples were negatively affected economically by their involvement in free-labor as their livelihood fully depend on off-farm income which in turn negatively affect the quality of the SWC structures as their main intention was to fulfill their daily norm work. Research findings by [47, 48] in central Tanzania and Ethiopian highlands respectively, reported similar cases where landless farmers invest their labor on SWC have limited short-term benefit pattern from the interventions. 12.3% of the respondents indicated physical SWC structures had economic interference for landless persons during free-labor, 10.6% of them stated formation of flood incidence due to its improper design. Physical SWC structures was difficult both technically and requires intensive human labor intensive (26.2% of respondents). [49] Finding revealed stone bunds are labor intensive. Easily destroyed if not stabilized and frequently maintained as stated by 8.8% respondents, 11.7% of them stated that they were home of rodent and weeds.

# 4. Conclusions and Recommendations

Among the implemented physical SWC structures, check dams, in the gulley at the bottom part of the watershed was comparatively effective in controlling soil erosion, rehabilitating degraded area and deposition of the soil. The current status of physical SWC in study area characterized as poor because have been less or no ecological and economic uses. Maintenance of SWC structures in communal land and gully was less. Due to this the destruction level of hillside terraces +trenches, hillside terraces, loose stone check dams and stone bunds were high in the communal grazing land (>50%) compared to the closed and cultivated lands in all landforms.

The socioeconomic factors such as farm size, sex of household head, availability of labor and level of training were positively and significantly correlated with the management and success of SWC structures. SWC structures were negatively affected by home distance to farm land, household head age and livestock holding number. As the distance of farm land from home increased the frequency of managing become low. The factors for poor performance of the implemented physical SWC structures were improper design, community participation in the stages of watershed management, livestock roaming, and absence of integration. The biophysical drivers like slope and soil depth should considered during planning, designing and implementing the SWC measures. SWC structures should be constructed by considering the household head age, labor availability, farm size, level of training, household sex and indigenous knowledge of the community.

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 Appendix:

Fig. A1. Household response on drivers that determine performance drivers of SWC in each slope of the study watershed.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Upper slope |  |  Middle slope |   |  Foot slope |   |  Bottom slope |   |
| Scientific name  | local name | scientific name | local name | scientific name  | local name | scientific name  | local name |
| Otostegia integrfolia | Chiendog  | Maytenus arbutifolia | Atat | Jacaranda mimosifilia | Bus | Lantana cammera | Alalimo |
| Sageretia spiciflora | Hakot | Euclea schimperi | Kuliao | Euphorbia tirucalli | Kinchib | Eucalphtus  | Kelamitos |
| Euclea schimperi | Kuli`ao | Dodonea angustifolia | Tahsos  | Acacia seyal | Chia | Acacia albida | Momona |
| Maytenus arbutifolia | Ata`at | Agave sisalana | Eka | Croton macrostachyus | Tambok | Sepania sesban | saspania |
| Dodonea angustifolia | Tahsos | Diospyros mespiliformis | Aye | Cordia africana | Awhi | Pennisetum purpureum | elephant grass |
| Cassisingueanea | Hambhabo | Acacia seyal | Chia | Ehretia cymosa | Millio | Acacia seyal | chia |
| Euculphtus  | Kelamitos  | Cassisingueanea | Hambo hambo | Ricinuscommunis | Gulie | Zizphus spina-christi | Geba |
| Acacia pol | gemero | eucalyphtus camaldulensiss | Kelamitos | Ficus carica | Beles | Croton macrostachyus | Tambok |
|  |  | euculphtus glorbious | Habitselim | Rhus natalensis | Tetaelo |  |  |
|  |  | euculphtus glorbious | Geba | Rulmux nervosus | Hakot |  |  |
|  |  | Dodonea angustifolia | Tahsos  | Lantana camara | Alalimo |  |  |
|  |  | Acacia ethaica | Seraw | Anogeisus leiocarpus | Hanse |  |  |
|  |  | Acacia brevispica  | Konteftefe | Zizphus jujube | Abetere |  |  |
|  |  | Lantana camara | Alalimo | Ziziphusspina-christi | Geba |  |  |
|  |  | calpurnia aurea | Htsawtsi | Cassia singueanea | Hambahambo |  |
|  |  | Cordia africana | Awhi | Melia azedarach | Nim |  |  |
|  |  | Maytenus senegalensis | Agudi | Acacia ethaica | Seraw |  |  |
|  |  | Ehretia cymaosa | Kerah | calpurnia aurea | Htsawtsi |  |  |
|  |  | Acacia abyssinica  | tseeda chia |  |  |  |  |
|  |  | Otostegia integrfolia | chiendog |  |  |  |  |
|  |  | faidherbia albida | Momona |  |  |  |  |
|  |  | Acacia lahai | Lihay |  |  |  |  |

Appendix 2: Biological soil and water conservation structures along transects of the watershed.