FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Assessment of Design and Constraints of Physical Soil and Water Conservation Structures in respect to the standard in the case of Gidabo sub-basin, Ethiopia

Getahun Hassen1*, Amare Bantider2,3, Abiyot Legesse6 and Malesu Maimbo5

Abstract: In Ethiopia institutional and extensive soil and water conservation (SWC) started in the 1970s. Due to several factors, most SWC works have not fully achieved the intended objectives. The disparity between dimensions of the implemented SWC work and the standard is the main factor. Therefore, this research work aimed to assess the design and constraints of SWC in the Gidabo sub-basin, of the Ethiopian rift valley. Data were generated through field observation, field measurements, household survey, interview, group discussion, and Arc GIS. According to the result, about 47.3% of the physical design of the implemented SWC structures failed to meet the standard dimension. In addition, the SWC lacks the standard supportive activities, such as the cut of the drain, check dam, biological work, and frequent maintenance. FGD and KII showed about 71.3% of the farmers accepted SWC technologies, but they have constraints for SWC. These were small land size, food insecurity, lack of resources, technical skill, field guidance, poor maintenance, as well as young migration. The researchers used the chi-square test for the significant variation of constraints along with different agro ecology. According to the chi-square result, significant association was observed between land size,

ABOUT THE AUTHOR

Getahun Hassen is a PhD candidate in the department of Natural Resources Management at Dilla University, Ethiopia. He has more than six years of teaching experience in different government and nongovernmental organizations. Also he worked as a coordinator of Dilla University research and dissemination support center until he began his current PhD study. Professionally he has five publications (research and review work) in internationally peer-reviewed journals. Besides, he has got more than ten certificates of participation in academic and social trainings at national and international forums.

PUBLIC INTEREST STATEMENT

Land degradation via soil erosion is a global problem affecting socio-economic and environmental conditions. Mainly the developing countries like Ethiopia are more victims of soil erosion. To solve the problem, both traditional and modern conservation works have been underway. Even if the modern technology of soil and water conservation practice seems relatively a recent phenomenon it has passed three to four decades since it was introduced. But the conservation work could not achieve the intended objectives as long as its age and its contribution to millions of food-insecured people. Among several factors, the technical limitations of the conservation work are the main ones for this. This paper thus demonstrates the major technical problems of the conservation work and its constraints against the standard. The research result is important in that it contribute in the global, national and local level to achieve sustainable socio-economic and environmental development.
access to fertilizers, seeds, pesticides, construction materials, technical skill, and maintenance of the structures versus agro ecology. Therefore, the implementation of SWC practices should be focused on the way to avoid/lower the observed mismatch of the structures against the standard. Also the constraints in different agro ecology should be solved through full community participation in order to follow the standard SWC measures for sustainable socio-economic and environmental development.

Subjects: Collaborative Design; Education; Political Economy; Environmental Economics; Research Methods in Education; Sustainability Education, Training & Leadership; Hazards & Disasters; Physical Geography

Keywords: Community; Constraints; Evaluation; Perceptions; Soil and Water Conservation; Conservation technologies

1. Introduction

Agriculture is a key livelihood source for over 85% of the Ethiopian population and thus it plays a crucial role in the country (Beyene, 2015). However, anthropogenic and natural factors are adversely affecting agricultural productivity (Erkossa et al., 2018). Mainly human-induced soil erosion takes the front stage on soil erosion and fertility depletion limiting increasing food production (Haregeweyn et al., 2017).

Ethiopia has been described as one of the most soil erosion areas in the world (FAO, 2011). The rate of soil loss by water ranges from 16 to over 300 Mg ha⁻¹ yr⁻¹, mainly depending on the degree of slope gradient, type of land cover, and nature of rainfall intensities (A. Tesfaye et al., 2014).

According to Yesuf et al. (2008) one billion cubic meters of fertile top soil is lost per annum in the country. Soil erosion made that most households are in a vicious cycle of poor agricultural productivity, low returns to enable investment, continued resource overuse, and increasing demand for more land (Ehui & Pender, 2005).

To alleviate the impact of soil erosion, institutionalized soil and water conservation practices, started in the 1970s mainly focused on soil/stone bund, trench, and agroforestry (Dagnew et al., 2015; Taye et al., 2013); while in 1990 watershed-based SWC work was integrated with natural resource intensification and livelihood options in the different micro watersheds of the country (Haregeweyn et al., 2015; SLMP, 2013).

Despite great efforts made on soil and water conservation work, the magnitude and rate of soil erosion are continuing (Wolka, 2014; Engdayehu et al., 2016). The impact of SWC practices is responsive to local natural resource management concerns and focused on multiple interests. According to Daniel (2001), and Girma (2000) topographic conditions, farming practice, intense rains, low soil fertility, poor land cover, and interest among farmers to adopt conservation practices determine the impact of SWC practices.

A recent study demonstrated that the technical aspects of SWC structures are an important part of conservation work, which determine the drainage network, rate of erosion, soil degradation, and soil productivity (Worku., 2017). According to Tsegaye and Awdnegest (2018), the mismatch between the recommended and implemented dimension of conservation work is among several factors for less achievement of SWC practices.

Ethiopia has a great climatic variety from dry to wet and many altitudes from low lands to highlands (Hurni et al., 2016). Selecting the right soil and water conservation technology for the right place is a key problem for farmers in the soil erosion areas (Namirembe et al., 2015). A major
need in SWC is the choice of the proper/compatible conservation technologies and dimension for ecological and socio-economic conditions (Namirembe et al., 2015).

Therefore, this research work was designed to test the physical and technical compatibility, acceptability, and constraints of SWC activities and farmers’ perception of SWC practices. Under this concept, the technical aspects of selected soil conservation structures and level of community participation on SWC were evaluated based on the national guideline recommended for different agro ecology and landscape type.

Also the farmers’ perception of the source of soil erosion and constraints to adopt the selected soil conservation practices were assessed in detail. The result of this study is very important to select the right SWC technology and make sure the effort of conservation for sustainable ecosystem services in the 21st century.

2. Materials and Methods

2.1. Study area description

Gidabo River sub-basin of this research work is situated in the south-eastern rift valley region of Ethiopia. The area is specifically in the limits of 6°11’N to 6°34’ N latitude and 38°12’E to 38°32’E Longitude. The southeastern rift valley region of Ethiopia is part of the Great East African Rift Valley. The administrative boundary of the Gidabo river basin is in the Southern Nations Nationalities and Peoples and Oromia Regional government (see Figure 1).

The highest altitude of the river basin is about 3029 m a.s.l in the south, and the lowest point is 1205 m a.s.l in the west part of the basin. The Gidab river sub-basin covers about an area of 102,738 ha, which is found in the dynamic and fragile landscapes (Bekele et al., 2018).

For instance, topographically the river basin has highly been affected by the late tertiary rifting activity and erosion processes (Wolde Gabriel et al., 2000). According to Ayenew and Becht (2008) and Bonini et al. (2005), the geological and geomorphological features of the region are related to Cenozoic volcanic rock (rhyolite, ignimbrite, trachyte basalt, and pyroclastic) and lacustrine sediments. The topographic variation of the area was caused for the economic variation of the people long different agro ecology.

Though the main economic activity of the river basin is forest-based agriculture (agroforestry); while mixed farming (livestock production and cultivation of crops) is the principal occupation of the people in the highland and lowland area of the river basin. Nowadays, agroforestry-based
economic activity is highly dominating the river basin that is caused by population growth and variability of climate.

In Figure 2, rainfall data for the last seventy years were collected from three stations named Bule, Wonago, and Dara. The stations in Figure 2 represent various agro ecologies with variable climate; for instance, Bule station is for highland, Dara and Wanago stations are mainly for mid land and adjacent lowland area.

The rainy seasons of the study area are characterized by a bimodal pattern, the main rainy (Kiremt in Amharic language) season occurring from June to September and the small rainy season (Belg in Amharic language) occurring between February and May (Bekele et al., 201). As seen in Figure 2, the average rainfall of the study area ranges from 900 to 1400 mm in the dry and rainy period, respectively, and the average monthly temperature of the area varies from 21°C to 25°C in the lowland and from 12°C to 18°C in the highland.

2.2. Research method and data collection
For this research work, mixed method of data collection approach was used. It is an often-used method for different disciplines and researchers to meet the needs of diverse interests and unique perspectives (Tashakkori & Teddlie, 2010).

Therefore, both qualitative and quantitative method were used to describe/investigate the dimension of SWC structures, acceptability, and constraints of SWC practices. As part of mixed-method approach, concurrent triangulation design was used to give equal priority to the concurrently collected qualitative (QUAL) and quantitative (QUAN) data.

The purpose of selecting this design is to have more defined relationships among variables of interest. This approach is important to increase the findings reliability and credibility through the triangulation of different but complementary data on the same topic to better understand the research problem (Morse, 1991).

2.3. Site selection and sampling technique
The research site choice was carried out based on the traditional agro-ecological classification approach, because it is simple, manageable, and common among the land users. Agro-ecological difference can be defined as a spatial classification of the landscape into area units with similar agricultural and ecological characteristics (Altieri, 1995).

In mountainous countries like Ethiopia, the topography particularly altitude, steepness, and slope characteristics plays an important role in agro-ecological zonation (Hurni, 1998). Based on
this fact three agro-ecological categories such as low land altitude ranges from 500 to 1,500 m, mid land altitude ranges from 1500 to 2300 m, and highland altitude above 2300 m was used with major variations in terms of slope steepness and farming system.

As to the sampling techniques, both probability and nonprobability sampling were used in this study. Probability sampling was used for household survey and nonprobability was used for focused group discussion (FGD) and key informant interview (KII). In this regard, multistage sampling was used to select kebeles and socio-economic data.

Based on agro-ecological variation, the extent of the implementation of SWC practices, accessibility, and population density in the first stage, four woredas (in Ethiopia local administrative group that forms a district/zone) were purposefully selected. Selected woredas are namely Bule from high land, Wonago and Dara from mid land and Abaya from low land agro ecology.

Secondly, seven kebeles (i.e. the lowest administrative body) were selected from the identified woredas, these are “Kochere, and Suqo” from Bule woreda, “Tumata Chirecha” from Wonago woreda, “Gelowacho, Korate and Adame from Dara Woreda and “Semero” from Abaya Woreda. In the third stage, based on the intended goals, participants for FGD, KII and household survey were selected from seven Kebeles that are found at different agro ecology.

2.4. Data types and sources
For the sake of reliability and validity of the data and to discuss the formulated goals, the researchers used both primary and secondary data sources. The primary sources of data were observation, field measurement, photographs, questionnaires, and interview. And secondary data sources were publications, books, journal articles, and internal records.

Evaluation of the design/dimension of the implemented SWC technologies was made in comparison with the standard for SWC. The standard guidelines tell the measures and approaches that are considered best for the different watersheds at local conditions in Ethiopia (Hurni et al., 2016; Lakew et al., 2005; Namirembe et al., 2015).

2.5. Tools for data collection
2.5.1. Field observation and measurement
Field observation and survey question were carried out to identify the type of conservation technologies used for SWC practices. Then transect walk was made to collect data of micro watersheds, technical design/dimension of the conservation structures, soil type, rainfall, temperature, slope, and age of conservation.

During field work an average of 11 sample sites were selected purposefully. From the identified sample site and conservation technologies; field measurement was carried on the slope gradient, soil depth, structural embankments (berm), depth, width, and the vertical interval between structures.

The slope gradient was measured with the water level method. A thin plastic rope with 10 m long and 4-m-long wooden Poles were used for marking on the ground. Then the slope was identified with the value variation of the vertical interval and horizontal distance multiply by 100 (see Fig 3 and Fig 4).

Finally, the result on conservation structures from field measurement was compared with the standard prepared for development agents and experts at Woreda level for different soil characteristics, topography, agro ecology, and rainfall conditions (Hurni et al., 2016; Lakew et al., 2005; MoARD, 2005).
2.5.2. Key informant interview
Based on the intended goals, the researchers purposefully selected participants for key informant interview (KII) from seven kebeles that are found at different agro ecology. To make the interview, three to four key informants were selected from each Kebele based on gender, experience on SWC work, and social recognition. The KII was aimed at obtaining important qualitative information about their knowledge and perception of the design, acceptability, and constraints of the SWC technologies (see Figure 10).

2.5.3. Focus Group Discussions/ FGD
For the sake of FGD three agro-ecology representative Kebeles were purposefully selected. From the selected Kebeles three to four focus groups were prepared with a maximum number of five to six participants.

The FGD participants include farmers, expertise, administrators, and development agents from the highland, midland, and lowland agro ecology. The aim of FGD was to obtain important qualitative information concerning the perception, knowledge, and idea of the participants about SWC technologies, design, acceptance, and constraints to adopt the conservation work.

2.5.4. Household heads interview
In the first stage of the household survey, ten randomly selected households were used to test the validity and clarity questionnaire before launching the last survey. Based on the feedback obtained during the pretesting, an adjustment was made on the flow, consistency, and clarity of the questions. The household heads were interviewed by 14 enumerators from seven kebeles, two enumerators for each Kebele, and with close follow-up from the researchers. Before the interview,
 enumerators were trained on how to translate the interview questions into the local language, while they interview participants.

The survey questionnaires covered a range of information, which includes farmers’ socio-economic condition, participation in SWC, acceptability of SWC work, perception on design/dimension of structures, and constraints of conservation practices.

2.6. Data processing and analyses
The data collected from both primary and secondary sources were analyzed and summarized using quantitative and qualitative methods of Microsoft excel 2010 and SPSS software version 20. The structured household survey data, such as demographic, socio-economic characteristics, and opinions of the farmers were analyzed and interpreted with appropriate statistical tools.

Among the statistical tools chi-square test, descriptive statistics, frequency, percentage, and graphs were used. The chi-square was used to test the level of variation of constraints along with different agro ecology. And the descriptive analysis was used for comparison of the design/dimension of the implemented SWC structures with the standards.

3. Results and Discussion

3.1. Household and the basic livelihoods of farmers
According to the data from the household survey, interview, and group discussion, the majority of the farmers in the study area are dependent on agriculture. In the highland agro ecology, farmers are mainly dependent on the production of enset, livestock husbandry (sheep, cattle, and horses), production of cereal crops and vegetables (potato, ginger, taro, chives).

In the midland area, the major livelihood of the community is agroforestry-based agriculture, such as enset, banana, coffee, avocado, mango, as well as homestead livestock production. Also fuel wood collection and daily labor in the urban areas is the additional livelihood option for the community.

The farmers in the lowland were more dependent on annual crop productions, such as maize, teff, haricot bean, root crops, charcoal production, collecting fuel wood, charcoal production, and daily labor, in the urban area.

In the past few decades, a decline in agricultural production increased the food in secured people; due to this, Safety Net programme, production of fuel wood, charcoaling, and daily labor in the nearby urban is an increasing livelihood option for survival.

Recent report by Regassa Debelo et al. (2017), Degefa (2016), and Legesse (2014) showed that the dominant source of livelihood of the community that depends on agroforestry-based agriculture is losing its productivity due to climate change, soil erosion, and poor SWC practices.

The major sources of income for the households are coffee, enset, fruits, tree products, animals, and animals’ products (WWRDO, 2006).

4. NEGASH

4.1. Community participation in soil and water conservation practices
The community participation in soil and water conservation (SWC) is mostly dependent on their perception of the soil erosion problems and the significance of the conservation technologies (Nigussie et al., 2018). According to the household survey about 70% of the farmers are participating in soil and water conservation of their own interest.
The farmers participate in the SWC practice in two ways; the first is community participation on SWC is under the Safety Net program. In this approach the people have a monthly payment for their soil and water conservation works. In this approach the numbers of women participants are higher than men.

This is because like the case of many developing countries, the majority of the women in the study area are economically dependent on their husbands. Particularly in the last few decades, the reduction of agricultural product primarily led to an increased number of food insecurity women. The other important issue for the Safety Net program was the higher number of participants in the SWC works that have payment for their conservation work (see Figure 5).

The second approach is the thirty (30) days of free community participation on SWC practices (see Figure 6). In this approach the community participates in the conservation work out of their good wills. The number of total participants as well as women participants in the 30 days of conservation work is less than the Safety Net program.

The major threat of the experts for the Safety Net program is the rise of dependency attitude among the farmers for aid. This condition has an adverse impact on the conservation work. Because effective natural resource conservation work needs farmers’ own interest in adoption of the conservation technology and regular maintenance of the implemented SWC practices, rather than working for aid, which has no continuation on conservation work.

The household survey in Table 1 showed that the participation of the community for SWC in the three agro ecology was restricted, and remained on selected activities than participating at all levels. According to Table 1, the level of farmers’ participation in SWC varies in the three agro ecologies.

About 82.7%, 61.8%, and 55.1% of the community in the midland, lowland, and highland agro ecology, respectively, participated in introduction about SWC, decide the date and days of conservation work, give labor force as well as provide construction materials. The reports by Lakew et al. (2005), Adgo et al. (2013) as well as MoARD (2005) showed that the national guideline for SWC recommends full community participation from problem identification to the maintenance of the SWC structures.

Besides the limited participation of the community on SWC work of the study area, the level of community participation is not similar in the three agro ecology. For instance, in the midland area the community participation is higher, while in the highland area the least community participation was recorded.

According to KII and FGD participants, the higher community participation in the midland was related to better access to transport services, infrastructures, government, and nongovernment offices, institutions, skilled manpower, and better information among farmers for SWC work.

Besides the lack of access to infrastructure, the land degradation (soil erosion) problem is more serious in the lowland and midland area than the highland. As Fig 7, Fig 8 and Fig 9 show, a large area in the highland was covered with grass that reduced soil erosion.

Whereas the land covers in the lowland and midland area were highly exposed the soil to erosion, because of population density in the midland and water scarcity in the lowland. The loss of soil caused the reduction of agricultural products that adversely increased the interest of the farmers to participate in the SWC work.

The data from the community and field observation depicted that the community participation in SWC work of the study area was inadequate and limited which failed to meet the lower standard of community participation recommendation for SWC work.
A similar result has been mentioned by Biratu and Asmamaw (2016) in the Gusha Temela watershed in Arsi Ethiopia the community participation in the SWC is lower according to the national standard.

The major SWC problem observed in Ethiopia was top to down approach. Mostly the conservation technologies go to farmers’ field without considering the full involvement of the farmers. The limited community participation in SWC work has adverse impacts on the conservation effort (Asfaw & Neka, 2017; Wolka et al., 2018).

4.2. The existing soil and water conservation technologies and its acceptability
According to the participants and field observation, the traditional SWC technologies are horizontal plough, land rotation, crop rotation, mulching, apply residuals (manure), fencing, and indigenous agroforestry.

On the other hand, although the introduced SWC technologies are soil bund, fanaya juu, micro basin, I brow basin, trench, and half-moon, this does not mean all these conservation technologies were uniformly implemented in all agro ecology or selected site.
Table 1. Level of community participation on SWC work at different agro ecology

| R.N | Level of community participation in SWC practices | Highland Agro ecology | Midland Agro ecology | Lowland agro ecology |
|-----|-------------------------------------------------|------------------------|----------------------|----------------------|
|     |                                                 | Yes (%) | No (%) | Yes (%) | No (%) | Yes (%) | No (%) |
| 1   | Participated only for introduction about SWC practices. | 51 | 49 | 69 | 31 | 53 | 47 |
| 2   | Participated in identifying area of conservation. | 17 | 73 | 40 | 60 | 28 | 72 |
| 3   | Participated only for advice | 33 | 67 | 45 | 55 | 37 | 63 |
| 4   | Participated in identifying/ prioritizing the SWC technologies. | 3 | 97 | 88 | 12 | 5 | 95 |
| 5   | Participated to decide the date of SWC for Safety Net. | 43 | 57 | 55 | 45 | 39 | 61 |
|     | Participated to decide the date of SWC for free service. | 65 | 35 | 93 | 7 | 74 | 36 |
| 6   | Participated to decide on the number of days for SWC under Safety Net. | 37 | 63 | 40 | 60 | 38 | 62 |
|     | Participated to decide the number of days for SWC under free service. | 52 | 48 | 60 | 40 | 56 | 54 |
| 7   | Participated to give labor. | 60 | 40 | 90 | 10 | 81 | 19 |
| 8   | Participated by contributing materials for construction. | 70 | 30 | 85 | 15 | 77 | 23 |
| 9   | The communities have interest to participate in the conservation work. | 65 | 35 | 80 | 20 | 69 | 29 |

According to (Teshome et al., 2014), the SWC technologies such as stone bunds and Fanya juu bunds were the most promoted technologies in Ethiopia. Among the introduced SWC technologies, the most common and more acceptable conservation structures in the selected sample area of highland agro ecology were soil bund, fanya juu, and bench terrace.

In the midland were micro basin, soil bund, and fanayajuu. While in the low-land area were micro basin and soil bund which were widely adopted technologies. The best SWC technologies are the ones that influence the farmers’ decision for acceptance and adoption, design of the structures, control soil erosion, improve land productivity, and simplicity of adoption (Teshome et al., 2014).

In Table 1 the household survey depicted that about 80% of the midland, 69% lowland, and 60% high land farmers told that the above-mentioned conservation technologies were acceptable in their respective areas. The farmers’ selection to accept the conservation structures indicates that technologies have been contributing to the reduction of soil loss and increasing agricultural productivity. However, the adoption of the SWC technologies based on the standard seemed unlikely because of the constraints to adopt SWC activities.

4.3. Physical design of conservation structures and constraints against the standard

The physical design of each conservation structure of the study area was compared with the standard recommended for different agro ecology, soil type, soil depth, and slop gradient as reported by (Hurni et al., 2016; MoARD, 2005; Lakew et al., 2005). In this regard, the recommended size for fanayajuu, soil bund, bench terrace, micro basin, and slope gradient for different agro ecology was presented in (Tables 2 and Tables 3).
All the time selection of SWC structures and design was focused on the slope, climate, soil characteristics, availability of labor force, and construction materials (Bashir et al., 2018). According to the data from the household survey, FGD and KII the farmers perceived that the newly introduced SWC technologies are effective measures to control soil erosion and improving land productivity.

However, the adopted SWC technologies in most sample sites of the study area failed to meet the standards to the extent of addressing deforestation, control soil erosion, and increase land productivity.

The participants told that the failure of the structures to meet the standard in the study area was related to the constraining factors listed in Table 4. Though the listed constraints are found in all agro-ecology variation of impact was observed in the three agro ecology that was described in section 3.9.
4.4. Technical result of conservation structures in highland agro ecology

According to the Ethiopian meteorology agency and information from the local agricultural office, the climate of the highland area is characterized by an average annual rainfall of 1150 mm and an average annual temperature is 15°C (see Figure 2).

The altitude of this agro ecology was situated in the range from 2800 to 3000 m above sea level. In this agro ecology the commonly implemented structures of the selected sample area were soil bund, fanya juu, and bench terrace. During field measurement and field observation, the researchers compared the implemented SWC technologies and design of the structures with nationally recommended (see Table 5).

According to the field result (Table 5), about 52.2% of the conservation structures were carried out according to the standard, such as dimension for embankment height, workable soil depth (cm), and average slope/steepness.

**Figure 10.** Interview with the farmers.

**Figure 11.** Conservation work below the standard.

Source: Researcher March 2020

---

Hassen et al., Cogent Food & Agriculture (2021), 7: 1855818

https://doi.org/10.1080/23311932.2020.1855818

Page 12 of 29
Whereas about 47.8% of the sampled site dimension of the structures, such as distance of the ditch to berm, depth of the ditch, width of the ditch, embankment width, and vertical interval between consecutive structures failed to meet the standard.

For instance, in Table 2 of sample site 1, the VI between the consecutive soil bunds was by 6 m higher than nationally recommended, whereas a smaller value was recorded in the depth and width of the ditch, embankment width, and distance of the ditch to berm. In the case of plot 2, the dimension of the graded fanyajuju, such as embankment width and embankment height was less than the standard, while the vertical interval between consecutive structures was higher than the standard.

According to the household survey, about 54% of the respondents in highland agro ecology indicated that the major challenge to apply the standard dimension of VI was the shortage of land that was caused by high population density.

According to the central statistical data for 2013, the density of the population in most Kebeles of the highland ranges from 450 to 670 persons/km². The farmers perceived that if the conservation structures are constructed according to the standard spacing, it will consume more land, this will exacerbate the problem of land shortage.

Respondents also added that acidic soil, poor access to fertilizer, seed, construction material, technical skill, lack of maintenance, as well as long last impact that not measured monetarily were discouraging the farmers to apply the standard design for conservation work. During field observation researchers also observed that the experts shared the fear of the farmers and implementing the SWC structures below standard rather than giving awareness to the community.

### 4.5. Technical result of conservation structures in the midland agro ecology

The midland agro ecology was characterized by an average annual rainfall of 1150 mm and a temperature of 21.5°C. According to Table 3, the major SWC structures in selected plots of this

| Table 2. Value for VI for bench terrace at different soil depth and slope gradient |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Slope gradient soil depth (cm)  | 25 cm           | 50 cm           | 75 cm           | 100 cm          | 1.25 cm         | 1.50 cm         |
| <15%                            | <1 m            | 1 m             | 1 m             | 1 m             | 1 m             | 1 m             |
| 20%                             | 2.80 m          | 5.60 m          | 8.40 m          | 11.30 m         | 14.10 m         | 16.90 m         |
| 30%                             | 1.80 m          | 3.50 m          | 5.30 m          | 7.10 m          | 8.90 m          | 10.60 m         |
| 40%                             | 1.30 m          | 2.50 m          | 3.30 m          | 5.00 m          | 6.30 m          | 7.50 m          |
| 50%                             | 0.90 m          | 1.90 m          | 2.80 m          | 3.80 m          | 4.70 m          | 6.60 m          |

Source: Hurni et al. (2016).

| Table 3. Recommended V.I for soil bund and fanyajuju at different soil depth and slope |
|---------------------------------|-----------------|-----------------|
| Slope %                         | Depth of soil   | Vertical interval |
| 1-15%                           | >50 cm          | 1 cm            |
| 15-25%                          | >60 cm          | 1.50 m          |
| 25-35%                          | >50 cm          | 2 m             |
| 35-44%                          | 50 cm           | 1.25 m          |
| 45%                             | 25 cm           | 0.62 m          |

Source: Hurni et al. (2016) and Local agricultural office conservation manual (2012)
Table 4. List of constraints along different agro ecology

| R.N | Lists of constraints                          | Midland | | | | Lowland | | | | Highland | | |
|-----|---------------------------------------------|---------|--------|--------|--------|---------|--------|--------|--------|---------|--------|--------|
|     | Response of land users                     | Yes  | No  | Yes  | No  | Yes  | No  | Yes  | No  | Yes  | No  | |
| 1   | Small farmland area                        | 145   | 5    | 3%   | 37    | 54%   | 32    | 47%   | 32    | 53%   | 28    | 47%   |
| 2   | Poor access to fertilizer, seed and pesticides | 105  | 45   | 30%  | 59    | 85%   | 10    | 15%   | 56    | 94%   | 4     | 6%    |
| 3   | Food insecurity                            | 132   | 18   | 11.7%| 63    | 91.3% | 21    | 30%   | 47    | 78%   | 13    | 22%   |
| 4   | Inaccessibility of construction material    | 75    | 75   | 50%  | 45    | 65%   | 24    | 35%   | 40    | 67%   | 20    | 27%   |
| 5   | Lack of technical skill on SWC practices    | 76    | 74   | 49%  | 57    | 83%   | 12    | 17%   | 51    | 85%   | 9     | 15%   |
| 6   | Lack of interest for young generation to work agricultural activities | 110  | 40   | 23%  | 46    | 67%   | 23    | 33%   | 40    | 67%   | 20    | 27%   |
| 7   | Lack of frequent and continues maintenance | 112   | 38   | 25.3%| 62    | 90%   | 7     | 10%   | 55    | 92%   | 5     | 8%    |
| 8   | Lack of field guideline for SWC practices   | 132   | 18   | 18%  | 61    | 89%   | 8     | 11%   | 53    | 89%   | 7     | 11%   |
| 9   | Weak interaction among stakeholders         | 128   | 22   | 14.7%| 59    | 85.5% | 10    | 15%   | 51    | 85%   | 11    | 15%   |
| 10  | Total No of respondents                     | 150   |       | 69    |        | 60    |       |        |        |        |        |        |
agro ecology were soil bund, fanayajuu, and micro basin. These conservation structures are mainly being implemented in clay soil.

In this agro ecology, of the total dimension of the implemented conservation structure, about 44% was carried out according to the standard, and about 56% of the dimension failed to meet the standard.

The recommended vertical interval between structures, such as level soil bund and level fanya juu are 1.5 m to 2 m and from 2 m to 5 m between consecutive micro basin (Hurni et al., 2016; Lakew et al., 2005; MoARD, 2005).

| Sample site 1 | Implemented | Recommended | Deviation from the recommended |
|---------------|-------------|-------------|-------------------------------|
| Specifications |             |             |                               |
| Type of structures | Soil bund | Soil bund | Standard                       |
| Average slope/ steepness (degree) | 17 | 1–26 | Standard                       |
| Workable soil depth (cm) | > 45 cm | 30–60 cm | Standard                       |
| VI b/n consecutive structures (m) | 7.5 m | 1.5 m | 6 m                           |
| Depth of the ditch | 65 cm | 60 cm | –5 cm                         |
| Width of the ditch | 50 cm | 60 cm | –10 cm                        |
| Embankment height | 60 cm | 60 cm | Standard                      |
| Embankment width | 75 cm | 1 m | –0.25 cm                      |
| Distance of the ditch to berm | 20 cm | 25 cm | –0.5 cm                       |

| Sample site 2 | Implemented | Recommended | Deviation from the recommended |
|---------------|-------------|-------------|-------------------------------|
| Specifications |             |             |                               |
| Type of structures | Fanya juu | Fanya juu | Standard                      |
| Workable Soil depth (cm) | 60 cm | 60 cm | Standard                      |
| Slope (in degree) | 22 | 1–2 | Standard                      |
| VI b/n consecutive structures (m) | 8 m | 1.5 m | 6.5 m                         |
| Depth of the ditch | 60 cm | 60 cm | Standard                      |
| Width of the ditch | 50 cm | 50 cm | Standard                      |
| Embankment height | 55 cm | 60 cm | –0.5 cm                       |
| Embankment width | 60 cm | 1.5 m | –90 cm                        |
| Distance of the ditch to berm | 20 cm | 20 cm | Standard                      |

| Sample site 3 | Implemented | Recommended | Deviation from the recommended |
|---------------|-------------|-------------|-------------------------------|
| Specifications |             |             |                               |
| Type of structures | Bench Terrace | Bench Terrace | Standard                       |
| Average slope/ steepness (in degree) | 20 | 3–50% | Standard                      |
| Workable Soil depth (cm) | 50 cm | 50 cm | Standard                      |
| VI b/n consecutive structures (m) | 5 m | 1–1.75 m | 3.25 m                       |
| Depth of the ditch | 1.5 m | 1.5 m | Standard                      |
| Width of the ditch | 5 m | 2.15 m | 2.85 m                       |
The field measurement in the midland area of sample site 1 (Table 6) showed the embankment width, embankment height, distance of the ditch to berm; vertical interval between consecutive soil bund failed to meet the standard.

This result indicated about 55.5% of the design/dimension of the soil bund is either higher or lower than the standard. In the sample site 2 (Table 6) dimensions of soil bund all design failed to meet the standard, except for selection of the SWC technologies and slope identifications.

The participants on FGD and KII also mentioned to the researchers that the soil types of the area were mainly covered with clay, which is hard to dig according to the standard. Regarding to sample site 3 (Table 6) dimensions of Fanaya juu structures, such as, embankment height and width, depth of the ditch, vertical interval between structures, and soil depth (cm) failed to meet the standard.

The field measurement result for the micro basin showed that about 67% of the dimension was constructed according to the standard. This value is better compared to the soil bund and Fanaya juu structures. The only problem observed on the micro basin was the wider vertical interval and smaller depth of the ditch.

About 97% of the participants in the midland agro ecology argue that the shortage of land, clay nature of the soil (i.e. sample 2), the long-lasting monetary impact of the conservation work, lack of access to synthetic fertilizers and improved seed as well as food insecurity were the major constraints against standard structures. A particularly small parcel of land size (0.2 ha–0.02 ha) for each farming family is challenging to apply the narrower vertical interval between structures.

According to the 2013 central statistical data, the density of the population in most Kebele of the midland area is more than 1000 persons/km², which is the highest population density at the national level. In this area land fragmentation/land shortage is a serious problem comparatively to the lowland and highland agro ecology; therefore, the land users are not interested to apply the standard design that consumes more land.

Besides the land size, lack of access to chemical fertilizer and improved seed caused the land to lose its productivity and food insecurity has been increased. This condition was affecting the farmers to apply the standard SWC work.

According to Abroha (2015) and Yahya and Xiaohui (2014), access to synthetic fertilizer and the improved seed has been identified as the main determinant factor to the farmers to decide on SWC works. During field work one of the interviewed farmers told that he is digging the ditch for SWC without getting breakfast.

According to him there were many farmers who did not eat breakfast during work, which is discouraging to dig deeper or wider to meet the standard. The interviewed respondents complain that food insecurity is challenging their effort on SWC work.

The other respondent farmers also argue that the technology itself had a complex design to build that can be characterized by the expertise and intensive labor force during construction of SWC structures. But contrary to this in most Kebles shortage of labor force is challenging.

Almost all schooled young farming family was migrating to the urban area for nonfarm work because of the hard work and less productive nature of the agricultural work. The same result was reported by Legesse (2014). Young people who attend school are no longer interested in becoming farmers in the study area. This condition has an adverse impact on access of labor force for SWC and constraints to apply the standard design of SWC work.
| Sample site 1 | Implemented | Recommended | Deviation from the recommended |
|---------------|-------------|-------------|----------------------------------|
| Specifications |             |             |                                  |
| Type of structures | Soil bund | Soil bund | Soil bund |
| Slope in (in degree) | 20 | 1–26 | Within the range |
| Soil depth (cm) | 50 cm | 45 cm | 5 cm |
| VI b/n consecutive structures (m) | 10 m | 1.50 m | 8.50 m |
| Depth of the ditch | 45 cm | >50 cm | Standard |
| Width of the ditch | 60 cm | 60 cm | Standard |
| Embankment height | 40 cm | 60 cm | 20 cm |
| Embankment width | 50 cm | 1.50 m | −1 m |
| Distance of the ditch to berm | 20 cm | 25 cm | −0.5 cm |

| Sample site 2 | Implemented | Recommended | Deviation from the recommended |
|---------------|-------------|-------------|----------------------------------|
| Specifications |             |             |                                  |
| Type of structures | Soil bund | Soil bund | Soil bund |
| Slope in (in degree) | 17 | 1–26 | Within the range |
| Soil depth (cm) | 20 cm | 45 cm | −25 cm |
| VI b/n consecutive structures (m) | 7 m | 1.50 m | 5.5 cm |
| Depth of the ditch | 40 cm | >50 cm | −10 cm |
| Width of the ditch | 57 | 60 cm | −10 cm |
| Embankment height | 40 cm | 60 cm | −20 cm |
| Embankment width | 50 cm | 1.50 m | −1 m |
| Distance of the ditch to berm | 23 cm | 25 cm | −0.5 cm |

| Sample site 3 | Implemented | Recommended | Deviation from the recommended |
|---------------|-------------|-------------|----------------------------------|
| Specifications |             |             |                                  |
| Type of structures | Fanaya juu | Fanaya juu | Fanaya juu |
| Slope in (in degree) | 17 | 1–26 | Within the range |
| Soil depth (cm) | 25 cm | 60 cm | −35 cm |
| VI b/n consecutive structures (m) | 6.5 m | 1.5 m | 5 m |
| Depth of the ditch | 50 cm | 60 cm | −10 cm |
| Width of the ditch | 60 cm | 60 cm | Standard |
| Embankment height | 50 cm | 60 cm | −10 cm |
| Embankment width | 50 cm | 1.5 m | −1 m |
| Distance of the ditch to berm | 20 cm | 20 cm | Standard |

| Sample site 4 | Implemented | Recommended | Deviation from the recommended |
|---------------|-------------|-------------|----------------------------------|
| Specifications |             |             |                                  |
| Type of structures | Micro basin | Micro basin | Micro basin |
| Soil depth (cm) | 25 cm | 45 cm | −20 cm |
| Average slope (in degree) | 16 | 1–26 | Within the range |
| VI b/n consecutive structures (m) | 10 m | 2–5 m | 7.5 cm |
| Depth of the ditch | 50 cm | 55 cm | −05 cm |
| Width of the ditch | 75 cm | 50–100 cm | Within the range |

(Continued)
4.6. Technical result of conservation structures in lowland agro ecology

According to the meteorological data and information from the local agricultural office, the kola agro ecology of the study area is characterized by an average annual rainfall of 1050 mm and a temperature of 23°C.

In this agro ecology, the dominant soil type is clay soil and sandy clay soil. According to the field measurement, field observation, household survey, and expertise interview at Kebele level, the soil depth of the area ranges from 30 to 60 cm.

The field observation also revealed that the common SWC structures in the lowland area are soil bund and micro basin. The structures were carried out on slope gradient ranges from 12 to 18 degrees. The sampled value of the structural dimension of the soil bund and micro basin of the lowland agro ecology was listed in the Table 7.

The field measurement showed that about 62% of the total implemented SWC structure was carried out according to the standard. The remaining 38% of the structural dimension failed to meet the standard.

Soil bund of sample 1 depth and width of the ditch, embankment height and width, as well as the distance of the soil from the bunk was constructed below standard (see Table 7). In the sample site 3 of soil bund structures, except embankment depth, width, and VI of the ditch, all structural dimensions were carried out according to the standard. This refers to only 30% of the design which failed to meet the standard.

The other commonly found structure in the lowland area with scarce water source was the micro basin. The sample site 2 and 4 of the micro basin showed standard dimension of width and depth of the ditch, VI between consecutive structures, embankment height, and Soil depth.

The overall field measurement for the micro basin in the lowland area showed that 88% of the structures were constructed according to the standard. About 22% of the micro basin dimension was constructed below standard on embankment width and distance of the soil from the bunk.

The major constraints of the farmers in the lowland area to follow the standard conservation design were shortage of water, construction materials, access to transportation, small land size, lack of skill on SWC work and chemical fertilizers, seeds, and pesticides. For instance, the shortage of water limited the effectiveness of biological conservation that could make effective physical conservation work.

Though small land size was the challenge for standard conservation work, the problem of land size was not a big problem as of the midland. Accordingly, about 51% of the farmers believe that small land size was the challenge to apply the standard dimension of conservation structures.
During field measurement, the researchers observed vertical interval (VI) between micro basin structures in the lowland was closer to the standard than the VI of the highland and midland area. This indicates the farmers in the lowland were more concerned about water collection than land size.

The standardized dimensions of conservation structures were calculated to make them capable of holding the generated peak discharge (Hurni et al. (2016)). Therefore, the implemented conservation structures in the sample site that failed to follow the standards cannot be capable to hold the runoff and that will adversely affect the fields Figure 11.

In Figure 6, the left side figure showed the soil bund is being constructed with 15 cm depth and 35 widths, which is below the standard. The right side figure depicted that conservation of soil bund was the lower part of the field before construction of cut off-drain or as check dam at the upper part of the field. This figure shows the conservation work carried out at the lower part of the field has not followed the standard that recommends conservation starts from the upper part of the field.

4.7. Supportive measures for physical conservation structures

A supportive measure of physical conservation structures refers to the application of vegetative materials (vetiver grass), continuous maintenance, water diversion, and less human interference that makes effective the physical conservation measures. During field observation in most conservation structures lack of supportive activities was observed beside the technical problems (see Figs 12 and Figs 13).

For instance, Figure 13 shows only a single cut-off drain which was constructed on steep and poorly covered farmland. Also Figure 12 depicts protected land that has physical conservation structures inside, but human interferences (human foot) led to land degradation through gully initiation.

The standard conservation work recommends that physical SWC work should be supported with a properly designed cut-off drain (diversion of water), planting vegetative materials, and frequent maintenance. Therefore, the identified failures on the conservation structures to meet the standard design/dimension have an adverse impact on the effectiveness of the conservation structures.

For instance, the higher spacing between structures reduced the ability of the structures to hold the peak discharge that can be generated between two consecutive bunds (see Figure 9). According to G. Tesfaye et al. (2019) the physical limitations of conservation structures have adverse impacts when it comes to drainage control of structures. A similar result was reported by Engdayehu et al. (2016) in the Debre Mewi Watershed, North West Ethiopia.

According to Förch and Schütt (2004), the success of SWC depends on the design and technics of the structure as well as the level of local people’s participation in the conservation work. Because the design and dimensions of conservation structures’ are very much dependent on the risk of erosion, runoff control, factor causing erosion, and improved soil productivity (Abraha, 2008).

Therefore, the observed failures to meet the standard among certain conservation structures in the sampled study area may cause serious damage to the field through high runoff collection. Also there is a threat that the farmers may refuse the whole conservation if the implemented conservation work is less effective in their agricultural production.

On the other hand, among the constraints of the existing SWC work was a lack of interest for the young generation to work agricultural activities; the basic reason behind the youngsters to loss interest for agriculture was the unproductiveness of the agricultural system.
## Table 7. Technical Evaluation of SWC structures in the low land agro ecology

| Sample site 1 | Implemented | Recommended | Deviation from the recommended |
|---------------|-------------|-------------|---------------------------------|
| **Specifications** |             |             |                                 |
| Type of structures | Soil bund | Soil bund | Soil bund                       |
| Average slope (in degree) | 13 | 1–26 | Within the range |
| Workable soil depth (cm) | 45 cm | 45 cm | Standard |
| VI b/n consecutive structures (m) | 3.5 m | 1.50 m | 2 m |
| Depth of the ditch | 15 cm | >50 cm | −35 cm |
| Workable soil depth (cm) | 45 cm | 45 cm | Standard |
| VI b/n consecutive structures (m) | 3.5 m | 1.50 m | 2 m |
| Depth of the ditch | 15 cm | >50 cm | −35 cm |
| Workable soil depth (cm) | 45 cm | 45 cm | Standard |
| VI b/n consecutive structures (m) | 3.5 m | 1.50 m | 2 m |
| Workable soil depth (cm) | 45 cm | 45 cm | Standard |
| VI b/n consecutive structures (m) | 3.5 m | 1.50 m | 2 m |
| Depth of the ditch | 15 cm | >50 cm | −35 cm |
| Workable soil depth (cm) | 45 cm | 45 cm | Standard |
| VI b/n consecutive structures (m) | 3.5 m | 1.50 m | 2 m |
| Workable soil depth (cm) | 45 cm | 45 cm | Standard |
| VI b/n consecutive structures (m) | 3.5 m | 1.50 m | 2 m |
| Workable soil depth (cm) | 45 cm | 45 cm | Standard |
| VI b/n consecutive structures (m) | 3.5 m | 1.50 m | 2 m |
| Workable soil depth (cm) | 45 cm | 45 cm | Standard |
| VI b/n consecutive structures (m) | 3.5 m | 1.50 m | 2 m |

| Sample site 2 | Implemented | Recommended | Deviation from the recommended |
|---------------|-------------|-------------|---------------------------------|
| **Specifications** |             |             |                                 |
| Type of structures | Micro basin | Micro basin | Micro basin |
| Average slope (in degree) | 13 | 1–26 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
| Workable soil depth (cm) | 30 cm | 30–60 cm | Standard |
| VI b/n consecutive structures (m) | 5 m | 2–5 m | Standard |
| Depth of the ditch | 50 cm | 50–60 | Standard |
For example, the high interest of the young farming family for off-farm activity (riding motorbike, daily laboring in the nearby urban area, and looking for work with monthly salary) has increasing the lack of labor force for physical SWC work.

4.8. Level of constraints along agro-ecological variation

The researchers used the chi-square test to check the significant association of constraints versus different agro ecology. According to the chi-square result at alpha level 0.05; there is a significant association between land size, access to fertilizers, seeds, pesticides, and construction materials, technical skill for SWC, and maintenance of the conservation structures versus different agro ecology.

| Specifications             | Implemented | Recommended | Deviation from the recommended |
|----------------------------|-------------|-------------|---------------------------------|
| Embankment height         | 20 cm       | 20 cm       | Standard                        |
| Embankment width          | 40 cm       | 1 m         | ~ 60 cm                         |
| Distance of the soil from the bunk | 20 cm | 30 cm | ~10 cm |

Figure 12. Gully initiated due to human interference.
Source: Researcher March 2020

Figure 13. Only cut of drain in poorly covered land.
On other hand, no significant association was observed between different agrologies versus food security, the interest of young generation, lack of frequent maintenance, field guideline, and interaction among stakeholders (see Table 8).

The chi-square test clearly depicted that the constraints such as land size, access to fertilizers, seed, pesticides, construction materials, technical skill for SWC, and maintenance were different along agro-ecological variation. Participants of FGD and KII in the midland stressed that the small land size is a more serious problem to apply the standard SWC practices because the population density is higher in the midland than the rest agro ecology.

Whereas the constraints like access to fertilizers, pesticides, seeds, SWC construction materials, and skilled manpower are a serious challenge to adopt the standard SWC structures. The reasons described by the farmers in the lowland and highland were remoteness of the area, poor access to infrastructures, and lack of institutions, which limited the access to skilled manpower and resources for SWC.

To sum up, the research result showed that the deviation of the design and size of the physical SWC from the standard is found in all agro ecology, but the extent or level of constraints were not uniform along with agro ecology.

4.9. The best conservation experience of the study area

During field observation, the researchers perceived both field-level practices and landscape-level conservation practice; such as agro-forestry practices, wood lot, and wind breaks. The study was mainly focused on the field level practices of SWC works. But the observed landscape-based conservation work of agroforestry and plantation forest that was established by the community and the government was the best experience among the observed conservation work in the area (see Figures 14 and 15).

Particularly the traditional agroforestry system and plantation work of the study area were the best systems that serve to improve the soil structure of the area (see Figs 14 and Figs 15). According to Temesgen et al. (2018), Regassa Debelo et al. (2017), Legesse (2014), and Kipe. (2002), agro-forestry practices are highly expanding in the study area, which has a significant contribution to soil fertility, access to water, fodder, and keeps up the balance for the socio-economic and environmental needs of the area.

The communities of the study area are known nationally and globally for their traditional agroforestry system that is recognized by UNESCO. The majority of the communities in the study area are cultured to live with trees side by side of agriculture, which contributed to the expansion of agroforestry.

A similar result was reported by Legesse et al. (2018), and Kipe (2002) about the cultural role of the agroforestry system. But the existing agroforestry system was losing its productivity due to the constraints described above. Empirical findings reported by Negash (2013) also showed that the agroforestry system of the study area is losing its productivity.

The study results on the existing agroforestry system and plantation forest confirmed the importance of expanded and well-protected landscape conservation work. Also the observed gap on the physical conservation structures that failed to meet the standard needs to be enhanced through awareness creation for the land users in a way to ensure sustainable socio-economic and environmental development. Otherwise, it will have an adverse impact on the agricultural productivity and food insecurity that will threaten the life of the community in the study area.
Table 8. Level of constraints along different agro ecology

| R.N | Response of land users  | Agro ecology |   |   |   | X² | P-Value |
|-----|-------------------------|---------------|---|---|---|----|---------|
|     | Lists of constraints    | Midland | Lowland | Highland |   |   |         |
| 1   | Small farmland area     | Yes   | 145    | 115    | 37 | 52.92 | 32     | 46   | 214   | 72.35 | < 0.001 | Significant |
|     | No                      | 5     | 34.95  | 32     | 16.08 | 28  | 13.98  | 65   |       |        |          |
|     | Total                   | 150   | 69     | 60     | 60   | 279  |         |       |       |        |          |
| 2   | Poor access to fertilizer, seed, and pesticides | Yes   | 105    | 118.3  | 59  | 54.4  | 56    | 47.3 | 220   | 16.45 | < 0.001 | Significant |
|     | No                      | 45    | 31.7   | 10     | 14.6 | 4    | 12.7   | 59   |       |        |          |
|     | Total                   | 150   | 69     | 60     | 60   | 279  |         |       |       |        |          |
| 3   | Food insecurity         | Yes   | 132    | 130.1  | 63  | 59.8  | 47    | 52   | 242   | 5.19  | > 0.05  | Not Significant |
|     | No                      | 18    | 19.9   | 6      | 9.1  | 13   | 7.9    | 37   |       |        |          |
|     | Total                   | 150   | 69     | 60     | 60   | 279  |         |       |       |        |          |
| 4   | Inaccessibility of construction material | Yes   | 75     | 43     | 45  | 39.6  | 40    | 34.4 | 160   | 85.89 | < 0.001 | Significant |
|     | No                      | 75    | 31.9   | 24     | 29.4 | 20   | 25.6   | 119  |       |        |          |
|     | Total                   | 150   | 69     | 60     | 60   | 279  |         |       |       |        |          |
| 5   | Lack of technical skill on SWC practices. | Yes   | 76     | 98.9   | 57  | 45.5  | 51    | 39.6 | 184   | 33.84 | < 0.001 | Significant |
|     | No                      | 74    | 51     | 12     | 23.5 | 9    | 20.4   | 95   |       |        |          |
|     | Total                   | 150   | 69     | 60     | 60   | 279  |         |       |       |        |          |
| 6   | Lack of interest for young generation to work agricultural activities | Yes   | 110    | 105.4  | 46  | 48.5  | 40    | 42.2 | 196   | 1.93  | > 0.25  | Not Significant |
|     | No                      | 40    | 46.6   | 23     | 20.5 | 20   | 17.8   | 83   |       |        |          |
|     | Total                   | 150   | 69     | 60     | 60   | 279  |         |       |       |        |          |

(Continued)
### Table 8. (Continued)

| R.N | Response of land users Lists of constraints | Midland | Lowland | Highland | $X^2$ | P-Value |
|-----|--------------------------------------------|---------|---------|----------|-------|---------|
| 7   | Lack of frequent and continues maintenance | Yes     | 112     | 123.1    | 62    | 56.6    | 55      | 49.2    | 229   | 0.005 | >0.5 | Not Significant |
|     |                                            | No      | 38      | 26.9     | 7     | 12.4    | 5       | 10.8    | 50    |       |     |                  |
|     |                                            |         | 150     | 69       | 60    | 279     |         |         |       |       |     |                  |
| 8   | Lack of field guideline for SWC practices  | Yes     | 132     | 132.3    | 61    | 60.8    | 53      | 52.9    | 246   | 0.127 | >0.5 | Not Significant |
|     |                                            | No      | 18      | 17.7     | 8     | 8.2     | 7       | 7.1     | 33    |       |     |                  |
|     |                                            |         | 150     | 69       | 60    | 279     |         |         |       |       |     |                  |
| 9   | Weak interaction among stakeholders        | Yes     | 128     | 127.9    | 59    | 58.9    | 51      | 51.2    | 238   | 0.006 | >0.5 | Not Significant |
|     |                                            | No      | 22      | 22.1     | 10    | 10.1    | 9       | 8.8     | 41    |       |     |                  |
|     |                                            |         | 150     | 69       | 60    | 279     |         |         |       |       |     |                  |
5. Conclusion and Recommendation

5.1. Conclusion
The purpose of this study was to identify the major SWC technologies; compatibility to the standard, acceptability of SWC measures, and constraints of SWC works. According to the results, two types of conservations were observed in the study area. These are field-level practices and landscape-level practices (agroforestry, wood lot, and wind breaks). The study was mainly focused on the field level practices of SWC works.

The data collected from field measurement, field observation, interview, and group discussion revealed that the farmers use both traditional conservation practices, such as horizontal ploughing, crop rotation, land rotation, manure, mulching, and fencing, as well as the newly introduced SWC technologies, such as bench terracing, soil bund, stone bund, fanya juu, check dam, half-moon, micro basin, and I brow.

Figure 14., Sample agroforestry.

Figure 15., Sample plantation forest.
Among the introduced conservation measures, soil bund, fanaya juu, bench terrace, — micro basin and cut of drain were the mostly frequently found SWC structures in the selected plots of the study area. Based on the national SWC guideline for different agro ecologies, physical features, and climatic conditions, about 47.3% of the physical design of the implemented SWC technologies in the sampled site failed to meet standard dimension/design.

The major constraints of physical SWC works of the study area were small farmland, weak interaction among stakeholders, food insecurity, inaccessibility of construction material, lack of technical skill on SWC practices, lack of interest for the young generation to work on agricultural activities, lack of frequent and continues maintenance, lack of field guideline for SWC practices, and poor access to resources that varies at different agro ecology.

Though the identified constraints were found in different agro ecology, the extent of the problem was varying along with agro ecology. The statistical analysis showed that there is a significant association between, land size, access to fertilizer, seed, construction material, and technical skill for SWC works versus agro ecology.

For instance, constraints like small land size have a significant impact on the midland compared to the lowland and the highland agro ecology as it was dependent on the high population density of the midland. On the other hand, access to fertilizers, pesticides, seeds, construction materials, and skill for SWC has a significant impact on SWC practices in the lowland and highland that was dependent on access to infrastructures, resources, and institutions.

The study showed that besides the technical problem, the structures have a limitation of supportive measures, such as well-designed cut-off drain, check dam, and vegetative materials. Also the result from the study depicted that the majority of the farmers have the knowledge about the source and impact of soil erosion problem.

Their knowledge about the source of soil erosion and its impact on agricultural products forced them to accept the introduced SWC technology. During field work the researchers observed that the area has some good experience of landscape-level conservation (agro-forestry system).

However, field-level physical SWC conservation structures are not well implemented to the extent of addressing soil erosion and socio-economic problems of the area due to technical and other socio-economic constraints. In short, the result of this study is very important to select the right SWC technology, dimension, and make sure the effort to sustainable ecosystem services in the Gidabo River sub-basin of Ethiopian Rift valley.

5.2. Recommendations
The result indicates the soil and water conservation work needs to focus on reduction or avoidance of the above-mentioned constraints. This can help to prepare a proper plan and approach to implement the conservation technologies according to the standard, which could lead to increase farmers’ participants in the SWC work, fewer land degradation, increase productive, and ensure the sustainability of the conservation structures and agricultural system of the area.

Also research-based field level conservation work should be done to use the local knowledge and positive motive of the community in a way to avoid the existing constraints for SWC work. Finally, we recommended that the good experience of landscape-level conservation (agro-forestry and plantation) system of the river basin should be encouraged and expanded for sustainable socio-economic and environmental productivity of the study area.
Acknowledgements

The author is thankful to German Academic Exchange Service (DAAD) In Country/In Region program and Dilla University for the financial support of the research. Also the researcher thankful to Dr. Belelew Malla and Mr. Yaregul Mulu for their language editorial work. A special thank deserves to ICRAF (World Agro-forestry Centre) for the financial management during the research work.

Funding

This research work was supported financially by the German Academic Exchange Service (DAAD). Also Dilla University has contributed for the research in material and logistic supports during the field work;Deutscher Akademischer Austauschdienst [57376093].

Author details

Getaahun Hassan1
E-mail: getaahunhassan5@gmail.com
ORCID: https://orcid.org/0000-0002-4074-2370

Amare Bantide2,3

Abiyot Legesse4

Malesu Maimbo5

1 Department of Natural Resource Management, College of Agriculture, Dilla University, Dilla, Ethiopia.
2 Centre for Food Security Studies, College of Development Studies, Addis Ababa University, Addis Ababa, Ethiopia.
3 Water and Land Resource Centre, Addis Ababa University, Addis Ababa, Ethiopia.
4 Department of Geography and Environmental Studies, Dilla University, Dilla, Ethiopia.
5 Malesu Maimbo, Program Coordinator of Water Management at World Agroforestry Center, Eastern and Southern Africa Region.

Citation information

Cite this article as: Assessment of Design and Constraints of Physical Soil and Water Conservation Structures in respect to the standard in the case of Gidabo sub-basin, Ethiopia. Getaahun Hassan, Amare Bantide, Abiyot Legesse & Malesu Maimbo, Cogent Food & Agriculture (2021), 7: 1855818.

References

Abraha, A. M. (2008). Analysis of factors affecting proper utilization of water through Irrigation Cooperatives at Kolla Tembiyen Wereda [Doctoral dissertation]. Mekelle University, Central Tigray, Ethiopia.

Abraha, B. (2015). Factors affecting agricultural production in Tigray region, northern Ethiopia. University of South Africa.

Adgo, E., Eshome, A., & Mati, B. (2013). Impacts of long-term soil and water conservation on agricultural productivity: The case of Anjenie watershed, Ethiopia. Agricultural Water Management, 117, 55–61. https://doi.org/10.1016/j.agwat.2012.10.026

Alltied, M. (1991). Agro ecology: The science of sustainable agriculture (Vol. 238). PART THREE: DEVELOPMENT, CLIMATE AND RIGHTS. Westview Press.

Asfaw, D., & Neka, M. (2017). Factors affecting adoption of soil and water conservation practices: The case of Wereellu Woreda (District), South Wollo Zone, Amhara Region, Ethiopia. International Soil and Water Conservation Research, 5(4), 273–279. https://doi.org/10.1016/j.iswcr.2017.10.002

Ayenew, T., & Becht, R. (2008). Comparative assessment of the water balance and hydrology of selected Ethiopian and Kenyan Rift Lakes. Lakes & Reservoirs: Research & Management, 13(3), 181–196. https://doi.org/10.1111/j.1440-1770.2008.00368.x

Bashir, S., Javed, A., Bibi, I., & Ahmad, N. (2016). Soil and water conservation. In Soil science concepts and applications. Faisalabad, Pakistan: Institute of Soil and Environmental Sciences, University of Agriculture.

Bekele, B., Wu, W., Legesse, A., Temesgen, H., & Visser, E. (2018). Random and systematic land use/land cover transitions in semi-arid landscapes of Ethiopian Central Rift Valley Lakes Region (East Africa). – Applied Ecology and Environmental Research, 16(4), 3993–4014. https://doi.org/10.15666/aer/1604-39934014

Beyene, F. (2015). Incentives and Challenges in Community-Based Rangeland Management: Evidence from Eastern Ethiopia. Land Degradation & Development, 26(5), 502–509. https://doi.org/10.1002/dr.2340

Biratu, A. A., & Asmamaw, D. K. (2016). Farmers’ perceptions of soil erosion and participation in soil and water conservation activities in the Gusha Temela watershed, Arsi, Ethiopia. International Journal of River Basin Management, 14(3), 329–336. https://doi.org/10.1080/15715124.2016.1167063

Bonini, M., Corti, G., Innocenti, F., Manetti, P., Mazzarini, F., Abebe, T., & Pecskay, Z. (2009). Evaluation of the Main Ethiopian Rift in the frame of Afar and Kenya Rifts propagation. Tectonics, 28(1), 1. https://doi.org/10.1029/2004TC001680

CSA (Central Statistics Authority). (2013). Population projection of Ethiopia for all regions Wereda level from 2014–2017. Addis Ababa.

Dagnew, D. C., Guzman, C. D., Zegeye, A. D., Tibeju, T. Y., Getoneh, M., Abate, S., Zemale, F. A., Ayana, E. K., Tilahun, S. A., & Steenhuis, T. S. (2015). The impact of conservation practices on runoff and soil loss in the sub-humid Ethiopian Highlands: The Debre Mawi watershed. Journal of Hydrology and Hydromechanics, 63(3), 210–219. https://doi.org/10.1515/johh-2015-0021

Daniel, D. (2001). Soil and water conservation manual: Guideline for Ethiopia. In Soil and water conservation team. Addis Ababa: Natural Resources Management and Regulatory Department, Ministry of Agriculture.

Degafa, S. (2016). Home garden agroforestry practices in the Gedeo zone, Ethiopia: A sustainable management system for socio-ecological benefits. Socio-ecological Landscapes and Seascapes (SEPLS) in Africa, 28.

Ehui, S., & Pender, J. (2008). Resource degradation, low agricultural productivity, and poverty in sub-Saharan Africa: Pathways out of the spiral. Agricultural Economics, 32(1), 225–242. https://doi.org/10.1111/j.1016-8510.2004.00026.x

Engdayehu, G., Fisseha, G., Mekonnen, M., & Melesse, A. M. (2016). Evaluation of technical standards of physical soil and water conservation practices and their role in soil loss reduction: The case of Debre Mawi watershed, north-west Ethiopia.

Erkossa, T., Williams, T. O., & Loekemamariam, F. (2018). Integrated soil, water and agronomic management effects on crop productivity and selected soil properties in Western Ethiopia. International Soil and Water Conservation Research, 6(4), 305–316. https://doi.org/10.1016/j.iswcr.2018.06.001

FAO. (2011). The state of the worlds’ land and water resources for food and agriculture: Managing system at risk.

Förch, G., & Schütz, B. (2004). Watershed Management—An Introduction. In Lake Abayo Research Symposium 2004—Proceedings. University of Siegen,
Forschungsinstitut Wasser und Umwelt. Water Resource Publications (Vol. 4, pp. 119-133).

Girma, (2000). A Participatory Approach to Agroforestry in Watershed Management: A Case study at Yanessie, Southern Ethiopia. Unpublished MA thesis. Wageningen University.

Haregeweyn, N., Tsnekawa, A., Nyssen, J., Poenes, J., Tsobo, M., Tsegaye Meshesh, D., Schütz, B., Adgo, E., & Tegegne, F. (2015). Soil erosion and conservation in Ethiopia: A review. Progress in Physical Geography: Earth and Environment, 39(6), 754-774. https://doi.org/10.1177/0309133315598725

Haregeweyn, N., Tsnekawa, A., Poenes, J., Tsobo, M., Meshesh, D. T., Fenta, A. A., Nyssen, J., & Adgo, E. (2017). Comprehensive assessment of soil erosion risk for better land use planning in river basins: Case study of the Upper Blue Nile River. Science of the Total Environment, 754, 1016-1028. https://doi.org/10.1016/j.scitotenv.2020.1332099

Hurni, H. (1998). Agro ecological belts of Ethiopia: Explanatory notes on three maps at a scale of 1:1,000,000. Soil Conservation Research Program of Ethiopia, Addis Ababa, Ethiopia, 31.

Hurni, H., Berhe, W. A., Chahukar, P., Daniel, D., Gete, Z., Grunder, M., & Kassaye, G. (2016). Soil and Water Conservation in Ethiopia: Guidelines for Development Agents (Second revised edition ed.). Centre for Development and Environment (CDE), University of Bern, with Bern Open Publishing (BOP).

Kipe, T. (2002). Five thousand years of sustainability?: A case study on Gedo land use, Southern Ethiopia (Vol. 295).

Lakew, D., Carucc, V., Asrat, W. A., & Yitayew, A. (2005). Community based participatory watershed development: A guideline. Ministry of Agriculture and Rural Development.

Legesse, A. (2014). The dynamics of Gedo agroforestry and its implications to sustainability (Doctoral dissertation PhD Dissertation. UNISA.

Legesse, A., Bogale, M., & Likisa, D. (2018). Impacts of Community Based Watershed Management on Land Use/Cover Change at Elema Micro-Watershed, Southern Ethiopia. American Journal of Environmental Protection, 6(3), 59–67.

Mechal, A., Wagner, T., & Birk, S. (2015). Recharge variability and sensitivity to climate: The example of Gidabo River Basin, Main Ethiopian Rift. Journal of Hydrology: Regional Studies, 4, 544–660.

MoARD. (2005). Community based participatory watershed development: A guideline. Ministry of Agriculture and Rural development.

Morse, J. M. (1991). Strategies for sampling. Qualitative Nursing Research: A Contemporary Dialogue, 127–145.

Namrabe, S., Nzyoko, J. M., & Gathenyia, J. M. (2015). A guide for selecting the right soil and water conservation practices for small holder farming in Africa. ICRAF Technical manual No.24. World Agroforestry Centre (ICRAF).

Negash, M. (2013). In. the indigenous agroforestry systems of the south-eastern Rift Valley escarpment [Ethiopia, PhD dissertation. University of Helsinki.

Nigusie, Z., Tsunekawa, A., Haregeweyn, N., Adgo, E., Cochrane, L., Floquet, A., & Abele, S. (2018). Applying Ostrom’s institutional analysis and development framework to soil and water conservation activities in north-western Ethiopia. Land Use Policy, 71, 1–10. https://doi.org/10.1016/j.landusepol.2017.11.039

Regassa Debelo, A., Legesse, A., Milstein, T., & Orkaydo, O. O. (2017). “Tree is life”: The rising of Dualism and the Declining of Mutualism among the geode of southern Ethiopia. Frontiers in Communication, 2, 7. https://doi.org/10.3389/fcom.2017.00007

SLMP, (2013). Sustainable Land Management Project (SLMP) revised draft document on Environmental and Social Management Framework (ESMF).Ethiopia: Ministry of Agriculture.

Teshkari, A., & Teddelie, C. (Eds.). (2010). Sage handbook of mixed methods in social & behavioral research. Sage publication Inc.

Taye, G., Poenes, J., Van Wesemael, B., Vamnaercke, M., Teko, D., Deckers, J., Goosse, T., Moetens, W., Nyssen, J., Hollet, V., & Haregeweyn, N. (2013). Effects of land use, slope gradient, and soil and water conservation structures on runoff and soil loss in semi-arid Northern Ethiopia. Journal of Physical Geography, 34(3), 236–259. https://doi.org/10.1080/02723646.2013.832098

Temesgen, H., Wu, W., Legesse, A., Yirsaw, E., & Bekele, B. (2018). Landscape-based upstream-downstream prevalence of land-use/cover change drivers in southeastern rift escarpment of Ethiopia. Environmental Monitoring and Assessment, 190(3), 166. https://doi.org/10.1007/s10661-018-6479-8

Tesfaye, A., Bhattu, W., Brouwer, R., & Zoog, P. (2016). Understanding soil conservation decision of farmers in the Gede watershed, Ethiopia. Land Degradation & Development, 25(1), 71. https://doi.org/10.1002/ldr.2187

Tesfaye, G., Fikirie, K., Debebe, Y., & Halliu, L. (2015). Evaluating technical standards of implemented soil and water conservation technologies in Jimma Zone, South- Western Ethiopia, Juniper (JP) Publisher.

Teshome, A., de Graaff, J., & Streusnmjerd, L. (2014). Evaluation of soil and water conservation practices in the north-western Ethiopian highlands using multi-criteria analysis. Frontiers in Environmental Science, 2, 60. https://doi.org/10.3389/fenvs.2014.00060

Tsegaye, B., & Awdenegest, M. (2018). Technical evaulation of selected soil conservation practices and farmers’ perception about soil erosion in Donbi Watershed, Wolaita Zone, Southern Ethiopia. Int J Agric Sc Food Technol, 4(2), 016–023.

Wolde Gabriel, G., Heiken, G., White, T. D., Asfaw, B., Hart, W. K., & Renne, P. R. (2000). Volcanism, tectonism, sedimentation, and the paleoanthropological record in the Ethiopian Rift System. Special Papers-geological Society of America, 83–99.

Wolka, K. (2014). Effect of soil and water conservation measures on soil physical properties of highland vilages of Ethiopia: an example. Journal of Environmental Science and Technology, 7(4), 185. https://doi.org/10.3923/jest.2014.185.199

Wolka, K., Mulder, J., & Biazin, B. (2018). Effects of soil and water conservation techniques on crop yield, runoff and soil loss in Sub-Saharan Africa: A review. Agricultural Water Management, 207, 67–79. https://doi.org/10.1016/j.agwat.2018.09.016

Worku, H. (2017). Impact of Physical Soil and Water Conservation Structure on Selected Soil Physicochemical Properties in Gondar Zuria Woreda. Resources and Environment, Vol. 7, pp. 40–48. doi. https://doi.org/10.5923/j.re.20170702.0

Yohay, H. P., & Xiaohui, Z. (2014). Constraints to women smallholder farmers’ efforts in ensuring food security at household level: A case of Msowoera ward of Morogoro region Tanzania. International Journal of Economics and Finance, 6(5), 47. https://doi.org/10.5539/ijef.v6n5p47

Yosuf, M., Di Falco, S., Deressa, T., Ringler, C., & Kohlin, G. (2008). The impact of climate change and adaptation on food production in low-income countries: Evidence from the Nile Basin. Intl Food Policy Res Inst.
