Status and challenges of integrated watershed management practices after-project phased-out in Eastern Tigray, Ethiopia

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Abstract
Land degradation in the form of soil erosion is one of the major causes for declining ecosystem functions in the northern highlands of Ethiopia including the Eastern Tigray. Hence, different integrated watershed management practices were introduced in the last few years to avert the problem. Currently, most of these practices are phased out. However, the status and challenges of these practices after phase-out are not well documented and required scientific research. On-field measurement from nine sample plots having a size of each 50 m*50 m at 200 m interval was conducted to assess the status and challenges of these practices. Results of the assessment showed that physical soil and water conservation structures were deteriorated by 47–64% after IWM project phased out. The key problems were lack of periodic maintenance, and limited support by biological conservation measures. The study results suggest that Watershed technologies are highly challenged after project phase-out. Hence, integration among the community, government and non-governmental organizations are needed to sustainably manage these resources.

Keywords Watershed · Soil and water conservation challenges · Tigray

Introduction
Land degradation in the form of soil erosion, sedimentation, water pollution, soil nutrient depletion, deforestation and overgrazing is the major cause for poor land productivity (Bekele 2003; Berry 2003; Arabia et al. 2013; Temesgen et al. 2013; Balasubramani et al. 2015). Several studies reported that soil erosion in the Ethiopian highlands ranged from 42 t ha⁻¹y⁻¹ on arable land to 179 t ha⁻¹y⁻¹ on range lands (Hurni 1993; Shiferaw and Holden 1999). More than 50 percent of Ethiopia's highlands were substantially eroded (FAO 1986), which led to reduced land productivity by 2.2 percent annually (Tamene et al. 2006). On the other hand, the total land area deteriorated in the country, between 1981 and 2003, was 297,000 km² (FAO 2006). Land degradation accompanied by population pressure and climate variability constrained agricultural productivity (Deresa and Hassan 2009; Teka et al. 2014). This, in turn, resulted to severe consequences, such as food insecurity and environmental hazards, such as chronic drought and poverty (Tekle 1999). To avert these challenges, since the 1970s and 1980s, many land restoration initiatives, such as soil and water conservation measures, have been implemented with a financial support from the international community, particularly the World Food Program (MoARD 2005; Zeleke et al. 2006; Nyssen et al. 2007; Gashaw 2015). However, due to the top–down approaches followed (no to low community participation), limited number of watershed practices (poor integration) and large/unmanageable watersheds (for monitoring and management), most of the implemented measures failed (Temesgen et al. 2013).

These challenges call for a societal shift towards a sustainable development model, which encompasses community participation, and objectives integration (CCME 2016; Teka 2019). Hence, the Ethiopian government in collaboration with partners (Irish development co-operation programme, Irish Aid) has implemented a range of integrated watershed management practices, such as soil and water...
conservation (both physical and biological) and exclosures to keep land free from human and livestock interference in Tigray since 1997 (Bekele and Tilahun 2007; Chisholm and Woldehanna 2012). Integrated watershed management is a method of continuous restoration, growth and efficient use of available natural resources in a watershed, and a multidisciplinary approach to soil depletion pause (Mekonen and Fekadu 2015; Karpuzcu and Delipinar 2011). Hence, until 2014, the total area delineated and treated with integrated watershed management activities in the region was 12,425,869 hectares (BoARD 2016).

Studies showed that the implemented integrated watershed interventions increased infiltration and decreased runoff production (Nyssen et al. 2007; Taye et al. 2013); improved soil fertility (Vancampenhout et al. 2006; Nyssen et al. 2007); improved vegetation regeneration and soil build-ups (Mekuria et al. 2007); improved soil fertility (Vancampenhout et al. 2006; Nyssen et al. 2007); improved vegetation regeneration and soil build-ups (Mekuria et al. 2007; Etsay et al. 2019); improved groundwater (Nyssen et al. 2010). However, most of the watersheds are phased out about five years after implementation. Phase-out refers to the withdrawal of project inputs without continuity of support or arrangements of watershed management practices of the government and non-governmental organizations (Zeleke 2014). Nevertheless, none of the above and other studies dealt on the status and challenges of the implemented watershed interventions after Watershed project phased out. Hence, this study aimed at providing information on the status and challenges of watershed management activities after their phased-out so as to support planners, researchers and practitioners in sustaining project development intervention.

Materials and methods

Study area

The study was conducted in six watersheds (Adikesho, Deberehawabit, Gemad, Debretson, Laelay wukro and Tsigeresa) located in the Kilte Awlaelo district of Eastern Tigray, Ethiopia (Fig. 1). These watersheds represent the midland areas (1500–2300 m.a.s.l) of the Tigray region, which occupy 86.9% of the land mass. Geographically, the study district is characterized by Degua/cool, humid highland zone (13.1% of the land mass) which is located at an altitudes of above 2300 m above mean sea level, and midland/Weina-Douga (86.9% of the land mass), which is located at an altitude that ranges between 1500 and 2300 m above mean sea level (Rabia et al. 2013). The mean annual rainfall ranges from 500 to 1200 mm. Maximum temperature (34 °C) was observed in May and June; while minimum temperature (16 °C) was observed between September and December. The study area is dominated by igneous and metamorphic rocks (Precambrian, Paleozoic) (Rabia et al. 2013). The main reference soil groups are classified as Leptosols (36.8%), Calcisols (15.84%), Vertisols (14.64%), Cambisols (9.01%), Regosols (5.83%), Arenosols (5.72%), Phaeozems (5.13%), Luvisols (3.44%), Fluvisols (2.17%), Kastanozems (1.26%) and Stagnosols (0.16%) (Rabia et al. 2013). Community’s livelihood mainly depends on agriculture, which is characterized as mixed farming in which crops are produced and livestock reared, and managed on the same farm. The major crops grown are barley (Hordeum vulgare), wheat (Triticum sativum), teff (Eragrostis teff) and millet (Eleusine coracana). While, the major livestock herds are sheep, camel, mule, bees, donkeys, cattle, chicken and goats.

Methods of data collection

Site selection

The studied watersheds were deliberately selected for having an age of seven years after the watershed project phased out, and representing the midland agro-ecology. The selection of these six watersheds was carried out in consultation with Watershed experts and district administrator. The selection considered three successful and three unsuccessful watersheds...
following the criteria set by the Tigray Bureau of Agriculture and Rural Development. The Bureau put three major categories to classify watersheds into successful and unsuccessful (threshold > 50%): (i) Ecological (vegetation cover, ground water recharge, flood reduction, surface run-off reduction and animal diversity); (ii) socio-economic (irrigation water availability, women participation, and fodder production); (iii) Status of implemented soil and water conservation measures (biological and physical).

On-field measurement

In each Watershed, 3 transect lines were laid along the slope to determine the status of soil and water management systems and their challenges. For sampling purposes, each Watershed was divided into three parts according to the FAO (2006): upper slope (> 25 percent), middle slope (15–25 percent) and lower slope (< 15 percent). Nine (9) sample plots having a size of 50 m*50 m were laid within each transect at a 200 m distance as suggested in (Demissie and Fisseha 2016).

Social survey

Additional information on the status and challenges of watershed management activities after phased-out watershed projects was obtained from household watershed beneficiaries’ interview and focus group discussions. The sample size was determined by the following equation proposed in Glenn (1992). Interviewees were selected from the identified three locations (upper user, middle user and lower user) following a systematic random sampling method.

\[ n = \frac{N}{1 + Ne^2} \]  

(1)

where \( n \) = sample size; \( N \) = household size of the population; \( e \) = acceptable sampling error (10%).

Data analysis

Data were initially tested for normality. The numbers of physical soil and water conservation measures lost and damaged in each watershed were not usually normally distributed. Hence, no normality was changed to log 1, using SPSS version 20 statistical software. The lost or impaired physical soil and water protection measures were compared against the successful and unsuccessful measures using an independent two sample t test. Descriptive statistics were also used to examine the major problems facing integrated watershed management activities at the watershed and the major physical soil and water conservation measures.

| Watershed name | Number of beneficiaries | Sample size |
|----------------|-------------------------|-------------|
| Adikesho       | 300                     | 57          |
| Debrwahbit     | 300                     | 75          |
| Gemad          | 255                     | 71          |
| Debretson      | 350                     | 77          |
| Laelay wukro   | 120                     | 54          |
| Tsigerda       | 300                     | 75          |
| Total          | 1625                    | 409         |

Results

Implemented IWM practices

Several physical conservation measures with the purpose of reducing surface runoff and increasing infiltration were implemented through governmental and non-governmental organizations in the study watersheds. The major physical IWM structures constricted on the upper, middle and lower slope of the study watersheds include hillside terrace, terraces, stone bund, shallow trench, deep trench, half-moon, percolation pond, gabion check dams, lose stone check dam and hand dug well (Tables 1 and 2).

Status of the implemented IWM practices

The results indicated that broken shallow trench with stone band structure in the upper slope was statistically different \((P < 0.022)\) between the successful and unsuccessful watersheds. About 64 percent and 47 percent of the IWM physical measures were damaged in both unsuccessful and successful watershed, respectively (Table 3). The demolished hillside terrace and stone band note significant variations between \(P < 0.005\) and \(P < 0.004\) (57.2 percent and 70.5 percent), respectively, on the active watershed.

The ruined IWM physical measures on the middle slope showed a significant difference \((P < 0.05)\) between the successful and unsuccessful watersheds (Table 4). The ruined hillside terrace on the middle slope of unsuccessful was by 14.4 percent higher than that on the successful watershed. Similarly, the ruined half-moon structure was slightly higher (by 19 percent) on the unsuccessful watershed than that on the successful watershed. On the other side, stone bund destruction on unsuccessful watersheds was by 14.3 percent higher than that on the successful one.

The IWM measures on the lower slope had a significant different between Watersheds (Table 5). The lost gabion check dam on the lower slope of the unsuccessful watersheds was by 47.8 percent higher than that on the unsuccessful one. Similarly, broken deep trench with stone bund, loose
stone check dam, percolation pond was by 20.6 percent, 14.1 percent, and 6.4 percent higher on the unsuccessful watershed, respectively (Table 5).

Major challenges of IWM practices

The key challenges of the implemented IWM activities stated by the beneficiaries included lack of facilities (Gabion and cement), lack of maintenance, overgrazing and limited capacity to maintain the implemented measures (Table 6). More than 42 percent of the surveyed households in Deberewhabit and Gemad watersheds perceived lack of facility as the major challenge for poor success of the implemented measures. Moreover, more than 33% percent of the respondents in Adikesho indicated lack of maintenance as the major challenge. The major challenges stated for the unsuccessful Watersheds were overgrazing (26 percent for Debretsion), and Lack of facility (18.5 percent for Laelay Wukro and 21.3 percent for Tsigerda).

Table 2 Soil and water conservation practices in six watersheds

| Name–w       | U–slope       | No of structures | MI–slope       | No of structures | L–slope       | No of structures |
|--------------|---------------|------------------|----------------|-----------------|---------------|-----------------|
| Adikesho     | Hillside terrace | 35               | Half-moon      | 37              | Gabion check dam | 25              |
|              | Terraces      | 65               | Stone bund     | 68              | Loss stone check dam | 18              |
|              | Stone bund    | 15               | Stone bund     | 14              | Percolation pond | 4               |
| Deberewhabit | Shallow trench | 98               | Hillside terrace | 103             | Deep trench | 31              |
|              | Hillside terrace | 41               | Deep trench    | 79              | Gabion check dam | 40              |
|              | Stone bund    | 60               | Shallow trench | 39              | Pond          | 9               |
| Gemad        | Shallow trench | 55               | Half-moon      | 37              | Gabion check dams | 9               |
|              | Deep trench   | 27               | Hillside terrace | 23              | Loose stone check dams | 32             |
|              | Stone bund    | 50               | Shallow trench | 49              | Percolation pond | 4               |
|              |               |                  | Deep trench stone bund | 22          | Hand dug well | 18              |
| Debretsion   | Hillside terrace | 65               | Half moon      | 180             | Gabion check dam | 25              |
|              | Shallow trench | 70               | Stone bund     | 68              | Loss stone check dam | 37              |
|              | Stone bund    | 81               |              |                 | Percolation pond | 2               |
| Lelay wukro  | Hillside terrace | 95               | Deep trench    | 75              | Half moon      | 250             |
|              | Stone bund    | 105              | Shallow trench | 56              | Gabion check dam | 9               |
|              |               |                  | Deep trench stone bund | 22          | Hand dug well | 18              |
| Tsigerda     | Hillside terrace | 125              | Half moon      | 200             | Gabion check dam | 7               |
|              | Stone bund    | 121              | Hillside terrace | 25              | Loose stone check dam | 2               |
|              | Shallow trench | 35               | Deep trench    | 65              | Farm pond      | 3               |

Table 3 Mean and standard error (± SE) compression of destroyed SWC structures (%) on the upper slope of successfully and unsuccessfully performing watersheds

| Name of Watershed                  | Shallow trench with stone bund | Hillside terrace | Stone bund |
|-----------------------------------|--------------------------------|------------------|------------|
| Successful                        | 46.6(3.4)                      | 40.0(2.1)        | 54.7(3.7)  |
| Unsuccessful                      | 63.6(5.8)                      | 57.2(4.9)        | 70.5(2.8)  |
| P-value                           | 0.022                          | 0.005            | 0.004      |

Table 4 Mean and standard error (± SE) compression of destroyed SWC structures (%) on the middle slope of successfully and unsuccessfully performing watersheds

| Name of watershed | Hillside terrace | Half–moon | Stone bund |
|-------------------|------------------|-----------|------------|
| Successful        | 47.1(5.6)        | 38.7(3.4) | 51.6(3.3)  |
| Unsuccessful      | 61.4(4.0)        | 57.7(4.4) | 65.9(3.4)  |
| P-value            | 0.05             | 0.003     | 0.008      |

Table 5 Mean and standard error (± SE) compression of destroyed SWC structures (%) on the lower slope of successfully and unsuccessfully performance watersheds

| Name of Watershed                  | Deep trench with stone bund | Gabion check dam | Loose stone check dam | Percolation pond |
|-----------------------------------|-----------------------------|------------------|------------------------|-----------------|
| Successful                        | 36.5(4.4)                   | 32.5(3.0)        | 57.8(3.1)              | 51.6(11.3)      |
| Unsuccessful                      | 57.1(2.6)                   | 80.3(6.0)        | 71.9(5.8)              | 58.0(10.1)      |
| P–value                           | 0.001                       | 0.000            | 0.05                   | 0.674           |
The major implemented IWM measures in the studied watersheds were shallow trench with stone bund, Hillside terrace, Stone bund, Half-moon, Deep trench with stone bund, Gabion check dam, Loose stone check dam and Percolation pond. Studies in Maego watershed, of northern Ethiopia (Dimtsu 2018) also reported such physical IWM measures implemented on the farmlands, closure areas and grazing land. These practices are also influenced by slope variation, in which, shallow trench with stone bund, hillside terrace and stone bund at the upper slope; hillside terraces, half-moon, and stone bund at the middle slope; deep trench with stone bund, gabion check dam, loose stone check dam, and percolation pond at the lower slope. The number and the spacing between IWM structures in the watersheds depend on the slope gradient. Gessesse et al. (2009) and Dimtsu (2018) reported that when the spacing decrease slope gradient increases.

After IWM projects phased out, all IWM practices had shown a reduction in size and quality. The damage was pronounced in 40 percent (for hill side) to 70.5 percent (for stone bund) of the IWM practices on the upper slope. Furthermore, on the middle slope, damage between 38.7 percent (for half-moon) and 65.9 percent (for stone bund) was observed. It was also observed that IWM practices on the lower slope had shown a reduction after IWM project phased out ranging between 32.5 percent and 80.3 percent (for gabion check dam). This finding supports the study results of Nyssen et al. (2004) that reported about 40 percent destruction of check dams after two years of project phased out in Watersheds around Hagere Selam, northern Ethiopia.

The major reasons for the failure of the implemented IWM activities after IWM project phased out were lack of inputs, such as gabion and cement, lack of maintenance, overgrazing and limited capacity to maintain the implemented measures, as shown in Table 6. Similarly, Zeleke et al. (2006) estimated that 25 percent of the implemented stone bunds and 60 percent of the hillside terraces were destroyed due to lack of maintenance. Furthermore, Mekonen and Tesfahunegn (2011), for Medego watershed in northern Ethiopia, reported that lack of maintenance was one of the factors for soil and water conservation activities failure. In south-east Ethiopia Goba District Tiki et al. (2016) reported that 100 percent of the stone bunds are lost due to lack of maintenance and overgrazing. At the Wyebal Watershed, Northwest Ethiopia, 84.6 percent of the check dams was destroyed in which free grazing and lack of maintenance were the major drivers (Walie 2016). Limited technical and supply supports were also reported as drivers elsewhere (Alemu and Kidane 2014). The IWM implementation and phasing-out process was also characterized by lack of strong local institutions and poor community engagement. Lack of effective community engagement, poor technology implementation, insufficient policy, lack of stakeholder participation and lack of ownership strongly contribute to failure of IWM practices (Pretty and Ward 2001; Habtamu 2011; Meshesha and Birhanu 2015).

### Table 6 Challenges of watershed management practices after IWM project phased out

| Challenges                              | Successful Watersheds | Unsuccessful watersheds |
|-----------------------------------------|-----------------------|-------------------------|
|                                         | Adikesho | Debrwahbit | Gemad | Debretsion | Laelay Wukro | Tsigerda |
|                                         | Freq. % | Freq. % | Freq. % | Freq. % | Freq. % | Freq. % |
| Over grazing                            | 20 26.7 | 15 20    | 15 21.12 | 20 26 | 7 12.9 | 15 20 |
| Lack of maintenance                     | 25 33.3 | 25 33.3  | 26 36.6 | 10 13 | 9 16.7 | 12 16 |
| Lack of awareness                       | 10 13.3 | 5 6.7    | 0 0     | 10 19.5 | 9 16.7 | 9 12  |
| Lack of facility                        | 20 26.7 | 30 40    | 30 42.25 | 10 13 | 6 11.1 | 6 8   |
| Total                                   | 75 100  | 75 100   | 71 100  | 77 100 | 54 100 | 75 100 |

Freq: frequency
Conclusion

The Integrated Watershed Management (IWM) practices implemented in the studied watersheds range from loose stone check dam to percolation pond. The type and quantity of these measures vary by variation in slope. After IWM projects phased out, all IWM practices, regardless of slope variation, had shown a reduction in size and quality. The major reasons for the failure of the implemented IWM activities after IWM project phased out were lack of inputs, such as gabion and cement, lack of maintenance, overgrazing and limited capacity, to maintain the implemented measures. It can be argued that integrated watershed management activities after IWM project phased out, regardless of the IWM class (successful and unsuccessful) are not sustainably kept. Hence, community engagement in all IWM processes is of paramount importance to sustainably manage the IWM practices.

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