Journal of Arid Environments xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Economic and environmental rehabilitation through soil and water conservation, the case of Tigray in northern Ethiopia

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ARTICLE INFO

Keywords:
Environmental rehabilitation
Integrated catchment management
Soil and water conservation
Tigray

ABSTRACT

The natural resources in the semi-arid area of Tigray, northern Ethiopia, have been exploited for years. This has caused severe land degradation, which in turn led to recurrent drought and poverty. To recover the degraded lands, soil and water conservation (SWC) interventions were given a policy attention since the 1970s. Starting 1990s, SWC-based integrated catchment management (ICM) implementation programmes, complemented by conservation-based agricultural development strategy, have been implemented. Many studies on ICM interventions and associated benefits have been reported so far. However, as most of the studies were conducted on experimental plots/small catchment scale, none of them have attempted to report the achievements and lessons at large scale. Hence, a comprehensive review is needed to explore and publicize the interventions and associated benefits. This review was conducted through detailed analysis of evidence and facts from literature, field observations and farmers' perceptions. The reviewed literature explicitly showed that ICM interventions have been successful in Tigray. Collective evidence has shown that most of the degraded landscapes are considerably restored, of which the soil fertility, availability of water, and rainfed and irrigated crop productivity have significantly increased over the last two decades. Consequently, environmental, ecological and socio-economic changes have been observed when compared to pre-implementation of ICM. Despite these achievements, some interventions often suffer from over-ambition, upward accountability and a top-down approach. Failures of Horeye and roof water harvesting, mismanagement of fertilisers, low survival of tree seedlings and lack of income from exclosures can be considered pitfalls that may affect the sustainability of the achievements. An important lesson drawn from Tigray is the participation of all stakeholders and the strong commitment and sense of ownership by the people and local government, which many projects lack worldwide. Observed experiences, achievements and implementation pitfalls can provide a lesson to other regions with similar agro-ecological, environmental and socio-economic setups.

1. Introduction

Because of the unwise use of land and water resources, the quality and quantity of different landscapes have been degraded globally (Darghouth et al., 2008). For restoring the degraded landscapes, soil and water conservation (SWC) intervention plays an inevitable role (Pimentel, 1993). SWC intervention has the capacity to sustainably maintain environmental and ecological services if properly implemented (Nyssen et al., 2015). Moreover, SWC interventions can improve livelihoods and societal developments (Hurni et al., 2015). To this effect, SWC interventions have been successfully implemented in various forms across the world.

Degraded lands have been converted into well-established environmental and economic achievements throughout the world (Cooper et al., 2008; Brooks and Eckman, 2000; Hurni et al., 2015). Examples are the Loess Plateau and the Three Gorge Area in China (Zhao et al., 2013; Zhang et al., 2015; Shi et al., 2004); Mayurakshi, Salaiyur and Adarsha Watersheds in India (Chowdary et al., 2009; Sikka et al., 2002; Wani et al., 2003); Sepetiba Bay watershed in Brazil (Neto et al., 2006); Anyangcheon watershed in Korea (Lee and Chung, 2007; Lee et al., 2008); Lam Sonthi watershed in Thailand (Phomcha et al., 2011); Kiroka village in Tanzania (Cooper et al., 2008); Merguellil catchment in Tunisia (Lacombe et al., 2008); Machakos district in Kenya (Tiffen and Mortimore, 1994; Cooper et al., 2008; FAO, 2014); and Enabereid, Abraha Atsbaha, Haro, Maybar and Debre Mawi catchments in Ethiopia (Haregeweyn et al., 2012; Cooper et al., 2008; Tesfaye et al., 2016). These studies showed that SWC has been employed to mitigate land degradation. However, despite substantial efforts to reverse the

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https://doi.org/10.1016/j.jaridenv.2017.12.002
Received 20 June 2016; Received in revised form 13 June 2017; Accepted 5 December 2017

Please cite this article as: Gebremeskel, G., Journal of Arid Environments (2017), https://doi.org/10.1016/j.jaridenv.2017.12.002

degraded areas, the achievements are far below the expectations (Amdihu et al., 2014; Garg et al., 2012; Mu et al., 2007; Baptista et al., 2015). The outcome of many SWC projects has not been sufficiently achieved because of the poor management of the before and after implementations, mainly top-down intervention approaches (Smith, 1999; Segers et al., 2008a), less integration among disciplines (social, technical and institutional) (German et al., 2006; Mekonen and Fekadu, 2015), lack of consistent biophysical impacts and benefits (Baptista et al., 2015), and high labour and capital intensive (Smith, 1999; Ruthenberg, 1974). As a result, the corresponding framework for participatory SWC implementation remains fragmented. On the contrary, achievements from Tigray can be considered a model of the implementations and positive impacts achieved from the SWC programmes (Nyssen et al., 2009b; Lanckriet et al., 2014a).

Tigray from northern Ethiopia is known for its drought-prone area where agriculture has been practiced for years (Sulas et al., 2009; Esser et al., 2002; Walraevens et al., 2009). This long-term unlimited use of farmlands for crop production combined with the unwise use of vegetation has caused severe land degradation (Frankl et al., 2012; Munro et al., 2008). The land degradation coupled with erratic distribution of rainfall has caused a recurrent drought and famine, which was historically demonstrated during 1888–1892, 1973–1974 and 1984–1985 (Gebrehiwot et al., 2011; Legesse et al., 2003; Osman and Sauerborn, 2001). These situations had delivered a clear message to the people, government and stakeholders that SWC interventions are essential for land restorations and to protect from drought occurrence. SWC interventions were initially implemented in farmlands; however, during the 1990s, integrated catchment management (ICM) approach was introduced into all landscapes (Nyssen et al., 2014; Asfaha et al., 2014). This programme was also strengthened by designing a conservation-based agricultural development strategy (Lal, 1989; van der Veen and Tagel, 2011). Implementations of SWC based on the ICM intervention have significantly improved natural resources in the last two decades (Alemayeuh et al., 2009). As a result, land management through SWC has become an integral part of the farming system in Tigray, and these experiences are being shared worldwide (Munro et al., 2008; Nyssen et al., 2010; WFP, 2012; Walraevens et al., 2015).

Although Tigray is known for its vast experience in SWC implementation programmes, the success and challenges observed have not been well documented and disseminated to users. Most of the previous studies (e.g. Alemayehu et al., 2009; Frankl et al., 2012; Nyssen et al., 2007, 2010; Taye et al., 2015; Hurni et al., 2015) focussed on experimental plots, and none of them tried to show their achievements and lessons at large scale. Thus, this study was proposed to review the experiences on SWC implementations and associated benefits with the specific objective (i) to summarise the experiences and lessons of SWC implementation programmes, (ii) to indicate the major challenges and issues to be considered in SWC implementation programmes and (iii) to compare SWC experiences of Tigray with related experiences around the world.

2. Background of SWC in Tigray

Indigenous SWC practices date back to 400 BCE (Ciampalini et al., 2012). However, planned SWC works were started through food aids by the World Food Program in the early 1970s (Ciampalini et al., 2012; Haregeweyn et al., 2015; Nana-Sinkam, 1995; Osman and Sauerborn, 2001). Since then, traditional terracing through stone bunds has been commonly practiced on cultivable lands in the highlands of Tigray (Munro et al., 2008; Hunting, 1974; Virgo and Munro, 1977; Hurni, 1993a,b). In addition, indigenous knowledge of farmers such as knowledge on *Daget* (local terracing) and improved physical SWC measures has been integrated at various slopes (Nyssen et al., 2000). However, the then existing SWC programme was mainly focused on physical measures and tree plantations, which lacked participatory planning and voluntary participation of the people (Osman and Sauerborn, 2001). Slope gradient-based SWC approach that considers the construction of physical SWC structures at farmlands was applied since the initiation of SWC works (Hurni, 1993a,b; Ciampalini et al., 2012; Esser et al., 2002). The Tigray Peoples Liberation Front started to implement this approach in the liberated areas of Tigray during 1988–1990 (Esser et al., 2002; Segers et al., 2008a). However, this approach lacked sustainable conservation of natural resources at a catchment level.

Rehabilitation of degraded lands at catchment scale was introduced in Gira Kahsu of southern Tigray since the mid-1980s (Asfaha et al., 2014). Continued construction of physical SWC structures has been given due attention during this period (Gebremichael et al., 2005; Nyssen et al., 2009a). The main actors of the conservation activities were the peasant associations (PAs), the SWC department of the Bureau of Agriculture, the forestry and wildlife conservation development authority (FWCDA) and different NGOs such as those related to churches, the Red Cross, the Relief Society of Tigray and Oxfam (Osman and Sauerborn, 2001). After the change of government in 1991, the new government has initiated the SWC works to implement during January as free service for 20 consecutive working days, followed by food for work for the remaining days of the dry season. Nowadays, it is a common habitual exercise by all farmers under the ICM principles. The ICM is now strongly promoted in Tigray under various land and socio-economic conditions.

3. Study area description

Tigray is located in northern Ethiopia (Fig. 1) between 12°15′ and 14°50′N and between 36° 27′ and 39° 59′E with an area of 80,000 km^2 (Hagos et al., 1999, 2016). It is surrounded by Sudan in the west, Eritrea in the north, and the Ethiopian regions of Amhara and Afar in the south and east, respectively. Altitude varies from 500 m.a.s.l. in the northeast to 4000 m.a.s.l. in the southwest (Hagos et al., 1999). It is characterised by undulating terrain and steep slopes, fragile environment, erratic rainfall and sparse vegetation coverage, which in turn facilitate soil erosion (Esser et al., 2002; Hagos et al., 1999).

The climate of Tigray is semi-arid, dominated by distinctive dry and wet seasons (Meire et al., 2013; Walraevens et al., 2015). The region receives 80% of its rainfall during the rainy season from June to September (Nyssen et al., 2011; Walraevens et al., 2009). The average rainfall varies from about 200 mm in the northeast lowlands to over 1000 mm in the south western highlands (Hagos et al., 1999). The dry period over the region extends up to 10 months, and the maximum effective rainy season extends from 50 to 60 days (Zenebe et al., 2013). Variations in rainfall are mainly associated with the seasonal migration of the inter-tropical convergence zone and complex topography (Nyssen et al., 2005, 2009d). The average temperature is estimated to be 18 °C, which reaches approximately 40 °C around Humera (Hagos et al., 1999).

Four land-use types, including cropland, villages and built-up areas, exclosures, and pastures and rangelands are identified in Tigray (Meire et al., 2013). Croplands are the dominant land-use type in Tigray. Thirteen major soil types are identified: cambisols, rendzinas, lithosols, acrisols, fluvisols, luvisols, regosols, nitosols, arenosols, vertisols, xerosols, solonchacks and andosol (Hunting, 1974, 1976; Virgo and Munro, 1977; Hagos et al., 1999). Texturally, these soil types cover from light to heavy soils.

The Tigray highlands drain toward the African Rift Valley in the east, the Mereb River in the north and the Tekeze River in North western (Lanckriet et al., 2015a,b). The geological formations consist of Precambrian metavolcanics and Mesozoic sedimentary rocks such as Adigrat sandstone, Antalo limestone, Agula shales and Amba Aradam sandstone, which in turn are intruded by Cenozoic dolerite dykes/sills (Merla et al., 1979; Gebreyohannes et al., 2013; Lanckriet et al., 2015a,b; Haregeweyn et al., 2008b). Tertiary basalts are found overlaying the Precambrian and Mesozoic rocks. In addition, the Enticho