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Review on Dynamics of Soil Erosion and Conservation Efforts in Ethiopia

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Abstract

This review paper was intended to review the dynamics of soil erosion and its conservation efforts in Ethiopia. Soil erosion rates are highly variable and large by international standards, and sheet, rill, and gully erosion are the dominant processes in the country. Institutionalized soil and water conservation practices in Ethiopia became significant only after the 1970s. The efficiency of conservation efforts show mixed results that are influenced by the type of measures and the agro-ecology. In general, the conservation effort is better in the dry lands as compared with humid areas. Although farmers have shown an increased understanding of the soil erosion problem, soil and water conservation practices efforts face a host of barriers related to limited access to capital, limited benefits, land tenure insecurity, limited technology choices and technical support, and poor community participation. Additionally, soil and water conservation research in Ethiopia is fragmented and lacking articipatory research, field observations, and adoptable methods to evaluate impacts. A potentially feasible approach to expand and sustain soil and water conservation programs is to attract benefits from climate change sequestration through carbon trading and institutional- research linkage regarding soil and water conservation practices in the country.

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Introduction

Soil erosion is one of the most critical environmental issues because of its adverse economic and ecological influence (Yuan *et al.*, 2016). It occurs due to several factors and these factors are worldwide and vary in their intensity and magnitude. In most cases they are natural in their origin, but the human interference triggers the erosive power of these factors. Land use/cover change and human activities aiming at different objectives are the primary cause of accelerated soil erosion (Pasquale *et al.*, 2013).

The highlands of Ethiopia occupy 90% of country's arable land and as a result population in the highlands is very dense due to farmers prefer these areas to avoid diseases like malaria. The worsening situation of soil and general environmental degradation has been reported to reduce the concentration of the population on highlands, thereby to help halt environmental degradation (Adugnaw, 2014). Nigussie *et al.*, (2015) stated that the fragmented nature and uneven spatial distribution of researches conducted on the problem indicates the necessity of conducting a research in order to overcome the uncertainties related with estimating the gross soil loss from the country.

Different studies in Ethiopia reported that various soil and water conservation measures at various spatial scales have a positive impact on erosion control, soil moisture conservation, vegetation regeneration, soil build up, reduction of sediment and economic aspects (Taye *et al.*, 2013; Haregeweyn *et al.*, 2012a, 2015b; Mekuria *et al.*, 2007; Nyssen *et al.*, 2009a; Adgo *et al.*, 2013; Adimassu *et al.*, 2013; Bewket, 2007). Studies that aim at a better understanding of the extent, causes, and impacts of soil erosion, as well as the soil and water conservation measures implemented through the various initiatives, are fragmented. In addition, comprehensive studies that evaluate past activities and draw lessons from experiences with the aim of aiding future development both at the regional and national levels are scarce.

According to Ciampalinia *et al.*, (2012) soil and water conservation practices have been applied for centuries, most likely first implemented during the Aksumite Kingdom (400 BC to 800 AD) in the Aksum area, Tigray Region, northern Ethiopia. Similarly, Beshah (2003) reported that the traditional terraces in Konsoarea are best examples of a living cultural tradition stretching back 21 generations (more than 400 years). Since the beginning of the 1990s, watershed management approaches that integrate soil and water conservation, intensified natural resource use, and livelihood objectives have been implemented in several micro-watersheds (Haregeweyn *et al.*, 2012a; MoARD, 2006; SLMP, 2013a). The concept of participatory watershed development and management emphasizes a multi-disciplinary and multi-institutional approach for multiple interventions (German *et al.*, 2007). Hence, indigenous soil conservation practices in Ethiopia are generally poorly recorded and not considered by soil and water conservation experts and policymakers (Haile *et al.*, 2006; Kruger *et al.*, 1996; Reij, 1991).

Soil erosion rates in Ethiopia

Different studies by different authors have estimated soil loss rates in different parts of Ethiopia at various scales. Analysis of a compilation of soil loss rates caused by sheet and rill erosion at plot and catchment scales indicates that this soil degradation process varies strongly spatially, with a mean soil loss 29.9 t ha^{-1} yr^{-1} where the highest rates were observed in Anjeni (110 t ha^{-1} yr^{-1}) and Chemoga (102 t ha^{-1} yr^{-1}) watersheds. In the northern Ethiopian highlands and the Central Rift Valley of Ethiopia there is larger erosive power of rainfall as compared with elsewhere in the world (Nyssen *et al.*, 2005; Meshesha *et al.*, 2014). Niang *et al.*, (2014) indicate a likely increase in precipitation and extreme precipitation events causing soil loss rates of 38.7 t ha^{-1} yr^{-1} from rangeland as compared with 7.2 t ha^{-1} yr^{-1} from cropland.

FAO (1986) estimated the gross annual soil loss of Ethiopia that 1.9 $x10^9$t, of which 80% originates from croplands and Hurni (1988) estimated a nationwide annual gross soil loss of1.5 $x10^9$t. Similarly, Sonneveld *et al.*, (2011) reported that soil loss varies remarkably from 0 t ha^{-1} yr^{-1}in the eastern and southeastern parts of Ethiopia to more than 100 t ha^{-1} yr^{-1} in the northwestern part of the country. Therefore, from the above estimates it can be seen that the soil loss estimation at national level is still inconsistent.

Tebebu *et al.*, (2010) estimated that an extremely high gully erosion rate of 530 t ha^{-1} yr^{-1}inDebreMawi watershed located in the northwest Ethiopia, which is approximately 20 times larger than the measured sheet and rill erosion rates at the same study site. A relatively similar gully erosion rate of 566 t ha^{-1} $yr^{-1}$was reported by Daba *et al.*, (2003) for the Damota watershed in eastern part of Ethiopia. But, lower gully erosion rate was reported in the northern part of Ethiopia by Nyssen *et al.*, (2006) which is 6.2 t ha^{-1} yr^{-1}. In general, most of the gully erosion studies conducted in Ethiopia are lacking detailed historical records on gully erosion (they are based on the interpretation of relatively low-resolution aerial photographs or in combination with satellite images and repeated photographs supplemented by data obtained from questionnaires).

Bard *et al.*, (2000) studied the environmental history of north Ethiopia with particular reference to the pre-Aksumite to post-Aksumite period (500 BC–900 AD) and concluded that during this period the region underwent effects linked to demographic development, climate change, and changes in vegetation cover, all of which contributed to soil erosion.

Soil and water conservation efforts in Ethiopia

Different Soil and water conservation initiatives have been started to conserve soil and water in Ethiopia, especially since the 1980s mainly implementation of soil bunds combined with trenches in croplands, which are constructed by mobilizing the community through the free-labor day scheme; soil bunds integrated with Sesbania trees in croplands, where the trees are also being used for animal feed through a cut-and-carry system and check dams constructed across gullies (TANGO, 2012). These initiatives include Food for Work (1973–2002), Managing Environmental Resources to Enable Transition to more sustainable livelihoods (2003–2015), the National Sustainable Land Management Project (2008–2018), Productive Safety Net Programs (2005–present) and Community Mobilization through free-labor days (1998–present). The Food for Work program started in the form of food aid and gradually shifted in the 1980s to a development oriented program through engaging the community in rehabilitation of degraded lands (Devereux *et al.*, 2006).

Studies in northern part of Ethiopia confirmed the More People–Less Erosion hypothesis (Tiffen *et al.*, 1994). Land management in Tigray has led to significant improvements in terms of soil structure, rain infiltration, crop yield, biomass production, groundwater recharge, and prevention of flood hazard (Nyssen *et al.*, 2008a).Studies on land use and land cover change over the past few decades document a trend towards the increased removal of remnant vegetation, but the trend has slowed and even reversed in some areas of northern Ethiopia because of the government's set-aside policy (Nyssen *et al.*, 2004a). In other studies, Nyssen *et al.*, (2009b, 2014) found a significant increase in woody vegetation and soil and water conservation structures in areas with higher population densities, especially during the last two decades. Some researchers stated that Soil and water conservation efforts do not lead to the desired effects, or are even counterproductive (Hengsdijk *et al.*, 2005; Keeley and Scoones, 2000).

The effectiveness of soil and water conservation measures is, however, influenced by the moisture regime and by the age of the structures. Kato *et al.*, (2011) reported that soil bunds, stone bunds, and grass strips are more effective under low rainfall regimes, whereas grass waterways are more suited to use under high rainfall regimes. Hurni *et al.*, (2005) indicated that soil and water conservation efforts in the Ethiopian highlands will work to a more limited extent in humid areas compared with the semiarid areas. Taye *et al.*, (2015) studied the evolution of the effectiveness of stone bunds and trenches for the reduction of runoff and soil loss in the semi-arid Ethiopian highlands and concluded that these measures are only fully effective in the first year of their construction.

The performance assessment of fanyajuu terraces, soil/stone bunds, grass strips, and double ditches was conducted at seven research sites in different agro-ecological settings by Herweg and Ludi (1999); the results indicated that the measures did not bring a net increase in crop yield and biomass production. In a case study of Anjeni in the northwestern Ethiopian highlands, Kassie *et al.*, (2011) stated that fanyajuu terraces cannot be characterized as a win win measure to reduce soil erosion because of the lower net value of crop income for plots with fanyajuu terraces as compared with those without them. By contrast, another case study from the Anjeni site by Adgo *et al.*, (2013) reported that soil and water conservation measures have long-term benefits to smallholder farmers.

An assessment of the effects of stone bunds on crop yields and farm profitability based on on-farm research in Tigray, northern Ethiopia, by Gebremedhin *et al.*, (1999) showed that investment in stone bunds yielded a 50% rate of return. However, another study in the same region on plots with stone bunds of different ages reported that the cost of building stone bunds is nearly the same as the value of the induced crop yield increase, despite an average increase in grain yield of 53% (Nyssen *et al.*, 2007).

Factors affecting adoption of Soil and Water conservation practices in Ethiopia

The major factors affecting soil and water conservation measures include, labor availability, limited capital, lack of or limited incentives and benefits, land tenure policy, technology choices, technical support, and community participation. The high labor demand required for the implementation of SWC measures was found to be an important bottleneck in several case studies (Bekele and Drake, 2003; Bewket, 2007; Gebremedhin and Swinton, 2003; Tefera and Sterk, 2010). Although lack of capital inhibits farmers from paying cash for soil and water measures (Adimassu *et al.*, 2013; Asrat *et al.*, 2004; Shiferaw and Holden, 1999; Tefera and Sterk, 2010), many farmers are willing to contribute a substantial amount of free labor as a gesture of their support for conservation programs (Asrat *et al.*, 2004).Land tenure insecurity arising from the government's ownership of land is also reported to discourage farmers from implementing SWC technologies (Bewket, 2007; Gebremedhin and Swinton, 2003).

Several studies note the application of inappropriate technology relative to local conditions as a reason for the low adoption rate or the unsustained use of soil and water conservation measures (Adimassu *et al.*, 2013; Amsalu and de Graaff, 2006, 2007; Bewket, 2007; Bewket and Sterk, 2002; Duguma and Hager, 2011). Some farmers either perceive the structures as ineffective (Bewket and Sterk, 2002) or have developed negative attitudes towards externally recommended measures (Amsalu and de Graaff, 2006). In addition, the lack of technologies that provide quick returns to subsistence-constrained farmers also seems to deter investments in land resources (Shiferaw and Holden, 1999). In order to enhance the sustained use of the measures, conservation interventions should focus not only on the biophysical performance of the measures, but also on the economic benefits (Amsalu and de Graaff, 2007; Duguma and Hager, 2011; Shiferaw and Holden, 1999; Tefera and Sterk, 2010).

A gap in technical support from development agents and other development officers is another factor that negatively influences farmers' cooperation in adopting conservation measures (Bekele and Drake, 2003; Dessie *et al.*, 2012; Tefera and Sterk, 2010; Tesfamichael *et al.*, 2013). EARO (1998) argued that extension services for natural resources management have been marginalized. Moreover, insufficient attention has been given to indigenous practices and the farmers' level of competence in solving their own problems, which is usually underestimated and deemphasized in the design of land management practices (Haile *et al.*, 2006).

In conclusion, soil erosion is a problem in large parts of Ethiopia, and it could get worse in the future because of the forecasted increase in population and the occurrence of extreme precipitation events. Most of the conservation efforts have mainly targeted social protection to frequently drought affected areas in northern and northeastern Ethiopia, whereas natural resources conservation itself was not given sufficient policy attention. Moreover, the extent and areal coverage of available soil and water conservation measures remain unknown. In general, the poor availability and reliability of soil erosion data, lack of adoptable methods combined with the high heterogeneity of environmental factors remain major impediments to soil erosion studies in the region. Moreover, a clear institutional arrangement and coordination between the extension and research efforts for appropriate land management efforts is lacking. Therefore, a full-fledged institution responsible for overseeing the research and extension aspects of land management programs remains an important but unrealized goal. A potentially feasible approach to expand and sustain soil and water conservation programs is to attract benefits from climate change sequestration through carbon trading and institutional- research linkage regarding soil and water conservation practices in the country.

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