TRENDS OF COMMUNITY-BASED INTERVENTIONS ON SUSTAINABLE WATERSHED DEVELOPMENT IN THE ETHIOPIAN HIGHLANDS, THE GUMARA WATERSHED

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Abstract

Soil erosion is the driver of food insecurity and environmental degradation affecting the lives of smallholder farmers. To tackle soil and water degradation government-led large-scale soil and water management programs have been introduced at a watershed scale. The long-term viability of those practices in the Gumara watershed remains a major challenge. The objective of the study was to better understand the general approaches used to implement and design watershed management practices so that soil and nutrient transport to downstream water bodies could be managed. Sub watersheds from the large Gumara watershed were identified for detailed study based on erosion hotspots using the SWAT model. These sub-watersheds represent communities organized for conservation works in the absence of food assistance programs. The data were collected from four focus groups of fifty participants each, field observation, and desk-level meetings with experts. A structured questionnaire was used to get relevant information to the participating farmers. According to the findings, each of the selected watersheds used similar approaches to implement conservation activities. The community withdrew from conservation efforts, even on their farm fields, since the success rate was below the expectation. At this spot realizing the long-term benefits of watershed development activities stayed challenging. The smallholder farmer, on the other hand, clearly relies on rain-fed agriculture and hopes to see immediate results to feed his family. In conclusion, government-led development programs have not been evaluated, technically supported, lack trusted in the community and hence development efforts were put in jeopardy.

INTRODUCTION

Soil erosion by water threatened the food security and environmental protection of the globe (Lieskovský & Kenderessy 2014). The sub-Saharan African countries, including Ethiopia, are the most affected by soil erosion (Israel et al., 2020; Terefe et al., 2020). Globally, soil erosion affects about 10 million hectares of cultivated land each year, with Africa accounting for 65 percent of the damage (Vlek et al., 2008; Pimentel, 1995). In Ethiopia, the amount of soil loss reported about 2 billion t yr^{-1}. The annual average soil loss from cultivated fields is about 100 t ha^{-1} (FAO, 1986; Bewket & Sterk 2002).

Gumara River watershed is one of the major tributaries to Lake Tana and the Blue Nile river basin (Setegn et al., 2008). The watershed attributes extreme soil erosion, high runoff and the highest rainfall intensity (Belayneh et al., 2019; Fazzini et al., 2015). Different researches were completed to quantify the rate of soil erosion in the watershed. According to Easton et al. (2010), the predicted soil loss from Gumara watershed was about a maximum of 84 t $ha^{-1}yr^{-1}$. A study conducted by Belayneh et al. (2019) and Zimale et al. (2017), reported that an average soil loss rate of 42 and 49.2 t ha^{-1} yr^{-1}, respectively. Wubie & Assen (2019) showed the soil degradation index (SDI) in the watershed was in the range of -236 to -364%, indicating that the area is subjected to high soil erosion. To reverse this trend, the Ethiopian government with the help of non-governmental organizations started a large-scale watershed development program (WDP) to increase agricultural productivity, and reduce soil erosion. The program focused on the construction of the physical structure in the highlands for the last two decades. However, the rate of soil erosion was not decreasing (Abate et al., 2015).

The effectiveness of conservation measures over longer periods evaluated as not effective, especially in the sub-humid and humid monsoonal climates (Yeraswork, 2000; Mhiret et al., 2020). Whereas, in the semi-arid highlands of the Tigray region, the implemented measures were effective in reducing soil erosion and increasing water storage (Nyssen et al., 2009). In humid highlands, sediment concentrations in the major rivers showed an increasing trend (Abate et al., 2016). According to Haile et al., (2006), the failure was related to the poor design of soil and water conservation practices (SWCP). Watershed planners lack knowledge of the hydrological processes and the landscape location (Guzman et al., 2017b, Bayable et al., 2016). In areas like Ethiopia where SWC was implemented in community mobilization, the standards of conservation measures were influenced by inadequate expert follow-up, lack of farmers' technical skill, and poor community participation (Sinore et al., 2018; Zimale et al., 2017; Reij et al., 1996).

The livelihood of smallholder farmers largely dependent on the long-term viability of WDP. The success of development projects largely determined by community participation and commitment. Participation is a group effort to establish long-term management requirements, identify objectives, determine potentials, technology selection and policies, and monitor and analyze outcomes (Johnson et al., 2001). Community participation promotes long-term watershed management activities (Lubell & Fulton 2007). However, government-sponsored conservation efforts, have taken a top-down approach, failing to understand the needs, concerns, and traditions of local people. The local people who were worried about and motivated to take action must have built up WDP from the bottom-up (Mullen & Alison 1999). Conservation programs failed to produce immediate results benefiting the poor farmer, making it hard to invest in long-term impacts. The objective of this research was, therefore, to better understand the general approaches used in the implementation of SWCPs in watersheds and the design of WDP in the Gumara watershed, to efficiently maintain soil erosion to the downstream water bodies.

MATERIALS AND METHODS

Description of Gumara Watershed

The Gumara watershed is found in the North-West part of Ethiopia in the Amhara National Regional State, South Gondar Zone at 624 km north of Addis Ababa (Figure 1). This watershed is situated in the eastern part of the Lake Tana sub-basin. Astronomically, the watershed lies between 11^0 34' 41.41" N and 11^0 56'36.95" N latitude to 37^0 29' 30.48" E and 38^0 10' 58.01" E longitude (Figure 1). Gumara watershed has an undulating topography ranging from 1755 m a.s.l. near Lake Tana to 3700 m a.s.l. at mount Guna (Figure 2a). The topography of the area has an important contribution to the surface runoff and soil erosion processes (Yibeltal, 2020). The steep slope in the upper part and gentle slope in the downstream characterizes the watershed (Figure 2b). The area is dominated by unimodal rainfall mainly concentrated from June to September. The mean annual total rainfall ranges from 1257 to 1544 mm. Based on the 2018 land use land cover classification, cultivated land constitutes the largest share of the watershed with 97.5% (1509 km^2). Grazing and forest land comprise 1.4% (22 $km^{2)}$ and 1.2% (19 km^2), respectively. Gumara watershed experienced large-scale land use/cover dynamics. Cultivated and settlement land expanded by 21.99% whereas forest, shrub, grassland, and wetland declined by 85%, 91%, 76%, and 73% over the period 1985–2016, respectively (Wubie et al., 2016*)* . Although there is a decline in natural vegetation, there is an expansion of some exotic tree species like eucalyptus on privately owned farm plots. The major means of livelihood in the area is subsistence-mixed agriculture (crop and livestock production).

Methods

Study site selection

Before the start of the research in the watershed, sub-watersheds were identified. Watershed development practices (WDP) have been started on degraded watersheds and the assessment was ideal to meet the community engaged in SWC efforts. Therefore, selecting erosion hotspot watersheds were taken as a tool to identify sample sub-watersheds. A hydrologic analysis tool soil and water assessment (ArcSWAT, Version 2009) model was applied to identify hotspot watersheds based on sediment yield output. The SWAT model used different input data such as digital elevation model (DEM) for watershed delineation, land use and soil data, weather data (Rainfall, minimum and maximum temperature, humidity, sunshine hour) and streamflow data to predict the streamflow. DEM, Land use, soil, weather and streamflow data were found from the USGS webpage, Ministry of water energy and irrigation, and Ethiopian meteorology agency, respectively.

Therefore, the SWAT model output provides the amount of soil loss in the watershed. Based on the given values greater than 65 t ha^{-1} yr^{-1} of sediment loss were considered for the research. Although a greater number of sub-watersheds had soil loss greater than 65 t ha^{-1}yr^{-1}, the research gave priority to those watersheds having access to roads and their proximity to agriculture offices. Besides, since the watersheds lie under the four districts, due consideration was given to include agriculture officers as a source of information assuming that different modes of watershed implementation approach employed. Finally, the four selected watersheds located under the four districts (Farta, Fogera and Dera) were, Girbi, Gena-mechawocha, Tankua Gebriel and Wanzaye (Figure 3).

Characteristics of selected watersheds

The study was conducted in the Gumara watershed specifically on the selected four sub-watersheds (Figure 4). The watersheds Girbi and Gena-mechawocha are under the Farta district administrative; Tankua Gebriel in Fogera and Wanzaye in Dera districts. The altitude of the selected watersheds ranging from 1800 to 2846 m a.s.l. (Figure 4). These watersheds cover an area of 581.5 ha for Girbi, 695.5 for Gena-mechawocha, 627.1 for Tankua Gebriel and 555.2 ha for Wanzaye.

The land use land cover of the four watersheds is shown in figure 5 (Gena-mechawocha (a); Tankua Gebriel (b); Wanzaye (c) and Girbi (d). In these watersheds the land use is classified as built-ups, forests, cultivated and grazing land. The built-ups were hard to identify and were the dispersed rural settlements. The area covered under this land use category indicated greater in Girbi watershed since the tip of the watershed includes parts of the Debre Tabor town (about 101 ha) and followed by Gena-mechawocha (7.4 ha, Figure 5). The area under forest cover, which includes trees planted around homesteads and there is an increasing trend over the past years (Halefom et al., 2019). This is attributable to the afforestation program of the government and planting eucalyptus trees at the household level. The area covered with forests in Girbi and Gena-mechawocha were about 277 and 250 ha, respectively (Table 1). However, in Girbi, almost all are eucalyptus plantations in the hillslopes and near the homesteads. The reason is due to its proximity to the urban area (Debre Tabor).

Cultivated land covers the greater percentage of the total watershed area with 28, 62, 72 and 68 percent in the Girbi, Gena-mechawocha, Wanzaye and Tankua Gebriel watersheds, respectively (Table 1). This land-use type increased from time to time due to an increase in population growth and the land redistribution in the Amhara Regional State in 1997 that allocated much of the marginal land to landless farmers. The grazing land area coverage for all the watersheds was minimum. The maximum grazing land coverage from these watersheds was 79 ha from Tankua Gebriel. Therefore, farmers use crop residues as feed sources of livestock.

Data collection and analysis

Data were collected qualitatively through focus group discussions (FGD) with farmers; field observations and district level experts were participated (Figure S1). FGD was used to obtain qualitative data from selected and representative households. The FGD was conducted based on prepared checklists and semi-structured questionnaires. Four FGDs having 15 members per group were used to conduct the research. A total of 6 women participated in the discussion. During this session, respondents expressed their opinions, views, feelings, and perspectives. During field excursions kebele managers and natural resource management (NRM) experts were included based on their experiences in similar works. The data collection considers experts working in the watershed where the administrative boundary of the watershed lies within the four districts of the south Gondar zone. From these four districts namely Farta, Fogera, and Dera, experts were included for data collection. In the south Gondar zone, these districts were relatively food secured areas where watershed programs were not supported with productive safety net programs. Whereas, food-insecure districts were sponsored by watershed development programs based on the labor invested and mandatory for an individual being registered as food in secured. The research focused to understand the approach in these districts to identify whether there exists common interest, external forces and factors, that led to short-term benefits and long-term sustainability in the watersheds. All the data were collected and administered by the researchers for a day-long period at each watershed. The field observation helped to better understand the various phenomena under investigation. Some of the observed occurrences were included an overview of the whole area of the watershed with transect walk at different slope locations, the level of natural resources degradation, private and communal grazing lands, water sources, and traditional water diversion ditches. The primary information was supported with secondary sources of information through reviewing published and unpublished documents. Thematic analysis was used to analyze the collected qualitative information. Therefore, the analysis was built most cohesively**.** During the discussion, an action research model was used. For conflicting ideas further detailed discussion and informal questions were forwarded to validate them especially from experts from kebele and district officers.

RESULTS AND DISCUSSION

Problem Analysis

The soil and water degradation (SWD) in the watershed remains a challenge. Figure 6 demonstrates the major challenges in SWD in a problem tree. The diagram constituting the major causes determining the SWD in the Gumara sub-watersheds. Here the detail of each cause-effect summarized as follows:

Water resources degradation : in the selected four watersheds there existed a shortage of water supply sources for human and animal consumption. Access to water predominantly dependent on groundwater and surface water. However, having groundwater in these watersheds was prohibitively costly, so the community was reliant on seasonal river and spring flows. Groundwater recharge is affected by several reasons, hence these sources can no longer satisfy the community's water needs. The steepness and ruggedness of the topography causing the generation of heavy run-off and excessive soil erosion and sedimentation down the slope. The steepness of the terrain contributes to increased run-off severity, leaving no room for stable soil production. Four of the watersheds have steep slopes on the upper part of the watershed and rugged topography (Figure 2 and 3). The incoming runoff washed out the fertile soil due to continuous farming and overgrazing, according to the focus group discussants (Figure S1). Over cultivation (small landholding); tillage frequency (farmers plow their lands 4-5 times); overgrazing (more livestock on degraded mountain tips and free grazing lead to erosion); complete removal of crop residues and animal dung from the field (crop residues and animal dung took away from fields).

Because of the growing human population and other economic constraints, forest resources being destroyed to expand agriculture. The key drivers of deforestation were the exploitation of wood for domestic use in the form of energy (because there were no alternative sources of energy), construction material (because there are no other sources of construction material), household utensils, farm equipment, and for sale to generate household income and support household livelihood. A wide area of the watershed is covered with cultivated land (Table 1). The exist natural forest in Wanzaye where many people illegally exploiting despite the presence of guards. Discussants voiced their concern and arguing that unless extra responsiveness is paid to the forested region, in this scenario this area remains historic. However, in Girbi, the hilliest part of the watershed totally covered with eucalyptus plantations (Table 1). It was done because of its proximity to Debre Tabor town and market access. Just a few scattered and remnant tree species were present around the church.

Low agricultural production and productivity : although population is a resource, it becomes challenging when it exceeds the carrying capacity of the supplying resources. The overall causes of land degradation are strongly linked with rapid population growth and then overexploitation of natural resources. This situation caused low productivity of agricultural services. As observed in the watersheds, cultivated lands were the most degraded land uses compared with grazing lands. The main reasons for cropland degradation were linked with poor management systems including frequent cultivation, bareness from crop residues, plowing steep slopes, and absence of physical conservation structures and none of the structures integrated with biological measures.

In the study areas, the majority of the land uses were cultivated land. According to farmers' concern, the level of land degradation indicated by the number of inputs like fertilizers applied to a unit of land increased from year to year. In addition, the cost of fertilizer increased from 35 USD in 2019 to 50 USD per quintal in 2020. Based on field observations, most private lands were under crop production, while insignificant number of communal lands were used for grazing and artificial forest lands. The average landholding per household in the watersheds was less than one hectare and farmers level of accepting the placement of SWC measures on this piece of land remains a critical concern.

Community engagement : because of a variety of factors SWD continues without having a significant impact on previous efforts. Some of the commonly agreed factors raised by the respondents include lack of awareness about water resource degradation, technical skills, and weak and unsustainable integration among stakeholders, engagement of non-governmental organizations, and the government. The following sections go into the details of each community issue (Figure 6).

Community mobilization

As part of the watershed development plan, the community engaged in four different approaches. The first approach was, the large-scale community mobilized for 25 working days between January and February, annually. Mainly, the practices include soil and water conservation (SWC) works. Secondly, a group of farmers organized to work on conservation works seasonally like gully prevention upon request from farmers. Thirdly, year-round every farmer is assumed to engage in maintenance works on individual farm fields. Currently, the implementation of practices was focused on cultivated lands. According to Farta, Fogera, and Dera offices of agricultural NRM experts, community mobilization is critical to construct numerous structures and cover larger areas. According to farmers in the four watersheds indicated; the approach of involving households in the community mobilization was not considering to respond the concerns of the people rather satisfying the campaign. A farmer who did not participate during the working day either punished birr (600 ETB in Gena, 300 in Girbi except destitute) or arrested for four days. In Wanzaye about 50% of the community participated in punishment. In particular, enforcement was common around Wanzaye. The urban villagers near Wanzaye and admins in this area mobilized communities irrespective of their land ownership in the watershed. The reason was, these communities being benefited from the watershed directly or indirectly. In the same watershed, experts reported that all areas of the watershed covered with SWCP, however, communal and individual farmlands were observed bare (Figure 7).

Farmers organized in groups to implement SWCP having five to ten members. The group was subject to finish a predefined length of bunds for example 4 meter per individual and when a group finished early, can go to its own business. According to the Farta NRM lead indicated, in previous day's activities done on cultivated lands were implemented privately, however, at field evaluation the structures were not well done and completely unsuccessful. Therefore, the approach changed into the group works to strengthen the community who had no able body and that may leave a piece of lands without conservation while reporting watershed management as a whole.

Challenges linked with mobilization

- Low level of community participation: surprisingly some individuals were unable to participate even installing SWC on their farm fields
- Lack of hand tools: there were no hand tools to aid construction efforts
- Farmers have been complaining that they have been involved in mobilization in the previous years, although some neighboring watersheds have completed their work
- Personal conflict: absentee farmers were punished by local leaders, which leads to personal conflict
- The interventions that have been made so far have not been sustainable
- No strict law (bylaw) executed by the local community
- No maintenance hence the community mobilized for work annually
- Low level of extension services such as pieces of training

The above challenges were associated with the top-down approach led by the government. According to NRM district-level experts, since the mobilization was supervised by higher authorities, the focus was given on the number of people who participated and the area covered by structures, regardless of the structures' design criteria. Besides that, the lack of an impact evaluation of SWCP in every watershed leads to poor achievement in the technical viability. Impact review helps in determining the appropriateness of the approaches used in carrying out watershed development efforts, as well as estimating the short, medium and long-term social and economic gains, efficiencies, and effects in the context of the stated objectives. Application of various approaches either led by agencies or the local community, successfully implemented watershed development efforts brought a significant change in the lives of the community in areas like India, and the USA (Alabama) (Wani, 2008; Muller & Alison 1999).

Implementation of large scale SWCP

The Gumara watershed has a higher rate of soil erosion than the other four watersheds that drain into Lake Tana (Ribb, Megech and Gilgel Abay; Zimale et al., 2018). Gumara emerged from mount Guna where the mountain remains fairly bare on the sides of the river emergence. In the rainy season with a low level of infiltration, and very steep slope the area generates high runoff. In these watersheds majority of soil was eroded in the form of sheet and rill erosion. The extent of gully erosion was incomparable with other sub-watersheds. In Gena and Girbi we observed stone outcropping in the cultivated fields that potentially retard the rate of soil erosion where conservation practices were limited. In some watersheds like Wanzaye there were no rocks in the fields and structures made with soil bunds.

As part of the integrated WMP, SWC works were substantial and the government of Ethiopia started SWCP in the 1980s (Bewket, 2007). Whereas, large-scale conservation programs further initiated since 2012. The practice continued up to 2021 for 25 days from January to February implementing various structures starting from the hillslopes to low-lying areas. All four watersheds followed the ridge to valley principle as indicated in the watershed management guideline (Desta et al., 2005). However, Fogera district natural resource management (NRM) experts explained, sometimes if there exist gullies downstream of the watershed and requested by the local farmers, priority could be given to stop gully development.

During the study period, farmers were engaged with SWC measures. The layout of conservation structures done by trained farmers selected among the community. These farmers surveyed the installation of SWCP. According to the response from trained farmers on the question of how they made the spacing between bunds and contour lines; they said, 'the kebele experts told us to make a spacing of bunds about 10-12 m if the land is a gentle slope and reduce the spacing depending on its inclination (Figure 8)." As a result, the observed structures were made of subjective spacing than keeping its standards.

In the four watersheds, there was no plantation from constructed measures. According to FDG responses, the reason was due to no access to seedlings, unavailability of nursery sites, free grazing, and rodents like mice. Even though farmers were well aware of the importance of plantation, they were unable to practice techniques. Therefore, structures are broken down.

Problems observed at field excursions

- The layout of structures was not technically oriented
- The spacing and vertical interval of bunds were not consistent and vary from one to the other
- Contour lines of structures dismantled since smallholders impacted by the layout during plow
- No proper design of structures resulting farmers do their best without professional advice
- Conservation works began at the middle of the field and replacement of old bunds with new ones
- Broken bunds observed during construction not included as a maintenance plan
- Poor link of the bunds with natural or artificial waterways and others
- Farm fields plowed to the edge of the riverbank, causing the land to quickly crumble each year (Figure 8).

The overall work that was performed in the watershed was planned annually integrating SWCP with other activities like river diversion, removing exotic weeds, soil fertility management, plantation, and forest management.

Sustainability of SWC practices

According to experts from the district office of agriculture sustainability of conservation structures made so far remains a critical question. Farmers participated in the event either through volunteer or not, huge labor and time were invested. However, it was difficult to see the structures after the rainy season. These structures were broken intentionally or accidentally, nothing was observed under maintenance. According to Dera and Farta district officers, maintenance was the property of the landowner. However, "no one is doing this, and yet we are doing SWC annually". One of the reasons was, sister stakeholders such as the Rural Land Administration and Environmental Protection (RLAEP) office were poorly involved to support development efforts. Land administers should be concerned about farmers' responsibility to care for the land and environmental protection should worry about the remaining forest management and planned communal lands. The issuance of land-use certificates improved the confidence of farmers in the ownership of land. However, the certificate had a limitation on improving land care and enforcing farmers to keep the constructed SWC measures sustainably. The Amhara National Regional State (ANRS) issued the RLAEP (Proclamation No.46/2000) to protect land use rights. "As long as landowners use land according to existing laws, this proclamation guarantees and secures their holding and use rights," according to Article 6(3). The specified goals of the policy were to protect landowners' long-term land-use rights while encouraging productivity and development. It also instills a sense of ownership in land users, encouraging them to protect the soil and thus maintain its efficiency. However, in the study watersheds, it is hardly implemented. That was the reason sloppy fields were used for annual crop production, eucalyptus plantations and overgrazed. Business as usual standards breaks at some stage between farmers and the implementing organization unless and until a mechanism is formed to keep measures sustainable. Farmers currently asking, "When will we stop mobilizing for SWC?".

Watershed as a development Unit

In the Gumara watershed, the WDP was a government-led top-down approach. These programs were not supported with extension service including training and hand tools. Experts indicated that farmers were resistant to new and adopted technologies, then the efficacy of invested efforts remains in question. In certain situations, model watersheds were established to expand the extension services pursuing that farmers can learn from what they observed. In addition, the implementation of SWCP at a small watershed scale is manageable and easily monitored. Even though model sites existed in some locations, their viability remained in doubt.

Therefore, shifting from business as usual thinking to lessons learned from successfully implemented areas is crucial. Research findings indicated that different areas have succeeded in establishing community governance mechanisms that were successful in resource protection and management (Pittroff, 2011; Mullen & Alison 1999). Promoting farmer to farmer learning programs starting from the modest goals (community and area coverage) to the larger scale. Attempting to achieve vague targets and accomplishments reported only numbers. To be critical in achieving the goals of watershed development, effective community-based watershed management programs should have led by the full interest of the community. Communal lands are shared resources, therefore, the community should be well understood in planning and use of resources as a management entity. Community empowerment could be seen in the forms of social mobilization, technological awareness, and land use rights (Pittroff, 2011).

As previously mentioned in section 2.4, assigning land titles to communities does not appear to be sufficient to sustainably protect the land degradation in the long run. However, just as usage rights are specified, similar mandatory development rules must be established at the plot scale. The development of administrative and legal processes that add specifics to these rights, such as implementation and maintenance of constructed bunds in the watershed are fundamental. In addition, overlapping of business among sector offices necessitates a collaborative approach to led development programs. As a result, a methodology is required to guide the selection and mobilization of appropriate communities and resources for the long-term sustainability of development efforts. Extension centers and stakeholders contribute to the enforcement of bylaws prepared by the consent of the community. The realization of equitable resource share and management among the community could demonstrate the level of achievements to other communities.

CONCLUSION

The study assesses the status of selected watersheds in the Gumara watershed to understand the approaches adopted to implement watershed development practices. These practices were annual governmental campaigns through community mobilization. Though farmers believe in the significance of installing SWCP at the watershed level, the performance of the practices was not as expected. Currently, farmers complaining about the approach followed by the government and the time they invested in conservation programs creates untrusted by the community. The campaign just considered the number of participating farmers regardless of the quality and standards of installed measures. As a result, farmers have withdrawn from active participation and tied up in the enforcement. In addition, experts were unable to provide technical support to the whole sub-watersheds during the campaign. Finally, the community should carry out maintenance of previously constructed structures and the decision-makers must evaluate the status of measures for the long-term sustainability of efforts. Further study on alternative watershed development and management modality of programs from different perspectives is advisable to sustainably satisfy the needs of the community and viability of natural resources.

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REFERENCES

Abate M, Nyssen J, Moges MM, Enku T, Zimale FA, Tilahun SA, Adgo E, Steenhuis TS. 2016. Long-term landscape changes in the Lake Tana basin as evidenced by delta development and floodplain aggradation, Ethiopia.*Land Degradation & Development* . DOI: 10.1002/ldr.2648

Abate M, Nyssen J, Steenhuis TS, Moges MM, Tilahun SA, Enku T, Adgo E. 2015. Morphological changes of Gumara River channel over 50 years, upper Blue Nile basin, Ethiopia. *Journal of Hydrology* 525: 152-164.

Bayable HK, Tebebu TY, Stoof CR, Steenhuis TS. 2016. Effects of a deep-rooted crop and soil amended with charcoal on spatial and temporal runoff patterns in a degrading tropical highland watershed.*Hydrology and Earth System Sciences* 20: 875-885.

Belayneh M, Yirgu T, Tsegaye D. 2019. Potential soil erosion estimation and area prioritization for better conservation planning in Gumara watershed using RUSLE and GIS techniques'. *Environmental Systems Research* 8(1): 1-17.

Bewket W, Conway D. 2007. A note on the temporal and spatial variability of rainfall in the drought-prone Amhara region of Ethiopia. *International Journal of Climatology : A Journal of the Royal Meteorological Society* 27(11): 1467-1477.

Easton ZM, Fuka DR, White ED, Collick AS, Biruk AB. McCartney M, Awulachew SB, Ahmed AA, Steenhuis TS. 2010. A multi basin SWAT model analysis of runoff and sedimentation in the Blue Nile, Ethiopia.*Hydrology and Earth System Sciences Discussions* 7: 3837–3878

Fazzini M, Bisci C, Billi P. 2015. The climate of Ethiopia. In: Billi P (ed) Landscapes and Landforms of Ethiopia. World geomorphologic landscapes. Springer, Dordrecht

Guzman CD, Tilahun SA, Dagnew DC, Zegeye AD, Yitaferu B, Kay RW, Steenhuis TS. 2017b. Developing Soil Conservation Strategies with Technical and Community Knowledge In A Degrading Sub-Humid Mountainous Landscape. *Land Degradation & Development* . DOI: 10.1002/ldr.2733.

Halefom A, Teshome A, Sisay E. 2019. Impacts of land use/land cover detection on climate variability of Gumara Watershed, Ethiopia. *International Journal of Water* 13(2): 101-121.

Haile M, Herweg K, Stillhardt B. 2006a. Sustainable land management–a new approach to soil and water conservation in Ethiopia. Land Resources Management and Environmental Protection Department Mekelle University, Ethiopia, and Center for Development and Environment (CDE), University of Bern and Swiss National Center of Competence in Research (NCCR) North-South, Bern, Switzerland.

Israel MA, Amikuzuno J, Danso-Abbeam G. 2020. Assessing farmers' contribution to greenhouse gas emission and the impact of adopting climate-smart agriculture on mitigation. Ecological Processes 9(1): 1-10.

Johnson N, Ravnborg HM, Westermann O, Probst K. 2002. User participation in watershed management and research. *Water policy* 3(6): 507-520.

Lakew D. 2005. Community-based Participatory Watershed Development: A Guideline. Addis Ababa, Ethiopia. Ecological Processess

Lieskovsky J, Kenderessy P. 2014. Modelling the effect of vegetation cover and different tillage practices on soil erosion in vineyards: a case study in Vrable (Slovakia) using WATEM/SEDEM. *Land degradation & Development* 25(3): 288-296. DOI:10.1002/idr.2162.

Lubell M, Fulton A. 2008. Local policy networks and agricultural watershed management. *Journal of Public Administration Research and Theory* 18(4): 673-696.

Mengistu A, Tilahun A, Peters KJ. 2013. Collective management on communal grazing lands Its impact on vegetation attributes and soil erosion in the upper Blue Nile basin North Western Ethiopia. PhD dissertation, Humbolt University of Berlin.

Mhiret DA, Dagnew DC, Guzman CD, Alemie TC, Zegeye AD, Tebebu TY, Langendoen EJ, Zaitchik BF, Steenhuis TS. 2020. A nine-year study on the benefits and risks of soil and water conservation practices in the humid highlands of Ethiopia: The Debre-Mawi watershed. *Journal of Environmental Management* 270: 110885.

Mullen MW, Allison BE. 1999. Stakeholder involvement and social capital: keys to watershed management success in Alabama 1. *Journal of the American Water Resources Association* 35(3): 655-662.

Nyssen J, Clymans W, Poesen J, Vandecasteele I, De Baets S, Haregeweyn N, Naudts J, Hadera A, Moeyersons J, Haile M, Deckers J. 2009. How soil conservation affects the catchment sediment budget a comprehensive study in the north Ethiopian highlands. *Earth Surface Processes and Landforms* 34: 1216-1233. DOI: 10.1002/esp.1805.

Pimentel D, Harvey C, Resosudarmo P, Sinclair K, Kurz D, McNair M, Crist S, Shpritz L, Fitton L, Saffouri R, Blair R. 1995. Environmental and economic costs of soil erosion and conservation benefits. *Science* 267(5201): 1117-1123.

Pittroff W. 2011. Rangeland management and conservation in Afghanistan. International Journal of Environmental Studies.

Reij C, Scoones I, Toulmin C. 1996. Sustaining the Soil. Indigenous Soil and Water Conservation in Africa. In: Drylands program, Earth scan Publications.

Setegn SG, Srinivasan R, Dargahi B. 2008. Hydrological modelling in the Lake Tana Basin, Ethiopia using SWAT model. *The Open Hydrology Journal* 2(1).

Terefe H, Argaw M, Tamene L, Mekonnen K, Recha J, Solomon D. 2020. Effects of sustainable land management interventions on selected soil properties in Geda watershed, central highlands of Ethiopia. *Ecological Processes* 9(1), 1-11.

Wani SP. 2008. Community Watershed as a Growth Engine for Development of Dryland Areas. A Comprehensive Assessment of Watershed Programs in India.

Wubie MA, Assen M. 2020. Effects of land cover changes and slope gradient on soil quality in the Gumara watershed, Lake Tana basin of North–West Ethiopia. *Modeling Earth Systems and Environment* 6(1): 85-97.

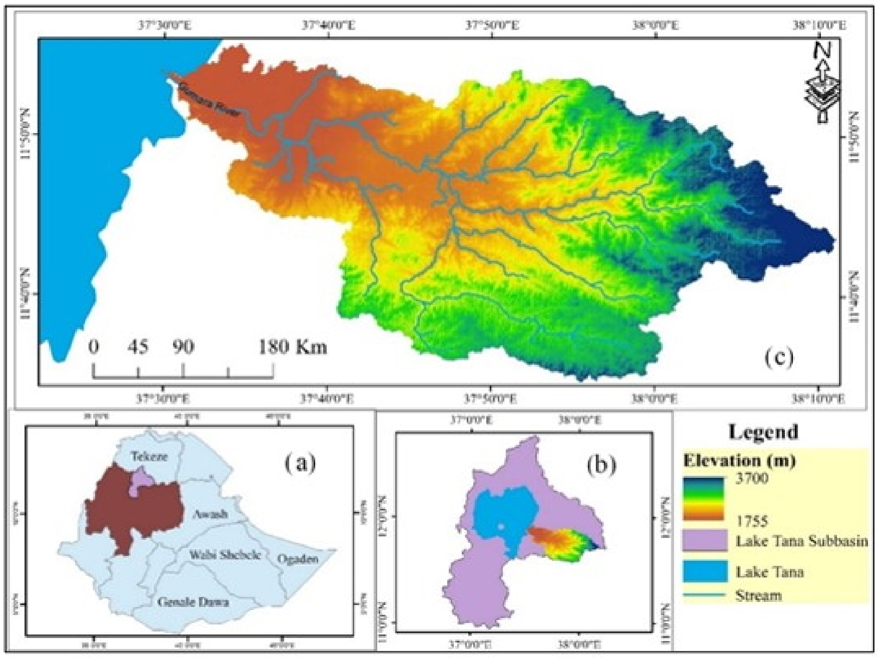
Yeraswork A. 2000. Twenty years to nowhere: property rights, land management and conservation in Ethiopia. Red Sea Pr.

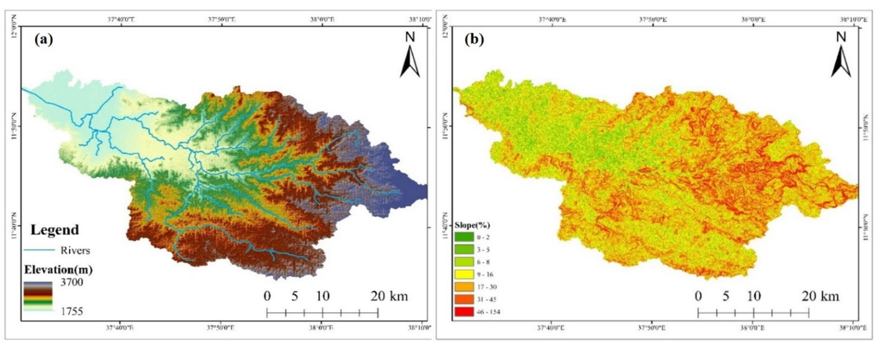
Zimale FA, Moges MA, Alemu ML, Ayana EK, Demissie SS, Tilahun SA, Steenhuis TS. 2018. Budgeting suspended sediment fluxes in tropical monsoonal watersheds with limited data: The Lake Tana basin. *Journal of hydrology & Hydromechanics* 66(1): 65-78.

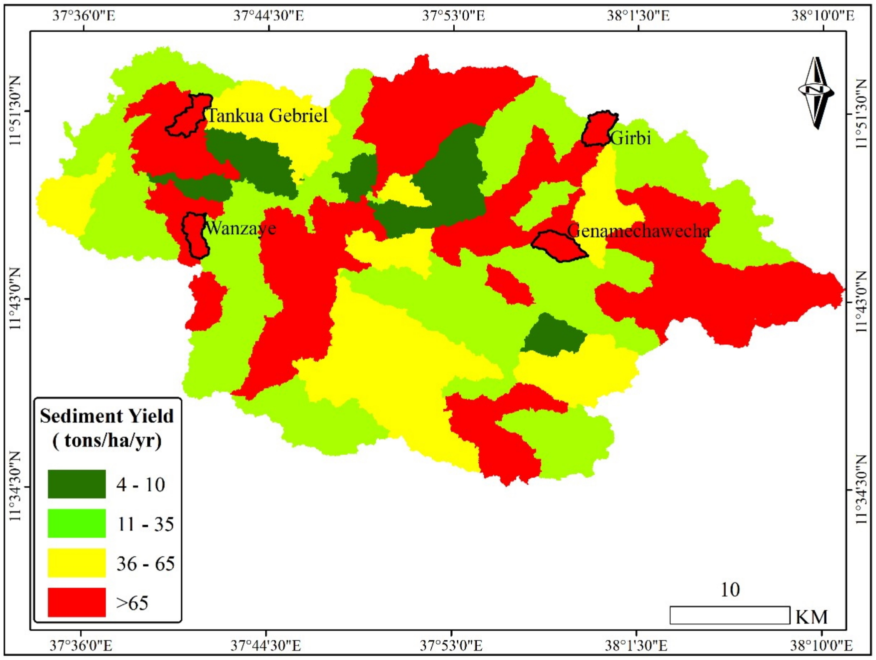
Zimale FA, Tilahun SA, Tebebu TY, Guzman CD, Hoang L, Schneiderman EM, Langendoen EJ, Steenhuis TS. 2017. Improving watershed management practices in humid regions. *Hydrological processes* 31(18): 3294-3301.

Table 1: Area covered by each land-use type in the four watersheds

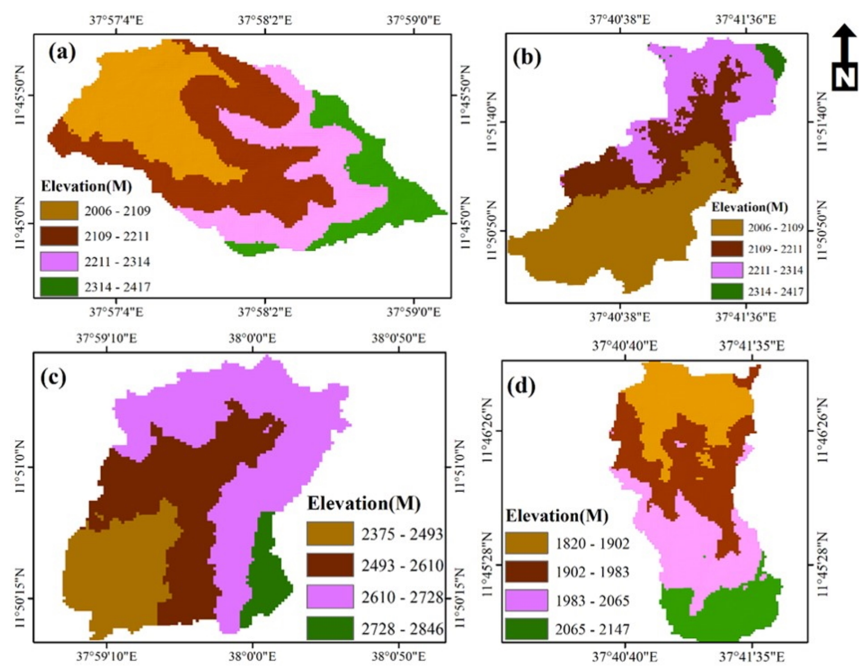
Land use classes	**Micro Watersheds**	**Micro Watersheds**	**Micro Watersheds**	**Micro Watersheds**
	Girbi (Area in ha)	**Gena Mechawecha** (Area in ha)	**Wanzaye** (Area in ha)	**Tankua Gebrial** (Area in ha)
Built-up	100.6	7.4	0.49	3.0
Forest	277.0	250.0	149.5	117.3
Cultivated land	161.4	429.4	401.9	427.9
Grazing land	42.5	8.7	3.8	78.9
Total area	581.5	695.5	555.2	627.1


37°30'0"E
37°40'0"E
37°50'0"E
38°0'0"E
38°10'0"E
11°50'0"N
11°40'0"N
Gumara River
N
0 45 90 180 Km
(c)
(a)
Tekeze
Awash
Wabi Shebele
Ogaden
Genale Dawa
(b)
37°0'0"E
38°0'0"E
12°0'0"N
11°0'0"N
Legend
Elevation (m)
3700
1755
Lake Tana Subbasin
Lake Tana
Stream

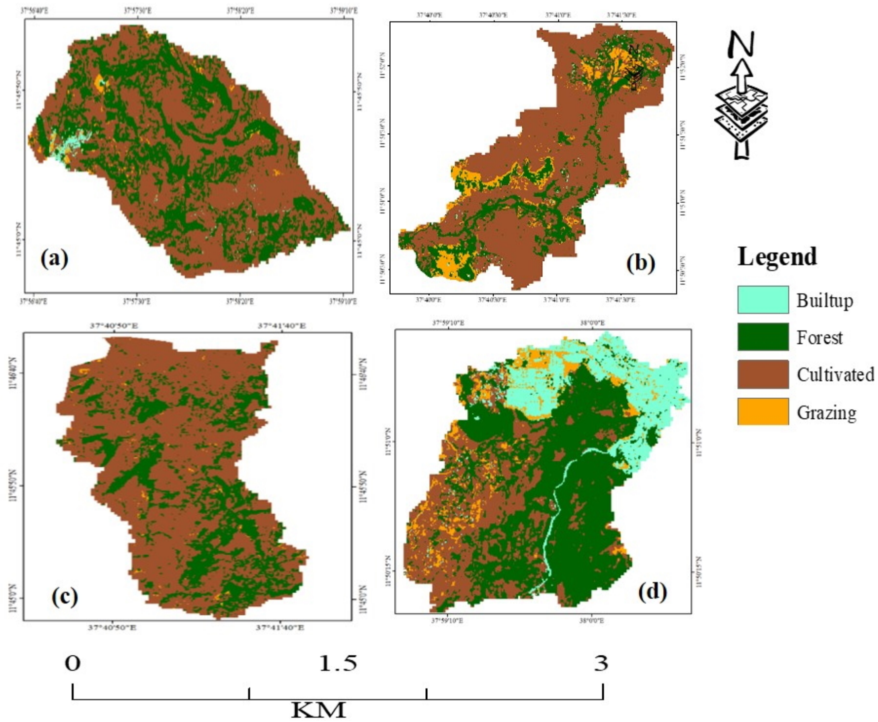

(a)
N
Legend
Rivers
Elevation(m)
3700
1755
0 5 10 20 km
(b)
Slope(%)
0 5 10 20 km

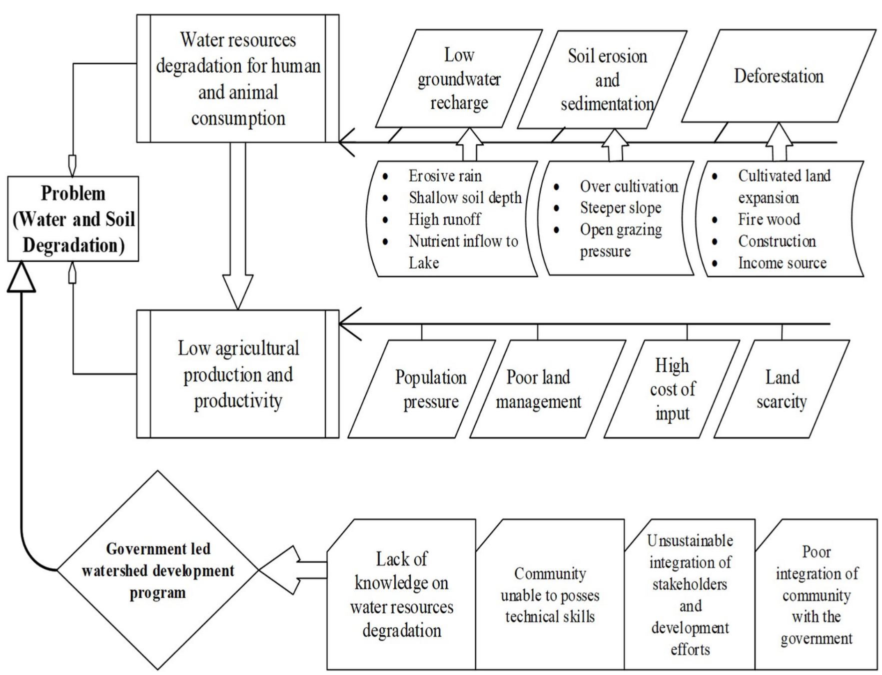


37°36'0"E
37°44'30"E
37°53'0"E
38°1'30"E
38°10'0"E
11°51'30"N
11°43'0"N
11°34'30"N
Tankua Gebriel
Girbi
Wanzaye
Genamechawecha
Sediment Yield
(tons/ha/yr)
4 - 10
11 - 35
36 - 65
>65
10
KM



(a)
37°57'4"E
37°58'2"E
37°59'0"E
11°45'50"N
11°45'0"N
Elevation(M)
2006 - 2109
2109 - 2211
2211 - 2314
2314 - 2417
(b)
37°40'38"E
37°41'36"E
11°51'40"N
11°50'50"N
Elevation(M)
2006 - 2109
2109 - 2211
2211 - 2314
2314 - 2417
N
(c)
37°59'10"E
38°0'0"E
38°0'50"E
11°51'0"N
11°50'15"N
Elevation(M)
2375 - 2493
2493 - 2610
2610 - 2728
2728 - 2846
(d)
37°40'40"E
37°41'35"E
11°46'26"N
11°45'28"N
Elevation(M)
1820 - 1902
1902 - 1983
1983 - 2065
2065 - 2147


(a)
(b)
(c)
(d)
N
Legend
Builtup
Forest
Cultivated
Grazing
0
1.5
3
KM


Water resources degradation for human and animal consumption
Low groundwater recharge
Soil erosion and sedimentation
Deforestation
Problem (Water and Soil Degradation)
Erosive rain
Shallow soil depth
High runoff
Nutrient inflow to Lake
Over cultivation
Steeper slope
Open grazing pressure
Cultivated land expansion
Fire wood
Construction
Income source
Low agricultural production and productivity
Population pressure
Poor land management
High cost of input
Land scarcity
Government led watershed development program
Lack of knowledge on water resources degradation
Community unable to posses technical skills
Unsustainable integration of stakeholders and development efforts
Poor integration of community with the government