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Evaluation of rainfall -runoff and suspended sediment concentration in the semi-arid Ethiopian highlands, Tekeze Basin, Ethiopia

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Abstract

The study was carried out at Weshikayina and Megachoch rivers in Tekeze Basin Ethiopia. Agricultural intensification, deforestation, and soil erosion are currently common problems in the highlands of Ethiopia. However, this research focuses to understand the primary drivers of rainfall-runoff and sediment concentration for Planning effective landscape interventions. Precipitation, runoff, and sediment concentration were continuously assessed in two sub-watersheds during the rainy season of 2019 and 2020. The velocity is determined by the floating time needed for the float to reach the specified length. At 10-min intervals, 0.6 litters of water were sampled using bottles and then using Whitman filter papers to measure the mass of the suspended sediment concentration in a laboratory. In various land uses, the soil infiltration rate has been calculated. The outcome shows that upland and mid-slope infiltration rates in shrubs and bushlands are poor relative to cultivated lands. From all 10-min flow depths, the best fit rating curve was developed and sediment rating curves were also developed using the regression function of power and exponential form. Sediment yields were averaging 11.5-ton ha^{-1} year-1 and 13.8-ton ha^{-1} year^{-1} for Weshikayina and 7.1-ton ha^{-} year^{-1} and 6.2-ton ha^{-1} year^{-1} for Megachoch in 2019 and 2020 respectively. Therefore, the Weshikayina watershed was highly degraded and more fragile than the Megachoch watershed in runoff and sediment yields.

Keywords Weshikayina · Megachoch · Semi-arid · Discharge · Sediment

Introduction

Watershed management practice has been suggested in several countries within the world, as an efficient way to address complex water and land resource challenges. In Ethiopia, this method is new and requires appropriate plans to beat overcome the barriers and practice effective, integrated, and sustainable watershed management practices. The highlands in Ethiopia are characterized by lack of a reliable hydrological data. Due to this reason, many dams and reservoirs were over-dimensioned as a result of an overestimation of runoff coefficients and lots of reservoirs replenish with sediments at an alarming rate as a result of the underestimation of sediment yield (Abraha 2009), while, in the most drought-hit countries in the world, almost no study has ever been conducted in characterizing the rainfall pattern of the arid and semi-arid regions of Ethiopia (K. Tilahun 2006). Due to these reasons, land degradation and repeated drought are the main threats to rain-fed agriculture within the semi-arid Ethiopian highlands (Deribe and Taye 2013). The correct planning, designing, construction, and operation of water resource uses are essential to combat the threat of land degradation, we want to know the physical process of abrasion and hydrological process in regards to topography, land use, and management (Singh et al. 2011).

There are several factors affecting water erosion or sediment transport that may fall under four categories, namely; rainfall characteristics (rainfall intensity and duration), soil properties (particle size, infiltration, erodibility, specific gravity, and bulk density), topography (slope and vegetation cover), and surface runoff (Henorman 2021). Storm characteristics can be characterized by two forms of function: in low rainfall intensities a linear function

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is fitted to soil loss-rainfall intensity, and in high rainfall intensities nonlinear functions are fitted to soil loss-rainfall intensity, in particular, increasing rainfall intensity yielded the highest runoff, soil loss and sediment concentrations (Mohamadi and Kavian 2015). Runoff response and erosion in semi-arid areas are extremely variable and patchy. The effect of rainfall-runoff on soil erosion can be investigated by using historic and direct measurements to analyze the land cover change concerning the change in soil erosion potential of the watershed or sediment discharges at the watershed outlet (Sharma et al. 2011). Tekeze river basins have high seasonal variability and about 70% of the total runoff happens during the main rainy season from the period of June to October (Welde and Gebremariam 2017). Many studies were conducted in the semi-arid part of the Tigray region about how to reduce soil erosion management practices (Tamene et al. 2006; Taye et al. 2013), but there is no research conducted in the semi-arid areas of the Amhara region such as Tekeze basin of Weshikayina and Megachoch watershed.

In general, this study has contributed to the area by assessing the general trend of parameters like land use, rainfall, and socio-economic activities and their effect on aggravating the runoff potential and sediment yield, because the study of sediment yield of the area enables a recommendation of appropriate soil conservation practices and rating curves have also been developed for the river which will be used for river work design in the future.

Materials and methods

Study area description

The study watersheds are located in east Belesa woreda, Central North Gondar in Ethiopia (Figure 1). The two
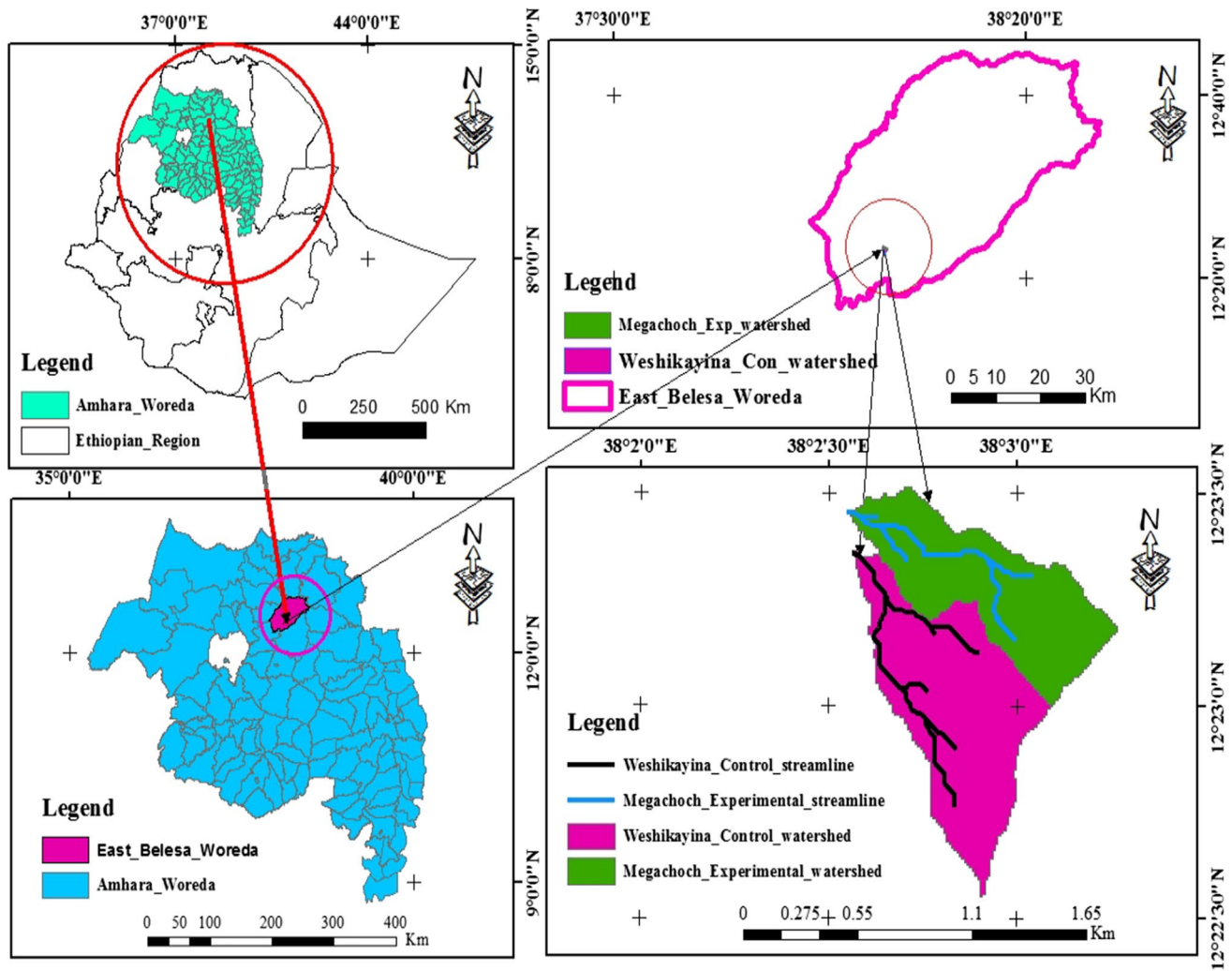

Fig. 1 Location of the study area

coupled watersheds were 60.28 ha for Weshikayina and 48.45 ha for Megachoch with similar topography, soil, relief, and vegetation. The UTM location of the study area ranges (38°2′32.6″-38°2′54.3″E to 12°23′27.3″-12°22′35″N). The elevation of the catchment ranges from 1888 to 2623 m above sea level. The climatic conditions are Semi-arid regions. The dominant soil types in the watershed were Eutric, Leptosols, Haplic Luvisols, Leptic Luvisols, Lithic Leptosols, and Exp-Rock. The soil formation of the watershed is dominated by shallow, highly weathered, and fractured basalt overlain by clay loam, loam, sandy loam, and loam and organic-rich soils.

Methodology

Daily steam flow measurement of Weshikayina and Megachoch small river collected from the outlets using staff gauge and also suspended sediment concentration is measured by collecting bottles of water in the field-collected by four data collectors in the outlets. The amount of sediment in a river can transport variations over time, hydrologists take measurements and samples as streamflow goes up and down during a storm event. Once how much water is flowing and the amount of sediment in the water under different flow conditions is distinguished, the weight of sediment that moves past the measurement site during a day, during the storm, and even during the whole year will be computed.

Field monitoring

First, a reconnaissance survey was conducted in October 2018 to identify measuring sites. Fieldwork started during October 2018, preliminary survey in Dengora kebele at Weshikayina and Megachoch watershed. A set of instruments consisting of a continuous recording rain gauge, water level stage recorder, and silt sampler 600mm bottle type was used to record rainfall, streamflow, and sediment flow, respectively in the site. Water-stage is measured every 10 min interval and then transformed into discharge using the calibrated rating curve obtained through periodic water level and velocity flow measurements. Suspended sediment concentrations (SSC) were determined by using the Whatman filter paper method filtering in a laboratory.

Rainfall, runoff, and soil loss from the runoff plots were measured from the start till the end of each rainy season in 2019 and 2020. A total of 90 and 94 flood events were recorded for the Weshikayina watershed and 50 and 50 flood events were recorded for the Megachoch watershed during the entire periods in 2019 and 2020 respectively. After October there are small rainfall events in the two rivers.

Field observations and interviews

The field observations and discussions were held to give a better understanding of the land use land cover condition, rainfall-runoff-soil loss processes in the watershed location when the watershed runoff and erosion occurs, and also the possible reasons for erosion in the area. It is useful for the watershed Hydrology and Soil Erosion Survey which is used to implement soil and water conservation measures through community field interviews.

Rainfall measurement

Measured precipitation data are important to many problems in hydrologic analysis and design. Rainfall measurement is measured using manual and automatic rain-wise rain gauges for the period from 2019 to 2020, to capture the rainfall distribution in the watershed.

Infiltration measurement

Soil infiltration rates were measured at different points throughout the watershed using a 30cm diameter single ring infiltrometer. These are useful to identify high infiltration zones and low infiltration zones of watershed areas. The infiltration test was measured at different locations representing various land use types and topographic positions including upslope, downslope, and mid-slope. A total of 6 measurements were carried out in the dry season at the bottom slope, hillside, and top slope part of the watershed at a Steady-state infiltration rate similar to (Sun et al. 2018a).

Measurement of water levels at gauging station

Staff gauges were installed in 2019 at Megachoch watershed and Weshikayina watershed to be able to read the water level in the stream. A staff gauge is a long ruler placed in a water body that is used to measure water surface elevation or just to determine the rise/fall of the water surface over time. The river cross-sections were collected by using leveling and theodolite instruments for site locations. The river measurements (depth, velocity, and sample sediment) have started from Weshikayina and Megachoch small rivers.

The following factors have to be considered in selecting a site for a stream gauging station (Raghunath 2006).

- The stream gauging station is easily accessible.
- Stability of the bed and banks of the stream to ensure consistency of area-discharge relationship, i.e., the cross-

section should not be subjected to change by silting or scouring, during different stages of flow.

- The bed and banks selected are free from vegetal growth, boulders, or other obstructions like bridge piers, and trees.
- The section is straight and uniforms for a length of about 18m at Weshikayina and 10m at Megachoch and no backwater effect straight Chanel in the selected sites.

Staff gauge measurements were done twice every day; at 6:00 A.M. and 6:00 A.M. every evening. Surface flow velocity was also measured twice every day at the control point using a float released along 18m and 10m straight reach of the river control watershed and sub-watershed respectively. Each area of the river cross-sections for leveling point touches in the measuring depth of the staff gauges was calculated using Auto Cad 2007.

River discharge measurement

Discharge is the product of velocity and cross-sectional area of water. At the catchment outlet, the discharge was calculated from measurements of water level using staff gauges. The flow rate was estimated at every 10min intervals using the water depth at the weir and developing a rating equation (S. Tilahun 2012). The correction procedure is followed based on the observation that the inaccuracy in replicated records or missed estimates derived using interpolations can be systematically related to the ratio of annual mean discharge derived from the sampled in a given replicate and that calculated from the 15-min records (Phillips et al. 1999). Therefore, runoff data will be analysed by area-velocity methods.

$$V_{\text{surface}} = \frac{\text{Travel distance(L)}}{\text{Time (t)}} \tag{1}$$

where V_{surface} = surface velocity (m/se), L = length of the specified reaches, and t = time for traveling the floating body. Because surface velocities are typically higher than mean or average velocities, the following correction method has been used.

$$V_{\text{mean}} = K \times V_{\text{surface}} \tag{2}$$

where k is a coefficient that is generally used as two-thirds of surface velocity (0.667 is a commonly used value). Mean flow discharge was then calculated as:

Mean discharge (Q) = V_{mean} (V) × the wetted cross − sectional area (A)
$$\tag{3}$$

where Q has measured runoff for each flow depth (m³/s), A is an area of the flow section (m²), and V is the mean flow velocity in the section (m/s). The area of an individual portion can be easily calculated the profile and stage are known using Auto-Cads.

Sampling of suspended sediment

A total of 280 and 294 samples for Weshikayina, and 160 and 135 samples for the Megachoch watershed were taken during 2019 and 2020 in the study periods. For the monitoring of suspended sediment, a one-point depth-integrated sampling technique has been used. Suspended sediment concentrations were obtained from water samples during the study period using manual and automatic water samplers (López-tarazón et al. 2010). The SSC data were manually obtained using the depth integration method during storm events with water samples collected in one litter of polyethylene containers (Edwards et al. 1970).

The suspended sediment concentration was determined by filtering through Whatman 320 mm diameter filter papers and the mass of sediment captured per litter of discharge was determined by weighing the mass of oven-dried sediment (Loughran 1976), Similarly, this study followed these principles. To determine sediment concentration after filtering, the sediment sample should be oven-drying at a temperature of 105 °C for 24 h.

The instantaneous sediment concentration measurements were considered to be representative of the time frame i, between which measurements were taken. Thus, concentration was considered constant during the duration of the 10-min intervals, and sediment load, SLi (tons), during that time interval was calculated by multiplying the watershed suspended sediment concentration, SSC (g/L), by the storm runoff volume, Rvi (m³) in Equation 4.

$$SLi = SSC \times RVi \tag{4}$$

The storm runoff volume was similarly calculated by assuming that the discharge flow rate was constant during the time interval, and thus runoff volume was obtained by multiplying the time duration, Δti (sec), by the discharge flow rate, Qi (m³ sec⁻¹).

$$RVi = \frac{1}{2}(Qo + Qi) \times \Delta ti \tag{5}$$

In this study, the volume of water passing a section per unit of time was calculated, using the area-velocity method during the measurement. The overall results are described by using excel descriptive statistics like mean, minimum, maximum, mode, median, variance, and standard deviations.

Results and discussion

Rainfall amount and distributions in Dengora Watershed

Temporal and spatial variation of rainfall characteristics is very important factors affecting the hydrological process of watershed areas. Weshikayina and Megachoch watersheds have unimodal rainfall which occurs from May to October. In 2019 annual rainfall of 776 mm and 788.6 was recorded in 2020 using an automatic Rain wise rainfall logger. This result clearly shows that there were temporal variations of rainfall annually in the watershed. The dry season, being from October to May has a total rainfall of about 2–4% of the total annual rainfall. The hydrological response has realized the complexity and nonlinearity of rainfall-runoff relationships in several environments (Nadal-Romero et al. 2008). From rainfall analysis results, monthly rainfall distribution for a given year is highly variable (coefficient of variation, CV > 69.2%). As shown in Fig. 2, maximum rainfall was recorded at 298 mm in July 2019 and 361 mm in August 2020 while minimum rainfall was recorded from November to April.
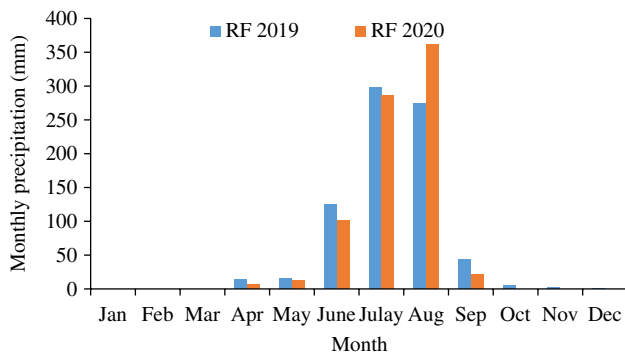

Fig. 2 Monthly record data rainfall distribution of Weshikayina and Megachoch watershed

Characterizations of the flood event

For the Weshikayina watershed, 90 and 94 total flood events, and Megachoch watershed 50 and 50 total flood events occurred during 2019 and 2020 in the study period respectively. These flood events were recorded from January 2019 to December 2020. The maximum amount of precipitation for a single event was 80 mm on 05 August 2019 and 85 mm on 23 August 2020. The total runoff volume generated by the twin watershed for the Weshikayina control watershed were 182081.4 m^3 and 234125 m^3 in 2019 and 2020 respectively. Similarly, Megachoch experimental watersheds were 61999.7 m^3 and 131628 m^3 in 2019 and 2020.

The collected data's number of plots, total sample volumes, mean runoff, soil loss, and sediment concentration were analysed using the Excel spreadsheet software. Temporal variations in monthly precipitation, runoff volume, and sediment transport were significant in July and August seasons using statistical data analysis. Annual comparisons of temporal variations using descriptive statistical data analysis indicated that total runoff volume was larger in 2020 than in 2019, and the total sediment yields were also larger in 2020 than 2019 period in the untreated Weshikayina watershed (Table 1). For Megachoch watershed, total runoff volume was larger in 2020 than in 2019, whereas the total sediment yields were larger in 2019 than 2020 period (Table 2). Mainly streamflow and sediment transport were dependent upon precipitation. The reason for the spatial variations among watersheds may be associated with differences in precipitation intensity among the watersheds, watershed morphology, topography, differences in land uses, and the intensity of pre-man oeuvre grazing and rates of post-grazing vegetation recovery.

Land use land cover type of watersheds

Land use land cover is one of the most important factors that affect surface runoff and erosion in a watershed. The major land use and land cover classes of the watershed from Fig. 3 or Table 3 include cultivated land (with and without terraces), forest land, bushland (open and clothed),

Table 1	Month	Rainfall (mm)		Runoff (mm)		Sediment (ton)	
Descriptive analysis of the Weshikayina watershed		2019	2020	2019	2020	2019	2020
	May	15.0	12	0.59	0.6	0.71	1.1
	Jun	125.5	101	10.95	45.5	23.87	207.7
	Jul	298.0	286	113.02	164.1	311.96	449.5
	Aug	273.5	361	160.28	236.7	347.17	170.9
	Sep	43.0	21	16.68	8.6	4.51	1.4
	Oct	5.0	0.0	0.67	0.0	0.06	0.0
	Total	760.0	781.2	302.19	455.5	688.28	830.5

Table 2 Descriptive analysis of Megachoch watershed

Month	Rainfall (mm)		Runoff (mm)		Sediment (ton)	
	2019	2020	2019	2020	2019	2020
May	15.0	12	0.21	0.1	0.08	0.0
Jun	125.5	101	4.22	21.7	21.98	36.2
Jul	298.0	286	53.12	84.4	218.56	154.9
Aug	273.5	361	66.03	165.5	97.94	108.8
Sep	43.0	21	4.32	0.0	1.64	0.0
Oct	5.0	0.0	0.07	0.0	0.03	0.0
Total	760.0	781.2	127.96	271.7	340.22	300.0

Fig. 3 Main land-use (2019 LULC) types for **A** megachoch experimental watershed **B** Weshikayina control watershed
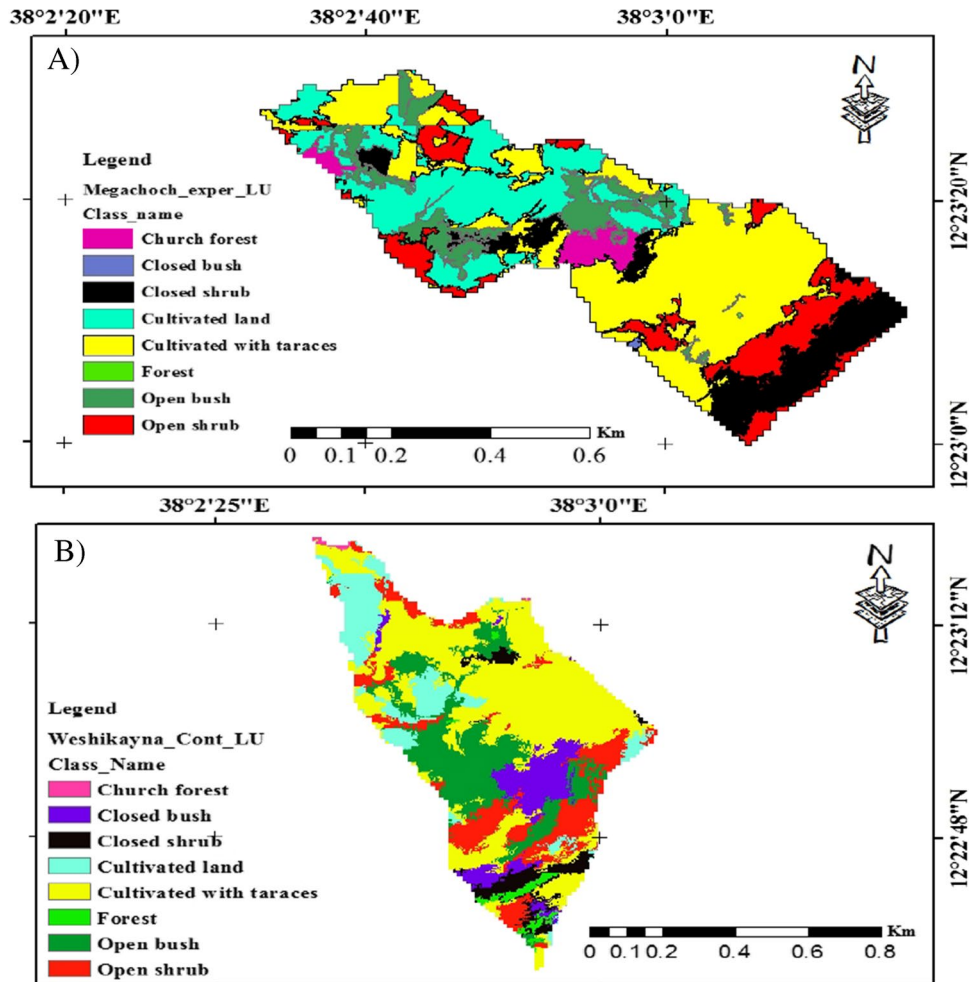
and shrubland (open and closed) land covers. Closed bush and closed shrubs are kept by the guard for green hill areas from grassing and deforestation. Cultivated land covers (60.9%), forest (3.46%), shrub (26.2%), and bushland cover (9.44%) of the total area of 48.45 ha for the Megachoch watershed, and cultivated land cover (53.1%), forest (1.8%), shrub (18.9%), and bushland (26.2%) of the total area 60.3 ha for Weshikayina watershed.

The dominant land use system in the watershed is cultivated lands (60.9%) followed by shrubland (26.2%) for the megachoch watershed cultivated lands (53.1%) and followed by bushland covers (26.2%) for the Weshikayina watershed. The greatest sediment concentration values for a given amount of rainfall occur at the beginning of the rainy season and then decrease, although discharge is initially small for a given amount of precipitation and then increases in June and

Table 3 Major land uses and land cover distribution for Weshikayina and Megachoch watershed

Land use	Weshikayina		Megachoch	
	Area (ha)	Perc. area (%)	Area (ha)	Perc. area (%)
Cultivated land	6.9	11.5	10.5	21.7
Cultivated with terraces	25.1	41.6	19	39.2
Church forest	0.2	0.3	1.65	3.44
Forest	0.9	1.5	0.01	0.02
Closed bush	4.8	8	0.1	0.21
Open bush	11	18.2	4.45	9.23
Closed shrub	2.7	4.5	5.84	12
Open shrub	8.7	14.4	6.9	14.2

Table 4 Dry season infiltration using single ring infiltrometer test

Sample codes	Location	Land use	Slope type	Slope range (%)	Average Infiltration rate (mm/hr)
M-1	Bottom	Cultivated	Flat	0–14	190
M-2	Middle	Cultivated	Gentle	14–25	147
M-3	Top	Shrub	Steep	>25	49
W-1	Bottom	Cultivated	Flat	0–14	289
W-2	Middle	Shrub	Gentle	14–25	62
W-3	Top	Bush	Steep	>25	47

August. Due to these reasons, the most dominant cultivated land-use system ploughing farmers are much amount of suspended sediment concentration into the catchment during the beginning of the rainy season in June and July.

Soil Infiltration rates and rainfall intensity with landscapes

These are useful to identify high infiltration zones and low infiltration zones of the watershed areas. The infiltration test was at the different topographic locations including upslope, downslope, and mid-slope. It is measured in mm/hr using a single ring infiltrometer in the field. The infiltration rate is steady and does not increase and decrease as more water is added, occurred when soil is nearly saturated to get up to constant infiltration capacity. The average infiltration capacity for upper, mid, and downslope positions was 9 mm/h, 12 mm/h, and 141 mm/h for the Weshikayina watershed and 9.5 mm/h, 10 mm/h, and 20 mm/h for Megachoch watershed respectively. A soil with a high percentage of sand has a high rate of infiltration, producing the least rate of runoff in a catchment. The tabular data on that infiltration rate situation with slope range and land use/land cover variations are shown in Table 4.

To compare the rainfall intensities with the infiltration capacity, the average infiltration rate was compared with the exceedance probability of the rainfall intensity (Fig. 4). During the rainy period, the average infiltration rate was
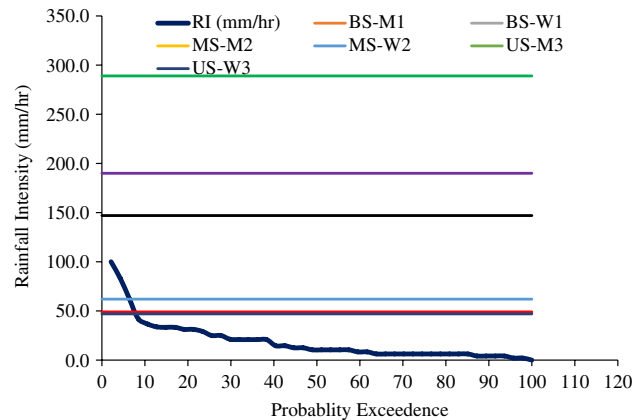

Fig. 4 A plot of the exceedance probability rainfall intensity and steady-state average infiltration rate

exceeded by the rainfall intensity. In the valley upslope positions where the soils are covered by hard strata, the lowest infiltration rates were observed. The majority of low infiltration rates were found in upslope positions. Land-use change is often considered to be the main factor influencing soil infiltration (Sun et al. 2018b). The infiltration rate of shrub and bushland at the upslope position was low because there was an impervious layer (hard pane); this was a good surface runoff occurrence in the upslope position.

Stage-discharge rating curve

Streamflow is measured by making a discharge measurement. Suspended sediment, the kind of sediment that is moved in the water itself, is measured by collecting bottles of water and sending them to a lab to determine the sediment concentration. To calculate discharge using cross-sectional area multiplied by mean velocity. Generally, the stage-discharge curve is represented by:

$$Q = aH^b \qquad (6)$$

where Q = discharge ($m^3 s^{-1}$), a and b coefficient obtained from power type regression graphs, H depth of water level reading.

The instantaneous sub-hourly data of depth as a function of discharge was computed by using the velocity–area method to establish a stage-discharge rating curve using power type regression function to create rating curves (R^2 =0.9) for depth less than 0.7m and (R^2 =0.72) for depth greater than 0.7m for Weshikayina watershed (Fig. 5). For the Megachoch watershed, using all data plotting exponential type regression function to create a rating curve was fitting (R^2 = 0.77), the result is presented as shown in Fig. 6.

Suspended sediment concentrations

The suspended sediment at the outlet of both Weshikayina and Megachoch watershed was taken samples to determine suspended sediment. Suspended sediment is a kind of sediment that is moved in the water itself from watersheds, and is measured by collecting bottles of water and sending them to a laboratory to determine or quantify the sediment load per hectare of each watershed. Issues associated with sediment transport in rivers area sediment sizes include silts and clays in the outlets. For determining suspended sediment load it's necessary to consider all particle sizes (sand +silt
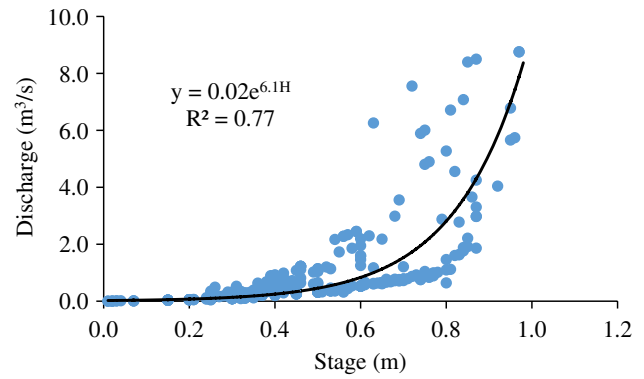

Fig. 6 All data plotting for Megachoch watershed discharge-rating curve

+clay). These sediment sizes are associated with environmental issues with erosions (especially loss of topsoil in agricultural areas, and gullies) and high sediment loads to reservoirs. Those all issues cause the rapid reductions in the storage capacity of the Atilikayina earth-fill dam. The temporal variability of sediment concentration in both watersheds shows that sediment concentrations are greater in the early phase of the monsoon rainfall period because, during the early phase, rills form in the recently-ploughed soils, with no green plants.

Sediment rating curve

Suspended-sediment concentration versus discharge plots can be a useful substitute for frequent sampling for the determination of transport rates from drainage basins (Loughran 1976). The sediment loads were obtained simply by multiplying the predicted concentrations by the observed discharge from outlets. Using observation data while developing the sediment rating curve significantly improves for predicting the sediment concentration and load (Moges et al.

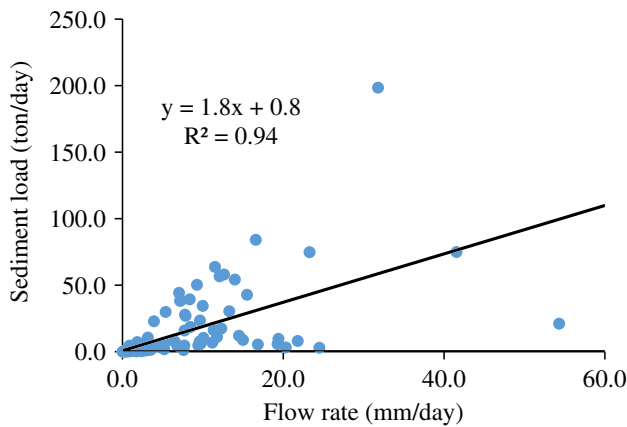**Fig. 5** Weshikayina watershed stage-discharge curve **a** (*D*=<0.7m), **b** (*D*>0.7m)
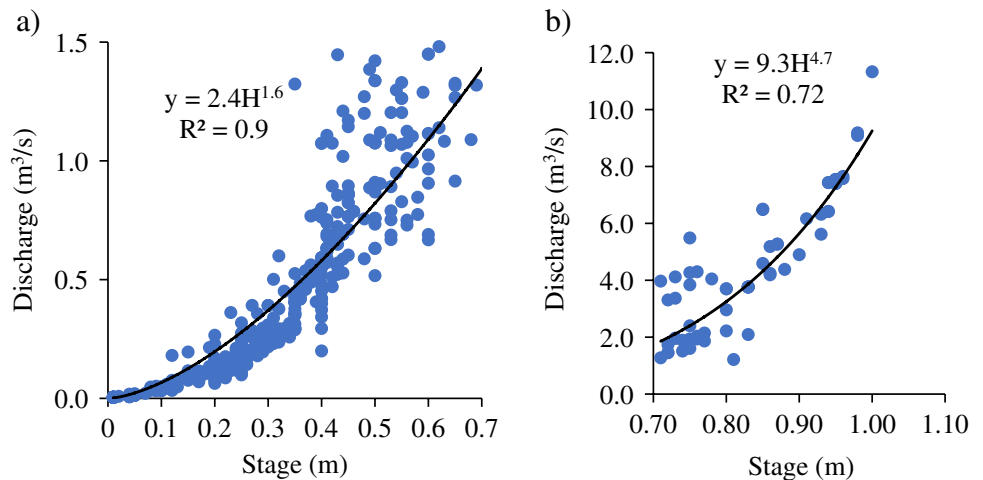
Fig. 7 Weshikayina control watershed sediment rating curve
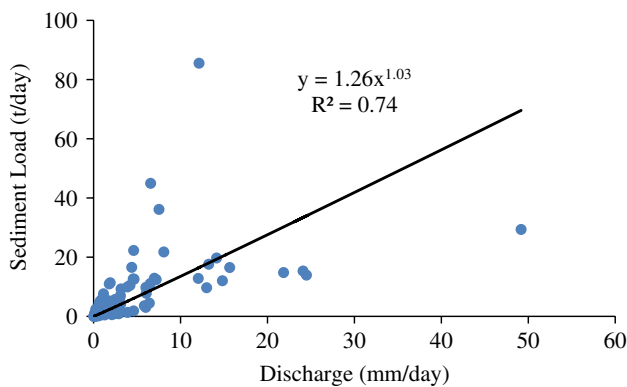

Fig. 8 Megachoch experimental watershed sediment rating curve

2016). The most often used is a power type function that relates sediment load to discharge as a product of discharge and concentration (Phillips et al. 1999). A general sediment rating curve is represented by:

$$M = a1 \times Q^b \tag{7}$$

where M is sediment load, Q is discharge, $a1$ and b are rating curve parameters determined by power type regression analysis using observed data (Gao et al. 2008). Using the power type regression function, we can develop sediment rating curves for the two watersheds in Figs. 7 and 8.

Sediment yield

The annual Sediment yield of the collected data was 11.5-ton ha⁻¹ and 13.8-ton ha⁻¹ for the Weshikayina watershed, 7.1-ton ha⁻¹ and 6.2-ton ha⁻¹ for the Megachoch watershed (Table 5), in 2019 and 2020 respectively. The result shows that the sediment load for the Weshikayina watershed is higher than the Megachoch watershed. Effective watershed management is, therefore, essential to control sediment yield for the Weshikayina watershed. These are essential to control runoff and increase the high infiltration rate in these watersheds to decrease siltation of sediment transport downstream of the Atilikayina earth-fill dam.

The result in Table 5 shows that there is an increased sediment outflow from untreated watersheds than the treated watersheds. Therefore, CARE Ethiopia rehabilitees Weshikayina watershed using gabion structures, and stone bands that are constructed on the upland positions, and need to assess the impact of development and management interventions on watershed recovery rates.

Several empirical formulas are available to estimate sediment yield, for example Youssef Hassanzadeh (1995), Yousef Hassanzadeh (2007), and Afshar and Hassanzadeh (2017) have used empirical equations to estimate sediment yield. But this study has quantified sediment yield by direct measurement. In comparison, the sediment yield quantified by the empirical equation is more inflated than those obtained by measurement. The sediment yield estimation by measurement is better than empirical formulas because as the measurement starts just from the beginning of the rainy season up to the end of the season accurate results are obtained.

The effects of LU and topography on seasonal runoff and sediment

This study showed that seasonal runoff production was higher on Weshikayina than Megachoch on hill slopes. The lower runoff in Megachoch is higher tillage and control soil loss using terracing than Weshikayina. High sediment concentrations with low flows were found at the beginning of the rainy season of the semi-monsoonal climate, while high flows and low sediment concentrations occur at the end of the rainy season (Guzman et al. 2013). This shows that at the

Table 5 The overall sediment load transport at the outlet of Weshikayina and Megachoch watershed

Number	Watershed	Sediment yield (tons year⁻¹)		Specific sediment (tons ha⁻¹)		Comment
		2019	2020	2019	2020	
1	Megachoch	340	300	7.1	6.2	Treated
2	Weshikayina	688	830.5	11.5	13.8	Untreated

beginning of the rainy season, cropland is tilled before the major storms arrive, while rangeland plots had compacted and sealed soils with almost no vegetation cover after a long dry period. The effects of land use and slope gradients in flood event analysis Weshikayina watershed were higher runoff amounts compared to Megachoch watershed. In the mid of August season, all land use/covered by forested and well-vegetated catchments can reduce suspended sediment concentration transport in the catchment.

The greatest suspended sediment in the studied catchments was observed during June, July, and August. Both watersheds are ploughed from the beginning of the rainy period in June to the beginning of August where the rill network and erosion were active and high sediment transport and reduced sediment transport from August and September due to vegetation covers including farming areas. This could be attributed to the implementation of SWC measures that covers large areas of cultivated land in both watersheds.

Conclusions

This study was conducted to examine, the rainfall-runoff and suspended sediment concentrations taking Weshikayina as the control watershed and Megachoch as the experimental watershed on the upstream Atilikayina earth-fill dam. Storm runoff and corresponding sediment concentrations were measured by monitoring and training four data collectors in the watershed outlets to quantify runoff and sediment losses in the two watersheds. The recorded data were mainly used to develop a discharge and sediment rating curve at the outlet of the Weshikayina and Megachoch watersheds. The peak sediment load on the observed data was recorded in July and August. The sediment load for the entire study period was computed to be 688 tons year^{-1}, and 830.5 tons year^{-1} for the Weshikayina watershed and 340 tons year^{-1} and 300 tons year^{-1} for the Megachoch watershed in 2019 and 2020 respectively. The result of sediment estimation shows that sediment concentration mainly corresponds to the high rainfall months. Because during these months (July and August) the area in the two watersheds is prepared for sowing and planting, hence soil is loose enough to be taken by a runoff. Based on the study, sediment concentration is reduced due to vegetation cover in the mid-season of August. Beyond this reduction, the author suggests adopting suitable soil and water conservation structures like terracing, stone bunds, and gabions.

Generally, the results of this research indicate that highly degraded and more vulnerable areas occurred in the Weshikayina watershed than in the Megachoch watershed using suspended sediment load corresponds to semiempirical equations compared with the measured data and another well-known formula in hydraulics. The application of these discharge sediment rating curves could be recommended to Megachoch and Weshikayina and similar rivers. Further studies in the semi-arid regions are needed to improve the measurement of natural radioactivity levels in drinking water, annual effective doses due to ingestion and hazard indices on infants, children, and effects of alternative land management practices on runoff and soil erosion processes at the catchment scale.

Author contribution We the authors, Tadele F. Aman, Tadege A. Worku, and Melsew A. Wubneh, conceived the presented idea. The corresponding author Tadele Fentahun developed the theory and performed the computations. Other authors have reviewed the work and made an edition.

Declarations

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