Long term trends of hydrology, sediment yield and crop productivity in Andit Tid watershed central highlands of Ethiopia

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Abstract

Previously in Ethiopia reliable climatic and hydro-meteorological data are not available and not maintained properly but the long-term database is needed for the assessment and planning of resource dynamics. To minimize the lack of reliable database, the Soil Conservation Research Program (SCRP) established observatory model watersheds since 1981. The study was initiated to compile, analyze and document the spatial and temporal distribution of the rain fall; trends of runoff and sediment loss and their relation and the influence of position of terraces on crop production. From the rainfall trend analysis result, the rainfall of the watershed has insignificant spatial (PCI=1.07) and temporal (CV=16.7%) variation which is also an indicator for less vulnerability of the watershed to drought. The precipitation coefficient (%) value of the watershed indicates that July and August have big rain with high concentration; September has big rain with moderate concentration and these three months contributed higher rainfall amount. The highest runoff and sediment yield were observed in August and July, while sediment concentration was generally high in June for the land was plown and open for crop production and hence small drops of rainfall can carry much soil and can contribute for high sediment concentration. All crops delivered statistically highest yield ($P<0.05$) immediately above bunds because the trapped and accumulated soil and plant nutrient could contribute for better performance and production of the crops. The outcome of this research highlights that, more refined data collection using better recording instruments is needed for explicit and accurately predict climatic, hydrological, soil loss and related processes investigation.

Key words: Hydrologic, PCI, precipitation coefficient, SCRP, sediment loss

Introduction

In most countries reliable climatic and hydro-meteorological data are not available and not maintained properly but the long-term database is needed for the assessment and planning of resource dynamics and its impacts on human life. Data on soil erosion and its controlling factors can be collected in the field or simulated conditions, in the laboratory (Hudson, 1982; Morgan, 1995). For realistic data on soil loss, field measurements are the most reliable because condition varies in both time and space, it is often difficult to determine the causes of erosion or understand the process at work (Hudson, 1982). But in countries like Ethiopia where the agro-climatic and topographic conditions are too diverse, it is difficult and expensive to monitor hydrological and related soil loss data (Tegenu, 2009). It is not possible to measure runoff-soil loss processes at every vulnerable spot in the country and most physical based models usually have extensive data requirements and it is difficult to build input parameters.

Andit Tid watershed was established in June 1982 as one of seven long term Soil Conservation Research Project (SCRP) sites. The SCRP was initiated in 1981 by the Institute of Geography of the University of Bern in Switzerland, implemented jointly by Soil and Water Conservation Department (SWCD) of the Ethiopian Ministry of Agriculture (MOA) and the University of Bern, and financed by both the Switzerland and Ethiopian governments. The goal of establishing these watersheds was stated as ‘to develop and promote ecologically sound, economically viable and socially acceptable conservation measures in Ethiopian highlands’. To achieve this goal long-term monitoring of these model watersheds has been conducted. In Andit Tid climate, runoff, sediment loss, crop production and land cover changes have been monitored since June 1982. It is widely reported that presently land degradation rates and erosion rates have been accelerating due to the increasing rural population (Grunder, 1988; Desta et al., 2000; Hurni et al., 2005). At the same time, a large number of soil and water conservation (SWC) practices have been installed attempting to reduce soil loss (Hurni, 1988; Nyssen et al., 2008; Herweg and Ludi, 1999). It is not clear what the effectiveness of these practices is beyond the immediate locations of where they have been tested (Vanmaercke et al., 2010).

Precipitation directly affects the availability of water resources and is one of the most important climatic factors and hydrological parameters (De Luis et al., 2011). Investigating the temporal–spatial variations of precipitation in previous time periods is critical for making reliable predictions of future climate changes. Furthermore, precipitation data of this type can be used to understand the response of hydrological cycles to climatic change and consequently the impact on the availability of water resources at regional and global scales (Allan and Soden, 2008; Xiao et al., 2017; Zamani et al., 2018). Given the changes in global warming and the resulting alterations in the hydrological cycle, an increasing number of researchers are paying attention to the temporal–spatial changes in precipitation and the subsequent outcome on the management of water resources, agricultural irrigation, and flood or drought forecasting (Gu et al., 2017).

The precipitation concentration can also be used to investigate the risks of extreme precipitation events. Additionally, the temporal precipitation concentration is a key parameter for monitoring the pace of physical processes occurring in the atmosphere (Monjo and Martin-Vide, 2016). Similarly, to evaluate precipitation heterogeneity at a monthly scale within a year, Oliver (1980) suggested a monthly precipitation concentration index (PCI), which was later adopted by De Luis et al. (1997). The PCI is very useful to assess the degree of seasonal precipitation concentration and provides information for the comparison of different climates in terms of precipitation regime for different seasons.

For several reasons, long-term monitoring of seasonal and annual crop yield and biomass production in the same research catchment over a decade is a unique and rare indicator of the performance of Ethiopian agricultural production. It enables a scientific assessment of quantitative on-farm measurements of a high density sampling in a relatively large area. Obviously many factors are involved in crop yield and biomass as an indicator, such as the natural environment (climate, soil, water, crop diseases), the social environment (cultural practices, organization, production needs and preferences), and the economic environment (farm gate prices, agricultural policies, land tenure, etc.).

The generated data have been and will extensively use by local and international researchers and students, for capacity building on sustainable land management and to design policy in the field of agriculture. The 13 years (1982 – 1994) data was analyzed and reported by Hurni

(2000) that provides important information on the impacts of treated watersheds and implications on productivity, sediment and discharge. Though there have been some discontinuity on data collection, the report is the second of its kind in availing systematically collected and organized data to establish trends of rainfall-runoff relationship, hydro-sedimentology, climate and other available data at watershed scale. The objectives of this study were: (1) to analyze the long term data and establish trends of climate (rainfall and temperature), discharge, sediment yield and crop productivity impacts of soil and water conservation practices, and (2) to provide a hydro-sedimentological characterization of the watershed, so that information has been available for longer time series monitoring since 1982..

Materials and methods

Description of the study area

Andit Tid watershed is one of the SCRP sites. It is situated on 39°43'E longitudes and 9°48'N latitudes (Figure 1) 180 km northeast of capital city Addis Ababa. The watershed covers a total area of 475 ha, and the altitude of the catchment ranges between 3040 to 3550 m.a.s.l. The mean annual rainfall is 1581 mm, the minimum and maximum temperatures are 7°C and 17°C, respectively. The minimum and maximum average soil temperatures are 8°C and 20°C, respectively. The agro-climatic zone of the watershed is moist humid. Andit Tid has been administered by the Amhara Regional Agricultural Research Institute (ARARI) under the supervision of the Debre Brehan Agricultural Research Center (DBARC). In the study area, there is a huge amount of collected and available data such as discharge, soil loss, climatic, crop productuction and land use/cover data for the last 35 years.

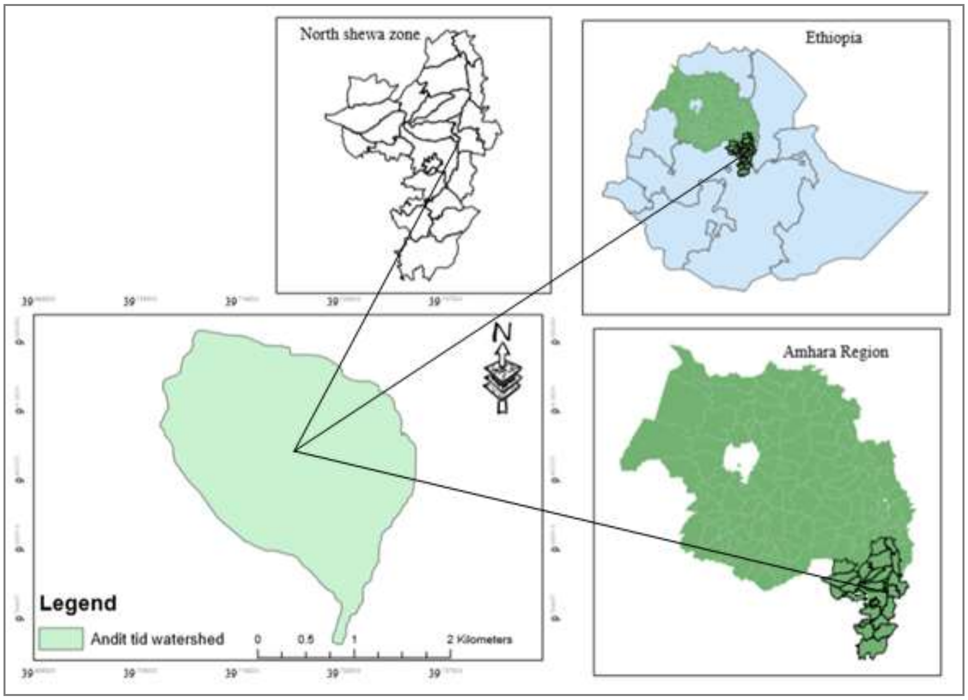

Figure1. The location map of the study area

Data collection and analysis

A-class meteorological instruments were installed near the outlet of the watershed. The rainfall data was recorded using both an automatic pluviometer rain gauge installed at the station (i.e., close to the outlet) and four manual rain gauges, distributed throughout the watershed to collect catchment-scale representative data. From continuous readings of the automatic rain gauge, rainfall characteristics including amount, intensity, and time intervals between storm events were determined.

We have used precipitation concentration index (PCI) which is the ratio of square of the rainfall amount of the specific month to the square of the total rainfall to show the distribution of rainfall in the watershed. According to the Oliver (1980), the PCI value of less than 10% represents a uniform rainfall distribution (i.e. low rainfall concentration); PCI values between 11-15 denote a moderate rainfall concentration; values from 16-20 denote irregular rain fall distribution, and values above 20% represents the irregularity(i.e. high rainfall concentration) of rainfall distribution (De Luis, 2011).

Precipitation coefficient (PC) was calculated as the ratio between the mean monthly rainfall and one twelfth of the mean annual rainfall. When the PC greater than one, the month is wet month that can contribute more than one twelfth of the mean annual rainfall and dry months contribute less than one twelfth of the mean annual rainfall. A month is rainy if the rainfall coefficient is greater than 0.6. The expression “small rains” are used to refer to months with rain fall coefficient of 06-0.9; and the expression “big rains” refer to months with rainfall coefficient of 1 and above. Big rainy months are further classified in to three groups: months with “moderate concentration” (coefficient of 1 to 1.9); months with “high concentration” (coefficient of 2-2.9); and months with “very high concentration” (coefficient of 3 and above) (WLRC, 2015).

The climatic data at the station also include minimum and maximum air temperature, minimum and maximum soil temperature. Air and soil temperature were measured using 1.5 and 0.1 meter above ground thermometers that were installed in the station under shelter respectively.

River discharge and sediment data collection

The river gauge stage was monitored continuously using limuniograph accompanied with manual water level measurements during storm events. Whenever there was runoff events, one-liter grab samples were taken every 10 minutes interval as soon as the water turned brown for sediment measurement. When the water level decreased and the runoff water returned to its original color, sampling rate decreased to 30 minutes intervals and then hour intervals. Together sediment sampling, the river water level was measured manually to determine the total stream flow and to estimate the suspended sediment carried by the flow at that specific time interval. The amount of sediment load within the sample was determined by oven drying the one liter samples then weighing the oven dried soil. Total soil loss for that sampling interval was then calculated by multiplying total water flow per time by the sediment concentration determined from the one liter sample. We used the rating equation developed by Bosshart (1997) to convert stage height to discharge:

$$Q\,(H <= 67) = 0.03 * H^{2.749} \quad \text{……………………………………………Equation (1)}$$

$$Q\,(67 < H <= 250) = 10.846 * H^{1.35} \quad \text{……………………………………Equation (2)}$$

Where Q is the runoff discharge in l/s and H is the true water level (height of stage) in cm

Drainage ratio which is the ratio of runoff to rainfall was calculated to identify when the rainfall and runoff reaches maximum and minimum. Time of concentration is useful in predicting flow rates that would result from hypothetical storms, which are based on statistically derived return_periods through IDF_curves (Monjo, R. (2016). The time of concentration (T_C) and time of peak discharge (T_P) were also generated as:

$$Tc = \frac{0.019471 * L^{0.77}}{S^{0.385}}$$ Equation (3)

$$S = \frac{\text{upper stream elevation} - \text{Lower stream elevation}}{L}$$ ………………………………..Equation (4)

$$TP = 0.6 * T$$ ……………………………………………………………………....Equatio n (5)

Where, T_C is time of concentration; L is the length of the largest stream; S is the slope variation between the upper stream and the lower stream and T_P is the time of peak discharge.

Crop yield data collection

Catchment harvest data is the representative yield and biomass sample including data on management practices, inputs, soil depth, slope, tillage, precursor crop, and crop type data taken from 35 fixed and 50 non-fixed plots from the farmers' land. In the fixed plot the samples were taken from 'a' (above terrace (zone of deposition)), 'b' (between terrace) and 'c' (below terrace (zone of transportation)) to represent the soil erosion gradient effect. This data was used to show the productivity impacts of SWC applied in the watershed.

The reliability of all collected rainfall (both rain gauge and pluvio-graph readings), stream flow and suspended sediment load raw data were checked before the analysis. Rainfall and stream discharge were cross-checked with pluvio-graph and limno-graphic river height charts. Data events at which the river height was beyond the rating equation were also avoided. Wrongly written starting and ending times for stream flow recordings and sediment samplings were also adjusted so that the total data calculations were not affected (Bosshart, 1997).

Results and discussion

Rainfall characteristics

Temporal and spatial rainfall characteristics are very important factor that affect runoff generation. The four rain gauges installed in the watershed provided information on the spatial distribution of rainfall. The PCI value of the watershed is 1.07% which means the rainfall in the watershed have uniform distribution (i.e. low rainfall concentration) as shown in Table 1. In fact the distribution of the rainfall can also be verified by the rainfall recorded from four different rain gauges distributed in different location of the watershed. Based on the recorded rainfall from these four rain gauge sites of the watershed there was insignificant variation among the rainfall amount. The precipitation coefficient (%) value of the watershed indicates that July (PC=2.551) and August (PC=2.395) have high rainfall with high concentration; September (PC=1.068) also has has high rainfall with moderate concentration and these three months contributed higher rainfall amount per year. The months of March, April, May, June and October have small rainfall with PC values of 0.68, 0.82, 0.74, 0.78 and o.653 respectively. The months of January, February, October and November are dry months as verified from the precipitation coefficient values as mentioned in Table 1.

Table1. The monthly average, annual standard deviation, CV (%), PC and PCI value of the watershed

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average RF(mm)	60.1	54.3	93.4	112.4	101.5	107.6	351.5	330.0	147.2	90.0	67.9	65.3	1581.2
St deviation	36.5	32.5	54.6	65.5	52.6	49.3	82.3	78.9	64.3	67.6	45.0	44.6	264.7

The long-term average annual rainfall based on 20 years of observation (1995–2017) is 1581mm. The maximum minimum annual rainfall ever received was 2183.6 mm in 1999 and 1069 mm which was received in 1995 as expressed in Table 2. As mentioned in Table 1 and Figure 2 the coefficient of variation for annual rainfall is 16.7%, which means the rainfall amount of each year is fairly scattered around the mean. Derib (2005) states annual rainfall with CV > 30% is an indication of high vulnerability to drought. Regardless of the higher monthly rainfall variability; the low variability of total annual rainfall minimizes the risk of drought in the study area. Hurni and Grunder (1986) verified that drought is not a problem in Andit tid because of low variability of annual rainfall. Similar to the previous study; this study also confirms that the watershed will not be vulnerable to drought and dry spell according to the low annual variability of the rainfall. The seasonal rainfall analysis result implied that; since 2008 the rainfall falling at Bulg (February to May) season is less than the long term average rainfall of the Bulg season in most years as shown in Table 2. Holden and Shiferaw (2000) also mentioned that the short rainy seasons have recently become more unreliable. The standardized climatic diagram of Andit Tid (according to Walter, 1964) is characterized by a bimodal rainfall regime with one dryer month (June) between Belg (first, small rainy season) and Kremt (second, main rainy season). Even though the rainfall amount of the Bulg season is smaller than the long term average of the Bulg rain fall; the rain fall regime of the watershed has still bimodal characteristics as mentioned in Table 2. During six months (April, May, June, July. August and September) mean monthly rainfall exceeds 100 mm; with similar result of Walter (1964); which states the four months (May, July, August and September) mean monthly rainfall exceeds 100mm.

Table2. The annual average and seasonal rainfall distribution of the watershed from 1995 to 2017 with missing value of 1996 and 1997

Year	Annual rainfall	Difference from mean	June-Sept rainfall	Difference from the mean June-Sept rainfall	Feb-May rainfall	Difference from mean Feb-May rainfall
1995	1069	-512.0	770.6	-165.6	93.1	-268.5
1998	1863.5	282.5	1026.2	90.0	433.9	72.3
1999	2183.6	602.6	1231.9	295.7	454.8	93.2
2000	1979.7	398.7	1147.3	211.1	347.1	-14.5
2001	1650.2	69.2	960.2	24.0	403.9	42.3
2002	1407.7	-173.3	794.8	-141.4	401.3	39.7
2003	1538.9	-42.1	906.8	-29.4	416.4	54.8
2004	1699	118.0	1000.9	64.7	380.5	18.9
2005	1574.9	-6.1	911.4	-24.8	401.4	39.8
2006	1768.8	187.8	871.6	-64.6	377.9	16.3
2007	1799.3	218.3	1079.3	143.1	487.9	126.3
2008	1391.5	-189.5	756.8	-179.4	180.6	-181.0
2009	1340.6	-240.4	708.0	-228.2	179.2	-182.4
2010	1655.3	74.3	1001.5	65.3	433.2	71.6
2011	1418.5	-162.5	910.9	-25.3	361.4	-0.2
2012	1364.5	-216.5	900.0	-36.2	310.3	-51.3
2013	1453.1	-127.9	955.4	19.2	317.8	-43.8
2014	1810.2	229.2	918.6	-17.6	585.9	224.3
2015	1193.9	-387.1	681.6	-254.6	216.3	-145.3
2016	1570	-11.0	1149.6	213.4	359.6	-2.0
2017	1469	-112.0	976.9	40.7	451.0	89.4
Average	1581.0	__	936.2	__	361.6	__

Air and soil surface temperature (^oC)

Air temperature was measured 1.5 m above ground on a daily basis for the period from 1995 to 2017. The daily minimum air temperature was ranged from -9 °C to 23 °C which was recorded on 22/7/2017 and 01/31/2008 respectively. The daily maximum air temperature was ranged from 2 °C to 26°C which was recorded on 11/22/2010 and 08/06/2006 &01/01/2017 respectively. The daily minimum soil surface temperature was ranged from -6 °C to 22 °C which was recorded on 07 and 09/01/2012 and 03/05/2004 respectively. The daily maximum soil surface temperature was ranged from 1 °C to 34°C which was recorded on 02/01/2014 and 16/06/2010 & 06/01/2015 respectively. The mean daily minimum and maximum air temperature of the watershed were 7.5° and C 17.6° C respectively. The mean daily air temperature of the watershed was 12.6 °C as indicated in Table3. The mean minimum and maximum soil surface temperature of the watershed were 8° and C 20° C respectively. The mean soil surface temperature of the watershed was 14.2 °C as mentioned in Table3.

Table3. The long-term minimum, maximum and mean air and soil surface temperature of the watershed

Month	Airminimum temperature (°C)	Air maximum temperature (°C)	Mean air temperature (°C)	Max soil surface temperature (°C)	Min soil surface temperature (°C)	Mean soil surface temperature (°C)
Jan	6.7	17.2	12.0	20.7	7.0	13.8
Feb	7.6	17.9	12.7	21.1	7.4	14.3
Mar	7.9	18.1	13.0	21.0	8.2	14.6
Apr	8.3	18.2	13.3	20.9	8.6	14.8
May	8.7	18.7	13.7	21.5	8.9	15.2
Jun	8.3	18.9	13.6	21.7	8.9	15.3
Jul	7.5	17.4	12.4	19.4	8.8	14.1
Aug	7.4	17.6	12.5	19.7	8.8	14.3
Sep	8.0	17.4	12.7	19.8	8.6	14.2
Oct	7.1	16.9	12.0	20.1	7.4	13.8
Nov	6.5	16.6	11.5	19.9	6.8	13.3
Dec	6.1	16.6	11.4	20.4	6.4	13.4
Minimum	6.1	16.6	11.4	19.4	6.4	13.3
Maximum	8.7	18.9	13.7	21.7	8.9	15.3
Mean temp	7.5	17.6	12.6	20.5	8.0	14.2

The air and soil surface temperature of the watershed did not have a continuous declining or increasing trend. Based on the long term time series air temperature data November and December were the coldest months with average value of 11.5 °C and 11.4°C respectively; whereas May and June are the hottest months with average value of 13.7°C and 13.6°C respectively as indicated in Table 3. In more than 96% of the records, daily soil surface temperature was higher than daily air temperature. The difference between air temperatures versus soil surface temperature was greater during the dry season than during the rainy season. With a few exceptions the daily range of soil surface temperature (difference between minimum and maximum temperature) was larger than that of air temperature; this is clearly shown in Figure 3. Soil surface temperature is more sensitive to seasonal weather variations than air temperature. During the dry season, especially in the months after the rainy season, when insulation and radiation are most intense, soil surface maximum temperatures are relatively high and soil surface minimum temperatures relatively low.

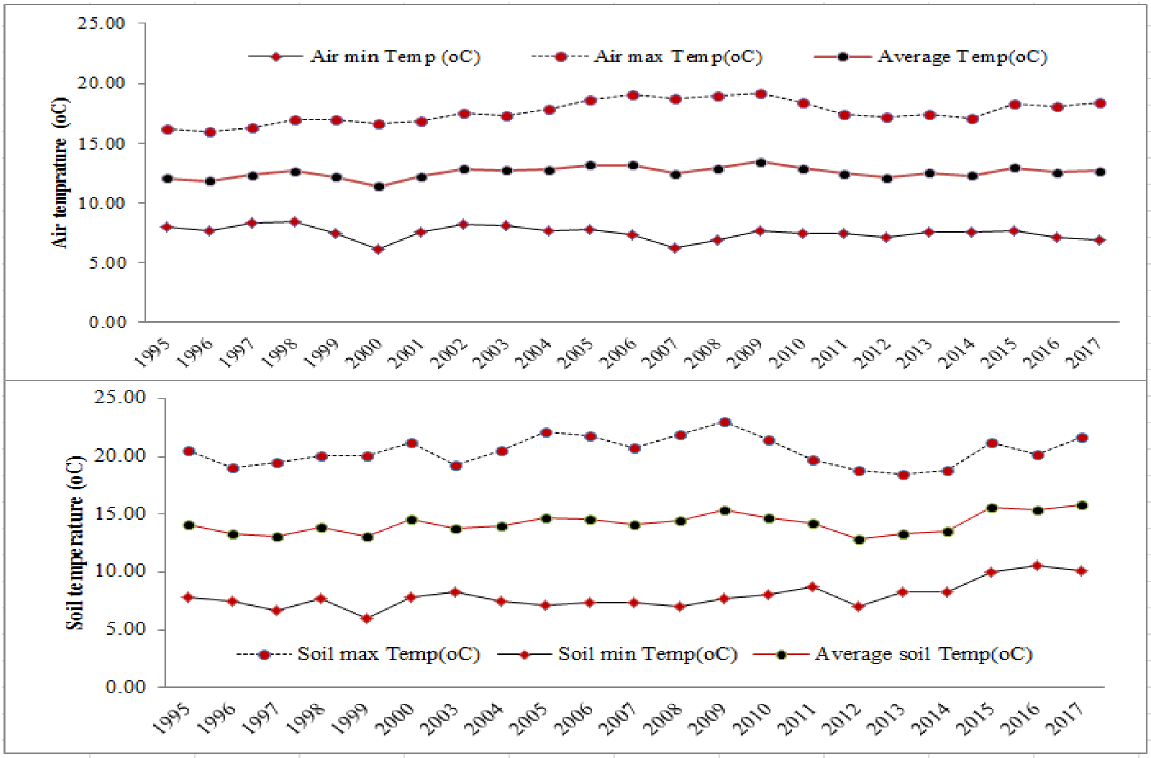

Figure3. Annual average air and soil surface temperature of Andit Tid watershed (^oC)

Trends of discharge and sediment yield

Two small rivers, Gudibado and Wadyat, drain the catchment from east to west. Their confluence is approximately 150 m above the gauging station, which is just upstream of the asphalt bridge crossing of the Hulet Wenz. Both rivers originate from the protected perennial grass lands on a wide plateau located in the upper portion of the watershed where water accumulates and saturates then drains to the two streams. Wadyat River is a perennial river, while Gudibado is mostly seasonal. The stream flow data in the period between 1994 and 2017 shows that the discharge varied between 93.6 mm (2014) and 1103.7 mm (1996) with a mean annual discharge of 417.7 mm.

The maximum and minimum annual average sediment loss of Andit tid watershed was 6.45 ton/ha and 0.825 ton/ha which was recorded in 1994 and 2007 respectively. The long term annual average sediment loss of the watershed is 3.4 ton/ha. The rates of river discharge and sediment yield indicate a major impact of mechanical soil conservation measures at catchment level. Since 2008, though the rainfall amount was decreased, the suspended sediment concentration and sediment loss are increased. This is because of the old soil conservation structures and the need of maintenance of the structure. The annual run off and sediment loss of the watershed were illustrated in Figure4.

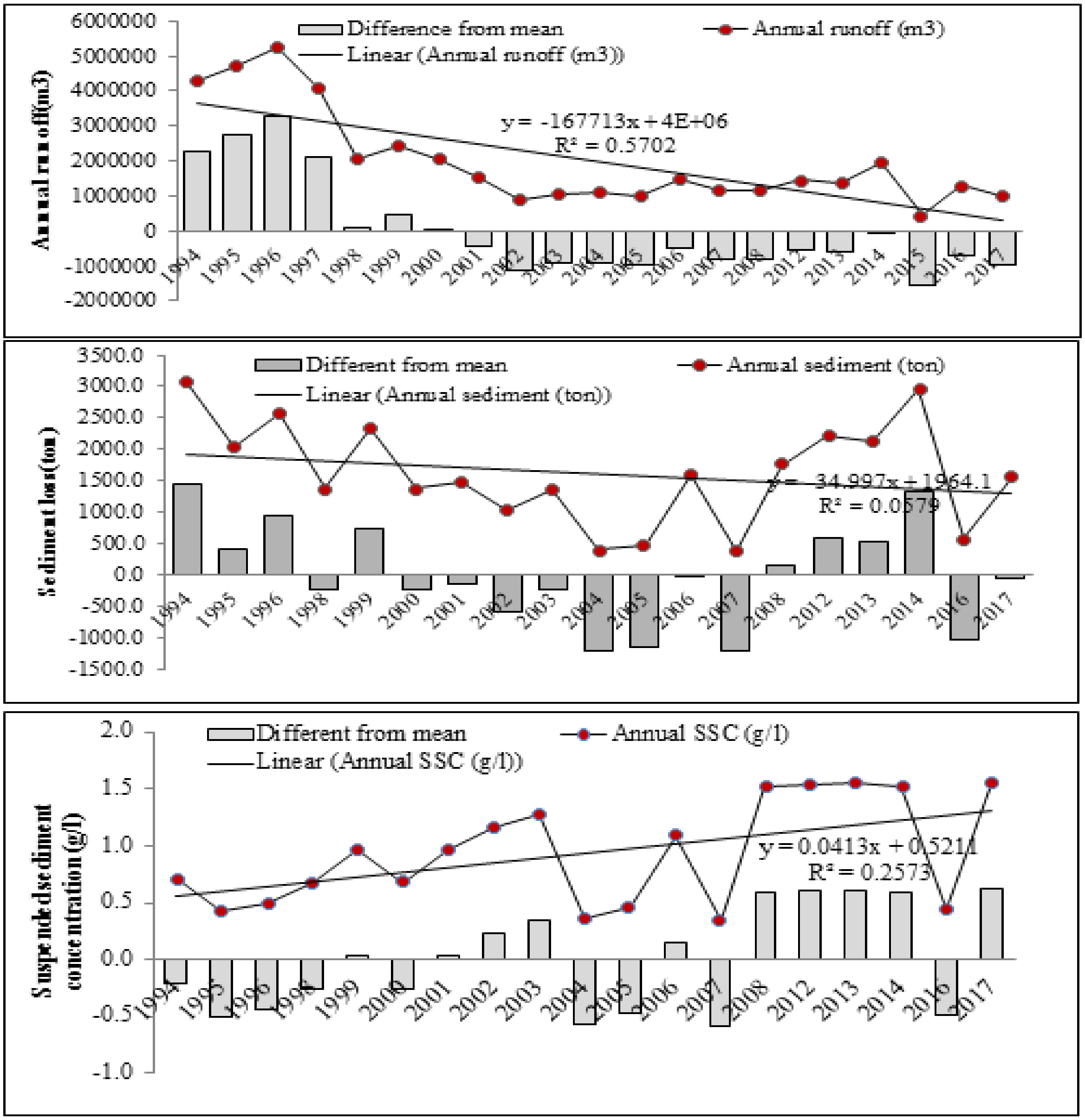

Figure 4. The annual runoff volume; sediment loss and suspended sediment concentration (SSC) of the watershed and the difference from mean of each individual year

From the Figure 4, the runoff volume was high from 1994 to 2000 but since 2001 it implies decrement and the total annual run off volume was below the mean. In similar condition the sediment loss of the watershed also high from 1994 to 1999 and it starts to decrease from 2000 and continued up to 2007. The decreased quantity of run off and sediment loss since

2000 was expected to be the result of soil and water conservation intervention works applied in the watershed. Whereas the increased trend of sediment loss starting from 2008 was the result of the oldness and destruction of applied soil and water conservation structures due to need of maintenance and other biological strengthen methods. The decreased quantity of runoff volume was clearly shown in the figure (Figure4**)** from 2001 to 2017; this may have the relation with other factors (rainfall patterns; soil structure and watershed shape) that did not addressed in this paper.

Table4. The annual runoff volume, sediment loss and suspended sediment concentration (SSC) of the watershed and the difference from mean of each individual year

Year	Annual runoff (m3)	Difference from mean	June-Sept runoff	Diff from mean June-sept runoff	Annual sediment (ton)	Diff from mean	Annual SSC (g/l)	June SSC(g/l)	July SSC(g /l)	Aug SSC(g/l)	Sept SSC (g /l)
1994	4260765	2276675	3555128.0	2054468.0	3064.7	1450.6	0.7	13.7	0.6	0.7	0.0
1995	4721545	2737455	3469422.2	1968762.2	2028.3	414.2	0.4	1.8	1.3	0.2	0.0
1996	5242418	3258328	2805852.8	1305192.8	2559.2	945.1	0.5	0.2	0.6	0.5	0.6
1997	4071007	2086917	2275910.2	775250.2	nd	Nd	nd	nd	Nd	nd	nd
1998	2060137	76046.75	1865094.1	364434.1	1376.3	-237.8	0.7	0.0	1.0	0.5	0.5
1999	2420500	436409.7	1761390.1	260730.1	2342.9	728.8	1.0	22.0	2.1	0.5	0.5
2000	2032989	48899.1	1589601.6	88941.6	1380.8	-233.3	0.7	0.0	1.5	0.6	0.6
2001	1520584	-463506	1411653.0	-89007.0	1466.0	-148.1	1.0	0.0	2.0	0.4	0.3
2002	880767	-1103323	856031.3	-644628.7	1021.3	-592.8	1.2	0.0	4.9	1.0	0.3
2003	1067722	-916368	906243.9	-594416.1	1368.5	-245.6	1.3	7.4	2.3	0.5	0.4
2004	1092495	-891595	924795.1	-575864.9	403.4	-1210.7	0.4	0.0	0.5	0.4	0.1
2005	1005153	-978937	980398.0	-520262.0	463.3	-1150.8	0.5	2.8	0.7	0.2	0.0
2006	1470352	-513738	1322937.4	-177722.6	1599.2	-14.9	1.1	0.0	2.5	0.6	1.0
2007	1147684	-836406	966320.3	-534339.7	392.1	-1221.9	0.3	0.5	0.7	0.2	0.0
2008	1155160	-828930	976442.7	-524217.3	1755.1	141.0	1.5	0.0	1.3	1.8	3.8
2012	1448200	-535890	1413896.5	-86763.5	2219.8	605.7	1.5	13.2	1.4	0.3	0.6
2013	1383312	-600778	1026795.4	-473864.6	2140.1	526.0	1.5	0.2	3.3	1.3	1.2
2014	1941020	-43070.4	1039890.4	-460769.6	2958.0	1343.9	1.5	0.0	1.2	1.1	1.2
2015	444779.5	-1539311	337438.1	-1163221.9	nd	Nd	nd	nd	Nd	nd	nd
2016	1303781	-680309	1209261.4	-291398.6	582.6	-1031.5	0.4	0.0	0.4	0.2	2.2
2017	995513.5	-988576	819362.8	-681297.2	1546.1	-68.0	1.6	0.0	5.2		

From the table (Table4) the long term annual run off of the watershed is $1.984*10^6$ m^3. From the total volume of the run off 75.6% was flowed during June to September in the summer season of the watershed and the remaining 24.4% was flowed during the remaining 8 months including the Bulg season. The long term average sediment loss of the watershed was 1613.7 ton (3.4 ton/ha). The long term suspended sediment concentration (SSC) was 0.9 g/l. The

$10m^3$ the sediment loss will increase by 6.7kg of sediment. This result confirms that 67 percent of the agent of sediment loss is runoff and the remaining 33 percent is the result of other factors (edaphic, topographic, and land cover).

Time of concentration (T_C)

The time of concentration of the Andit Tid watershed is the result of the length of longest stream and the slope gradient of this stream. With this the length of the stream is 4174 m and the upper stream elevation and lower stream elevation are 3540m and 3020 m respectively with this the time of concentration of the watershed is 26.61 minute.

Trends of crop yield under conserved lands

Crop yield samples were collected on cultivated land along the existing conservation structures, i.e. within the open area between terraces/bunds. Each cropping season sampling was done permanently on various farmers' cultivated fields in the entire catchment. Three comparable samples within a terrace were taken on different locations: one immediately above (zone of deposition), one in between, and one immediately below (zone of transportation) the conservation structures.

Table 5. Statistical variation of crop yield over different position of terrace ("a": above, "b": in between terrace and "c": below terraces with α=0.05)

	Average crop yield(kg/ha)			
Position	wheat	Barley	Linseed	Horse bean
A	1245.8a	2084.8	691.2a	927.31a
B	1040b	1850.2	608.9ab	839.7ab
C	1020.2b	1651	563b	734.5b
Mean	1102	1862.3	621	833.8
LSD(0.05)	**	ns	*	*
CV (%)	18.54	43.07	20.97	14.34

The result of on-farm yield data in relation to its positions on terraces is shown in Table5. The table shows the impact of conservation structures on the crop productivity. All crops delivered statistically highest yield immediately above bunds and the lowest yield immediately below bunds. This is the result in which the bunds could trap the soil which comes from the upper parts and the accumulated soil expected to have plant nutrients that helps for better performance and production of crops.

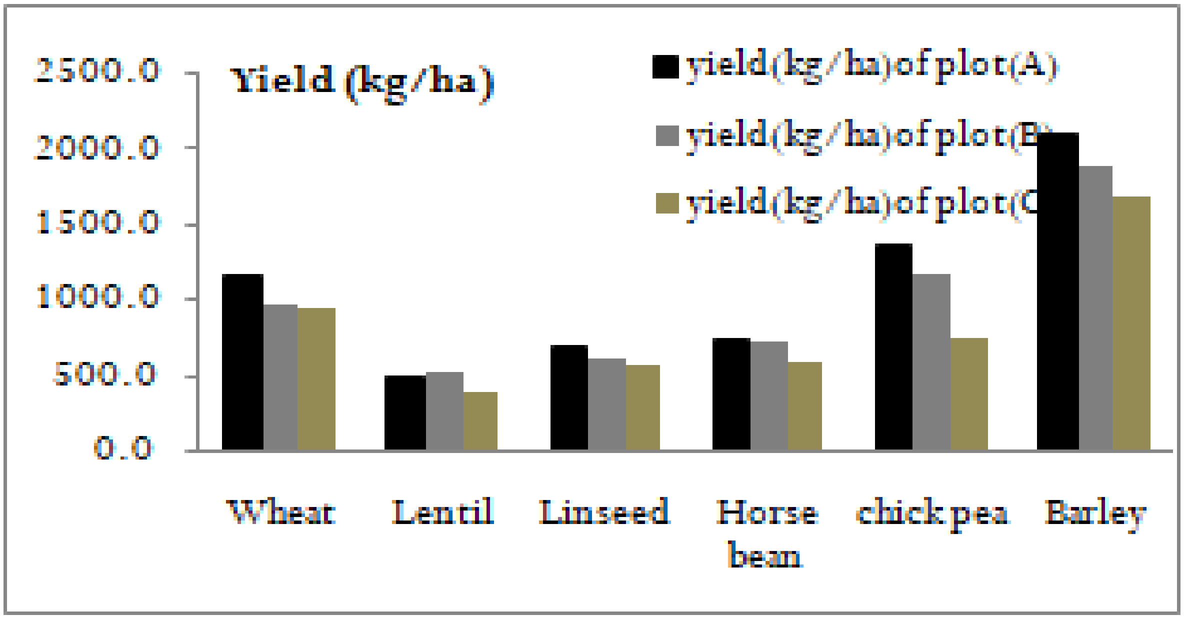

Figure 6. The response of major crops yield for different locations of terraces

The long term average grain yield result of crops in the study watershed was slightly greater than the grain yield reported by Hurni (2000) from the period (1983-1994). In general, the situation in Andit Tid is difficult for peasants. It is characterized by relatively high population and livestock densities, a high degree of land degradation, low crop yield and production as well as drastically reduced fallow periods (Hurni, 2000). Beside shortage of land, the lack of manure for fertilizer is a main problem for the farmers. Yields are further endangered by hailstorms, frost, pests (i.e. wag, fake) and rodents. The result of on-farm yield data of commonly growing crops in relation to its positions on terraces is shown in Figure6, 7and 8. Even though the general trend of grain yield in the watershed is low, the graph shows the impact of conservation structures on the yield of crops. Lower yields in the zone below the bunds are expected to be the result of two processes: (1) decreased nutrient level in the soil caused by a loss of topsoil and (2) moisture stress caused by a diminished effective water storage capacity. Nearly for the last 3-4 years the grain yields of all commodity crops are generally declining this is expected to be the result of the diminishing the efficiency of the long term bunds constructed on those plots.

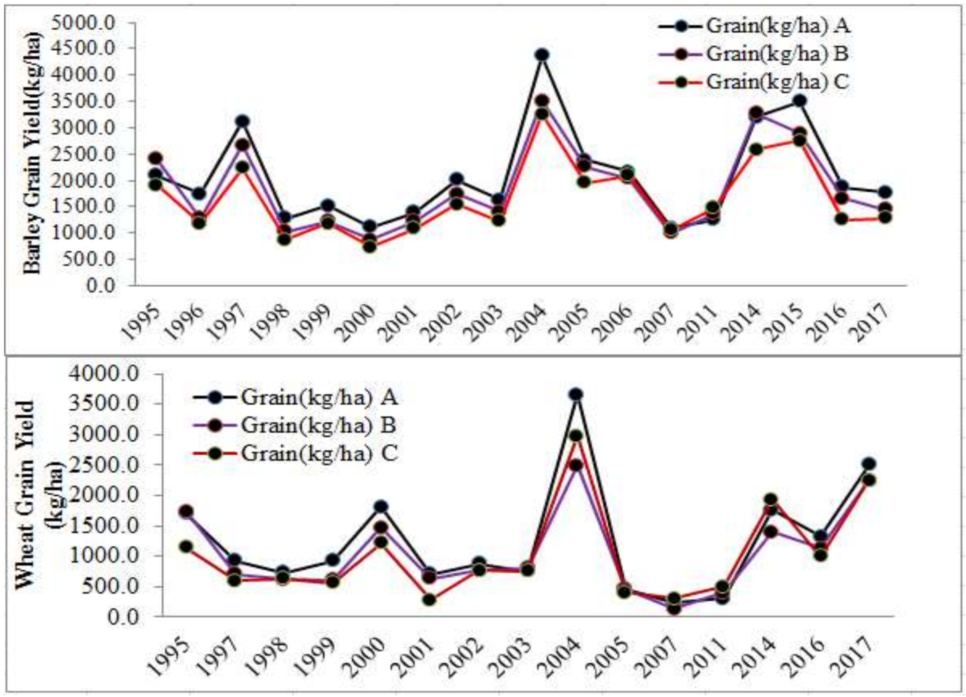

Figure 7. The long term response of Barley and Wheat yield for different locations of the terraces, (a = above / b = in between / c= below conservation structures)

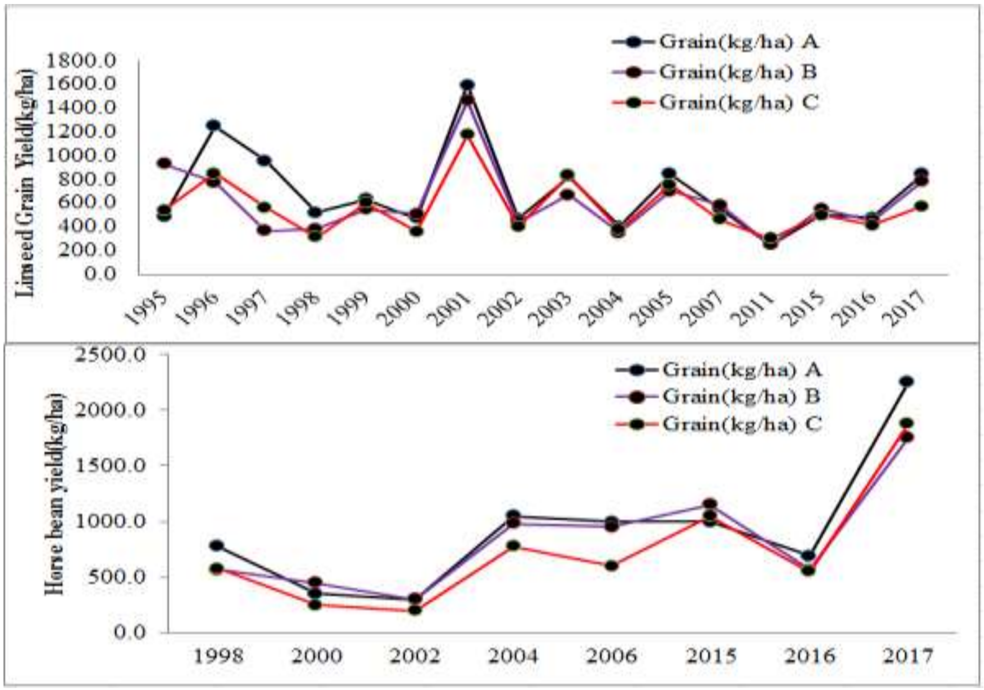

Figure 8. The long term response of Linseed and Horse bean yield for different locations of the terraces, (a = above / b = in between / c= below conservation structures)

The effects of diminishing topsoil in the upper zone of the conservation structure, and the resulting lower plant nutrient capacity immediately below the bunds were not systematically analyzed. Additional information, for example about soil depth and crop type can be found in the primary database.

Conclusion and Recommendation

Having realistic data in all hydrologic, climatic, sediment loss, crop production and land use change is the best thing in natural life. For having these realistic data on the mentioned parameters, actual field measurements are the best option because events may temporally and spatially varied. But in most countries including Ethiopia the data on hydrologic, sediment loss, climatic and crop production could not be collected and maintained properly for several reasons. Now even though it's impossible to measure hydrologic, sediment loss, climatic and crop production at every vulnerable spot in the country; it could be possible to saw the trends of these parameters at watershed level. Currently we could establish a well-structured, reliable and user's friendly data bank for rainfall, surface and atmospheric temperature, discharge, sediment loss and crop production potential and in the meantime we could provide a hydro-sedimentology characterization of a watershed.

On behalf this research paper compiles the analysis of spatial and temporal distribution of the rain fall; trends of run off and sediment loss and their relation and the influence of position of terraces on crop production. Based on the rainfall analysis the mean annual rainfall of the watershed is 1581mm and the distribution has bimodal characteristics which concentrated from March to May and July to September. The PCI value of the watershed is 1.07% which means the rainfall in the watershed have uniform spatial distribution. From the rainfall trend analysis result the rainfall of the watershed has insignificant variation (CV%=16.7) which is an indicator for less vulnerability to drought. The precipitation coefficient (%) value of the watershed indicates that July (PC=2.551) and August (PC=2.395) have big rain with high concentration; September (PC=1.068) have big rain with moderate concentration and these three months could contribute more than one twelve of total rainfall amount and January, February, October and November are dry months. The long term average runoff and sediment loss of the watershed is 417.7 mm and 1613.7 ton respectively. There was the decreased quantity of run off and sediment loss since 2000; it was expected to be the result of soil and water conservation intervention works applied in the watershed; whereas the increased trend of sediment loss starting from 2008 was the result of the oldness and destruction of applied soil and water conservation structures due to need of maintenance and other biological strengthen methods. The average surface and atmospheric temperature of the watershed is 14.2^{0}C and 12.6^{0}C. The result of on-farm yield data shows the impact of conservation structures on the crop productivity. All crops delivered statistically highest yield immediately above bunds and the lowest yield immediately below bunds. This is the result in which the bunds could trap the soil which comes from the upper parts and the accumulated soil expected to have plant nutrients that helps for better performance and production of crops.

Now Andit tid watershed has over 37 years of data, which should be useful to predict long term changes in a number of parameters that can be used to develop and manage the water and land resources in similar agro-ecologies. So the data helps the researcher to forecast possible climatic scenarios; to calibrate and validate hydrological models; to investigate the long-term impact of soil and water conservation interventions in ecosystem services and water storage capacity of the soil as well as to assess the soil health and crop productivity of soil and water conservation interventions in very fine manner.

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