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Effects of rainfall variability on river discharge in Dawa river basin, Southern Ethiopia

Fekadu Temesgen Tesfaye

College of Social science and Humanities Department of Geography and Environmental Studies, Bule Hora University, Bule Hora, Ethiopia
Email address:fekadugisrs@gmail.com
Tell phone No. (+251) 9 13 16 29 62

ABSTRACT
Understanding the link between river flow and rainfall is crucial particularly in dryland areas where there is high spatial and temporal rainfall variability. The purpose of this study is to show the link between rainfall variability and river discharge in Dawa river basin in southern Ethiopia. In order to analyze the surface hydrological effect of rainfall variability, historical rainfall and river flow data from 1972 and 2017 were used. The rainfall data were obtained from the Ethiopian Meteorological Agency, whereas the river flow data was obtained from the Ethiopian Water Resource Agency. The link between rainfall variability and river flow was modeled using linear regression model. During the 1972 - 2017 period, in all seasons, the temporal trends of the rainfall flow and the river flow show decreasing trends. In summer, winter, autumn and springs seasons the rainfall show decreasing trends with annual decrease of. 0.04 mm, 0.064 mm, 0.05 mm and 0.15 mm respectively. While the river flow show decreasing trends in summer, winter, autumn and springs seasons with annual decrease of 2.89 m^3s^{-1}, 0.26m^3s^{-1}, 1.08 m^3s^{-1} and 0.41 m^3s^{-1} respectively. The result shows that rainfall variability resulted in diminish river flow discharge in annual from the year1972 to 2017 in the study area. Thus, it is recommended that strategies should be designed by the agricultural experts for the agricultural sector for the impacts of declining and erratic nature of rainfall and decreasing trends of river flow in to consideration in their routine activities in the study area.

Key words: Effect; Rainfall variability, River basin, River discharge, trends

1.Introduction

Climate is the main factor in the terrestrial system (Arpita and Netrananda , 2019;IPCC, 2007) and it has constituted from several ingredients such as humidity, atmospheric pressure, temperature and rainfall (Arpita and Netrananda, 2019; Asefa et al., 2014).Through anthropogenic activities these climate components enforced to show unusual behavior on the surface of the earth (Houghton, 2005) and this unusual behavior is a symptom of climate change

(IPCC, 2007a).Climate change is projected to have large impacts on river basin function including changes to magnitude and frequency of rainfall events (Ayron et al., 2015; Muller et al., 2011) and relative humidity (Ayron et al., 2015; Still et al., 1999). The climate driven changes will in turn alter the timing and availability of freshwater for human and natural resource in a river basin (Ayron et al., 2015). The world climate changes mainly influence rainfall distribution and availability of water on the earth surface (Mishra,2017) due to rainfall is the main source of water in a river basin (Ahmed et al., 2011; Huntington, 2006; Gupta, 1991) and the volume of water bodies in a river basin is immediately connected to the amount of precipitation takes place in it (Sahu et al.,2012; Karanurun and Kara, 2011; Samuel et al., 2008; WHO, 2004;Miller et al., 1997).The rainfall occurred in a river basin is an important factor in deciding the volume of water available to satisfy different needs such as agricultural, industrial, domestic water supply and for hydroelectric power generation (Arpita and Netrananda,2019). The pattern and volume of the rainfall (Gajbhiye et al., 2016; Kumar and Gautam, 2014; Modarres and da Silva, 2007) are among the most crucial elements that influence surface water flow in regular state of manner in a river basin (Kumar and Gautam, 2014). The existence of the river flow firmly decided by rainfall circumstance which rained in a river basin (Dominguez et al., 2012;Magrin et al., 2005).In rainy seasons, the different parts of a river basin cause to arise excess runoff as a source of regular river flow in a specific basin (Jamtho et al., 2003;Armstrong, 2001). So, it can be believed that rainfall variability causes last only a limited period high flood peaks during the rainy season (Feng et al., 2015; Meron and P. Willems, 2012) but it is most responsible for lower flows in the dry season in a river basin (Sahu et al., 2014; Koch et al., 2012; Guo et al., 2008; Woldeamlak, 2003). Thus, the consequence of rainfall variability on the river flow has to be carried out systematically in the river basin since the rainfall variability is one of the principal factors for the existence of regular river flow in the basin (Karpouzos and Kavalieratau,2010; Garbrecht et al., 2004; Jamtho et al., 2003). As a result, understanding how rainfall variability influence river flow would enable planners to formulate policies towards minimizing the undesirable effects of future rainfall variability on stream flow pattern (Kumar et al., 2010;Luis et al., 2002) through more improved datasets and sophisticated data analyses (Arpita and Netrananda, 2019; Meshram et al., 2018; Kumar et al., 2010). Furthermore, future rainfall variability scenarios can cause significant impacts on water resources by resulting changes in the hydrological cycle (Seo and Ummenhofer, 2017; lshappa and Aruchamy, 2010). However, in order to predict the future effects rainfall variability on river flow, it is important to have an understanding of the effects of historical rainfall variabilities have had on river flow (McMillan et al., 2014; Masih et al., 2011). Besides, the knowledge of effects of rainfall variability is essential indicator for resource base analysis (Hwan and S. M. Carlson, 2015) and development of effective and appropriate response strategies for sustainable management of river flow in the basin (Bart and A. Hope, 2014; Kassa, 2009; Abebe,2007).

Having derived by these views, the purpose of this study is to assess the effects of rainfall variability on river flow in the Southern Ethiopia with particular reference to Dawa River basin for the last four decades. The Dawa River with its basin is one of the largest river and basin in both Oromiya and Somali regions and it is the part of the south eastern drainage system of Ethiopia. In the past decades the study area used to experience consistent rainfall and regular river flow for all seasons. But, nowadays the amount of rainfall and rate of river flow towards the lower parts of the basin decreases significantly and it becomes an area where urgent sever river water shortage prevails in the basin. Taking in consideration the uncertainties related with rainfall and stream flow patterns will provide a knowledge base for better management of water and other related human activities in Dawa basin.

2. Methodology

2.1.The study area description

The study river basin is located at $4^0$5'8'' to 6^0 27' 18''N and 38^0 2' 48'' to $41^0$2' 34''E (Fig. 1). It is found 567 km southwest of Addis Ababa and forms the parts of the southeast highlands of Ethiopia It covers 11 administrative districts from both Oromia and Ethio-Somali Regional states. The districts include Uraga, Bule Hora, Yabelo, Arero, Odoshakiso, Liben, Filtu, Moyale, Dire, Bore, and Adolana Wadera Woreda. The study area has as spatial coverage of 42,202 km^2.
The study area consists of different topographic conditions. The elevation ranges from 323 m to 3011 m a.s.l. It is characterized by mountainous and highly dissected stretches of land with steep slopes at the upper river parts while an undulating terrain and gentle slopes at the downriver parts. According to the classification of FAO (1999) the topography of the study area consists of level slope 19822.36 km^2 (46.97%) with slope gradient value range from 0 – 1.398, very gently sloping 9483.16 km^2 (22.47%) with slope gradient value range from 1.398 – 3.495, gently sloping 6902.92 km^2 (16.35%) with slope gradient value range from 3.495 – 6.291, sloping 4148.44 km^2 (9.83%) with slope gradient value range from 6.291 – 9.786, strongly sloping 1611.64 km^2 (3.82%) with slope gradient value range from 9.786 – 14.213, moderately steep 221.16 km^2 (0.53%) with slope gradient value range from 14.213 – 20.970 and very steep 12.16 km^2 (0.03%) with slope gradient value range from 20.970 – 59.415.
According to the National Meteorological Agency as measured at Negele town ($5^0$19' 58''N and $39^0$19' 27''E with elevation of 1496 m), the climate condition of Dawa river basin is generally characterized by sub-tropical and tropical agro-climatic conditions with a range of rainfall from 600 mm to 1250 mm (for the year between 1972 and 2017) and temperature ranges from 15 ^{0}c to 22.8 ^{0}c (for the years between 1972 and 2017).
The livelihoods of the majority of the settlers in the study area are mainly depending on pastoral practices. In addition, mixed types of agriculture on subsistence scale is the major source of livelihood of the people in the study area. Land and livestock are the most important assets of the people, with which they lead a sedentary life. A Variety of crops are produced by a house hold like Maize, Enset, Coffee, banana and etc. Moreover, and settles live in urban areas depend on trade.

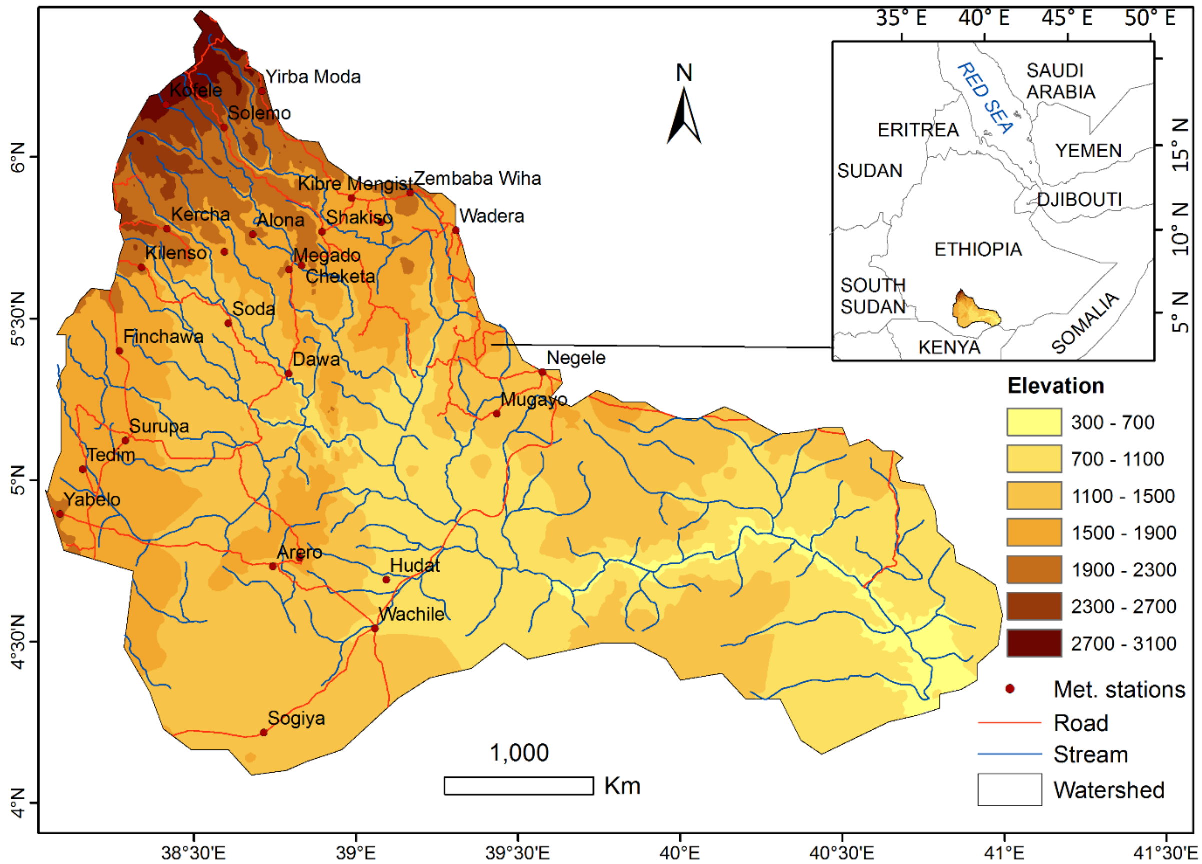


Figure 1. Location map of the study area (Source: authors, 2017).

2.3.Methods and materials

2.3.1.Data sources and method of collection

Hydrological data

The river flow data needed for the study were obtained from the Hydrological Department of the Ministry of Water Resources of Ethiopia (MWRE) taken continuously from 1972 to 2017, which has kept the record since the last five decades at daily time basis. The staff gauge readings were taken twice in a day (6:00 AM and 6:00 PM) and the average of the two is registered as the daily flow. According to the Ministry of Water Resources (2017), the river flow data of the Dawa hydrometric station were of best quality and reliable. The river flow data were used to evaluate the flow variability in relation to the hydrological effect of rainfall variability in the Dawa River basin.

Meteorological data

For this specific study, the necessary daily rainfall data were obtained from a nearby weather station, at Negele Borena town ($5^0$19’ 58’’N and $39^0$19’ 27’’E with elevation 1496 m), which were recorded by the National Meteorological Agency of Ethiopia (NMAE) since 1972. Hence, the meteorological data were obtained from the NMAE. As data preparation, the rainfall data of the study area which were obtained at daily baisis in the period from 1972 to 2017 were aggregated in to annual and monthly rainfall.

Basin delineation

For basin delineation both Digital Elevation Model (DEM) and field based ground control points (GCPs) were used. Mainly, the catchment delineation was carried out using the freely available SRTM DEM (30 m resolution) obtained from the USGS website. For delineation, hill shed was calculated from the DEM to have a clear topographic view of the river basin. From the hill shed the water divides were followed and digitized in a GIS environment. The delineation was supported by GCPs that were collected from the field along the divides. Moreover, the SPOT satellite images (with 2.5 m spatial resolution) available in Google Earth platform in the study area were used for verification.

2.3.2. Methods of data analysis and interpretation

The river flow data derived from the staff gauge readings were converted in to cubic meters per second using rating curves and the data were used to analyze the hydrological effect of rainfall variability in the river basin by correlating with river flow to investigate their cause-effect relationships.

For the purpose of analysis, the river flow data, which were available in units of volume of water passing the measurement station per unit of time, were first converted in to their depth equivalents and expressed in the same scale as with the rainfall data. Both the river flow and the rainfall data were then organized as seasonal and annual time scales so as to distinguish the effects of rainfall variability on hydrological situation. To make better comparisons between rainfall and river flow data the linear trend was analyzed using a temporal trend analysis. The trend analysis were used to understand trends of the long term changes in both the rainfall and stream flow data.

Finally, in order to understand the link between the rainfall and stream flow simple linear regression model was used. The linear regression model helps to understand the cause and effect relationship between rainfall and stream flow (Woldeamlak, 2002).

Simple linear regression model:

Correlation analysis is used to describe the strength and direction of the linear relationship between two variables (Aiken and West, 1991).In addition, in linear regression, each observation consists of two values (Poplawski, 2006; Bergner and G. Zouhar, 2000). In this simple model, one value is for the dependent variable and the other value for the independent variable, a straight line approximates the relationship between the dependent variable and the independent variable (Berry,1993).Therefore, to see the relationship between the two variables, the linear regression model has its own mathematical equestion and it has the form **Y=a + bx,** where Y is the dependent variable and X is the independent variable, b is the slope of the line and a is the Y intercept (Poplawski,2006; Klausmeyer and M. R. Shaw, 2009).

3. Results

3.1. Rainfall variability and stream flow

3.1.1. Annual rainfall and stream flow

The temporal trend of rainfall and stream flow records in the period of from 1972 to 2017, showed that the average annual rain fall decreased continuously, whereas stream flow decreased irregularly (Figure 2). The rainfall decreased from by 4.55 mm in 1972 and 0.72 mm in 2017, with an annual decreased of 0.07 mm. With similar trends stream flows also followed the same decreasing trend in the same period. The stream flow decreased from 38 $m^3 s^{-1}$ in 1972 to 9.16 m^3s^{-1} in 2017.with an annual decreased of 0.64 $m^3 s^{-1}$. But, the stream flow showed highest peak in 1998 (39.38 m^3s^{-1}). Similarly from1998 –2017 periods, the average annual stream flow followed decreasing trends. It decreased from 39.38 $m^3 s^{-1}$ in 1998 to 9.16 $m^3 s^{-1}$ in 2017 with annual decrease of 1.59 $m^3 s^{-1}$ (Figure 2).

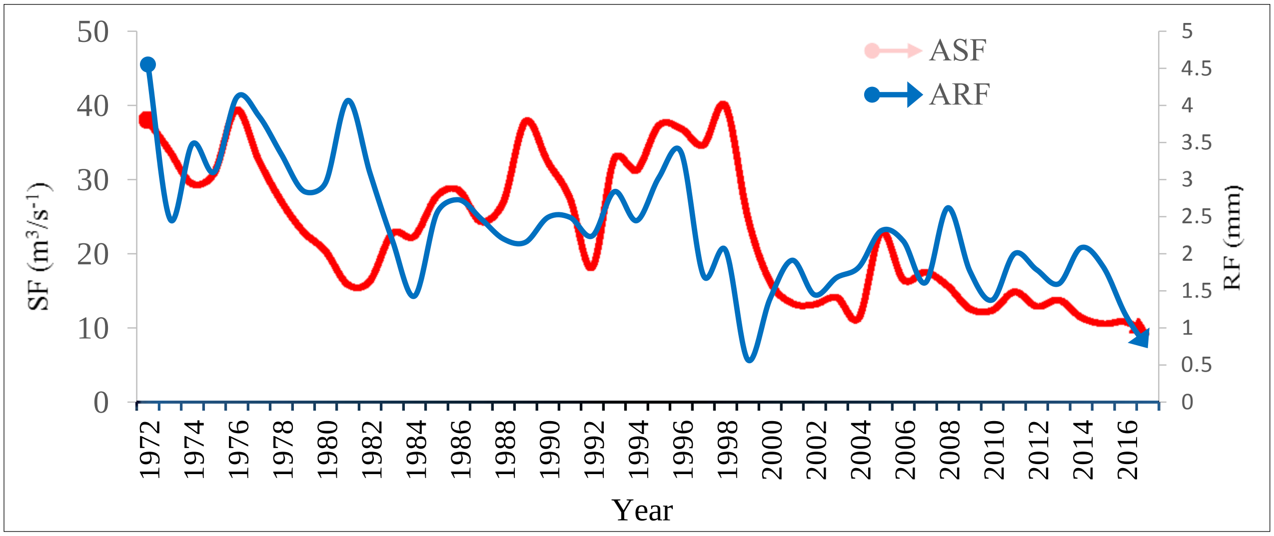
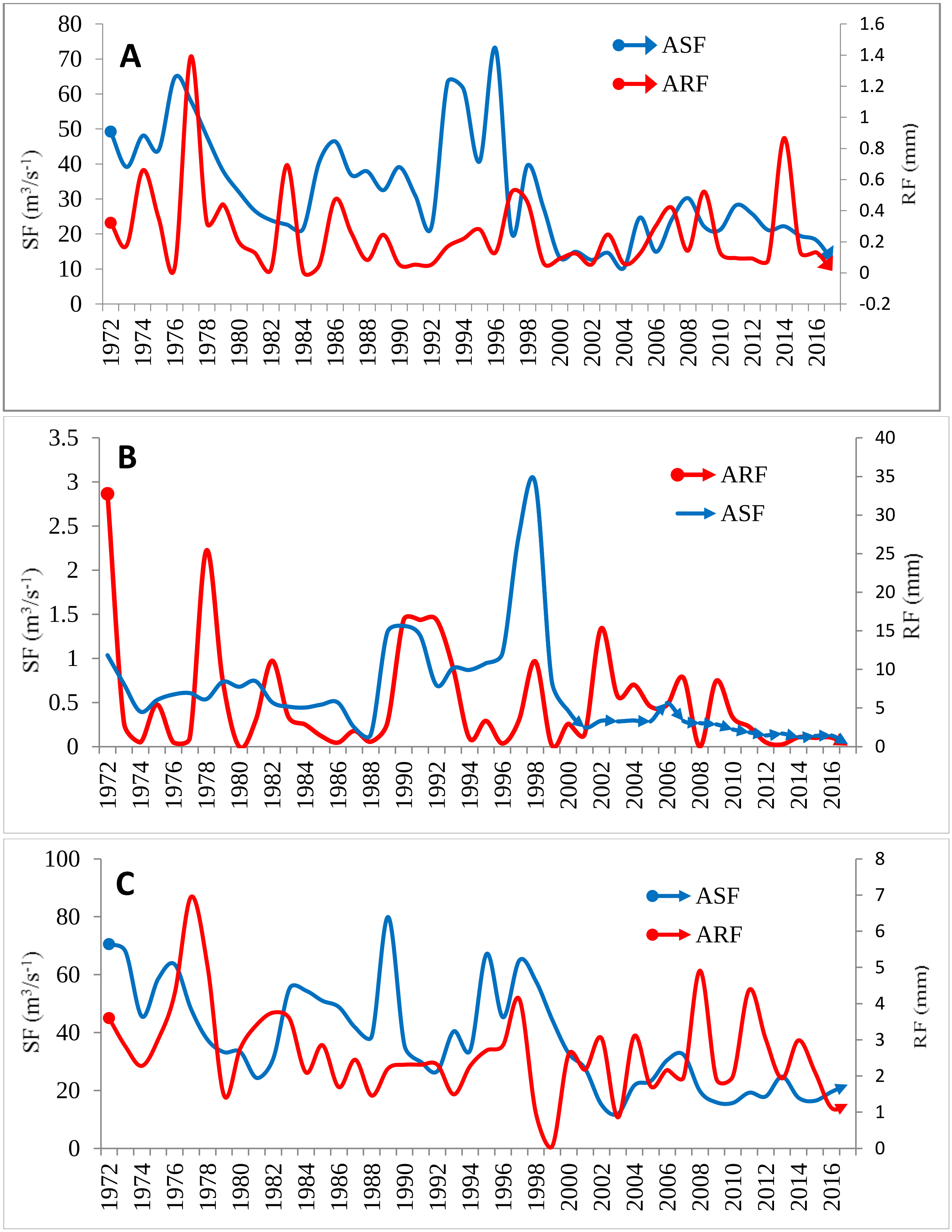


Figure 2. Average annual rainfall and stream flow (1972-2017).

3.1.2. Changes in seasonal rainfall and stream flow

During the period between 1972 and 2017 periods, in summer season, the temporal trend of the rainfall flow records showed that rain fall remained to be on average 0.32 mm to 0.01 mm and the stream flow fluctuated between 49.24 $m^3 s^{-1}$ to 12.35 $m^3 s^{-1}$ (Figure 3A). During the period between 1972 and 2017 periods, in winter season, both rainfall and stream flow followed decreasing trends. The rainfall decreased from 2.87 mm in 1972 to 0.01 mm in 2017, an annual decreased of 0.064 mm. While the stream flow descended from11.84 m^3s^{-1} in 1972 to 0.34 m^3s^{-1} in 2017, an annual decreased of 0.26m^3s^{-1} (Figure 3B). In the period between1972 and2017, in autumn seasons both rainfall and stream flow followed decreasing trends. The rainfall decreased from 3.59 mm in 1972 to 1.23 mm in 2017, an annual increase of 0.05 mm. As a result, the stream flow decreased from 70.56 m^3s^{-1} in 1972 to 22.03 m^3s^{-1} in 2017, an annual decrease of 1.08 m^3s^{-1} (Figure 3C). In the spring season the rainfall decreased from 8.45 mm in 1972 to 1.65 mm in 2017, an annual decrease of 0.15 mm. As a result, the stream flow irregularly decreased from 20.36 m^3s^{-1} in 1972 to 1.94 m^3s^{-1} in 2017, an annual increase of 0.41 m^3s^{-1} (Figure 3D).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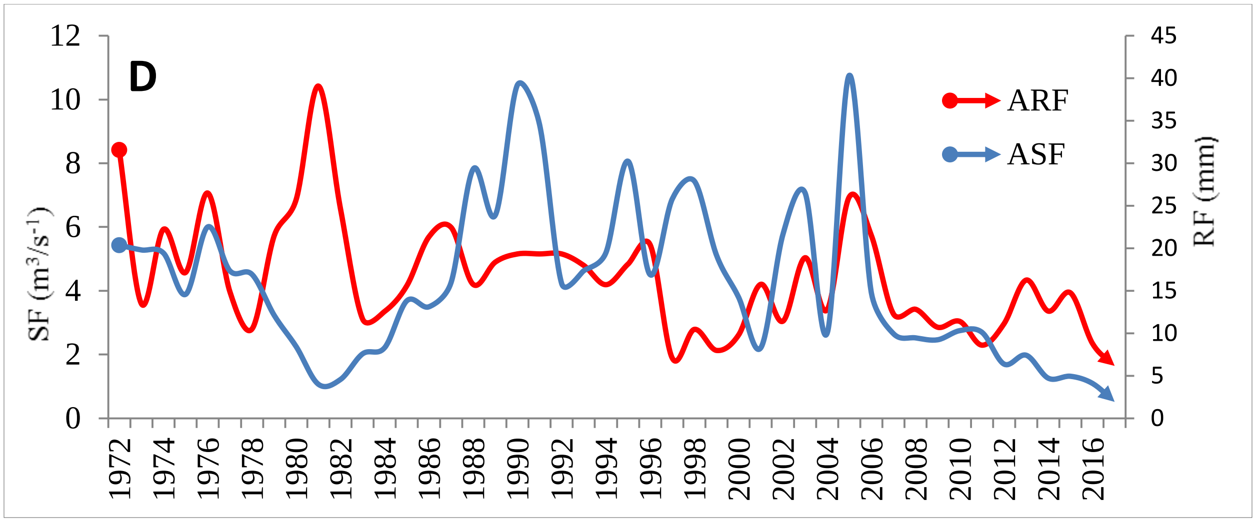


Figure 3 Trends of seasonal rainfall and stream flow (1972-2017).

3.2. Hydrological effects of rainfall variability

3.2.1. Annual hydrological effects of rainfall

In 1972 the highest average annual amount of rainfall was recorded; and lowest amount of rainfall was recorded in 1999 and the rainfall amount again raised but it showed decreasing trend towards 2017.In addition, the average stream flow also showed decrease trend (Figure 4). Therefore, so as to reach in conclusion and make the result more tangible scientifically, linear regression model was used to correlate the annual average RF and SF. Therefore, the result of linear regression model indicated that there were strong positive correlation between average annual rainfall and stream flow (R=0.796). This implies that when the rainfalls increased directly determine the volume of stream flow which empty towards the streams as other factors remained constant. In addition, a linear regression between rainfall and stream flow portrayed statistically more significant (P=0.02) relationship between the average annual rainfall and stream flow. Generally speaking, 79.6% of the river basin average annual stream flow is determined by average annual rainfall (Figure 8).

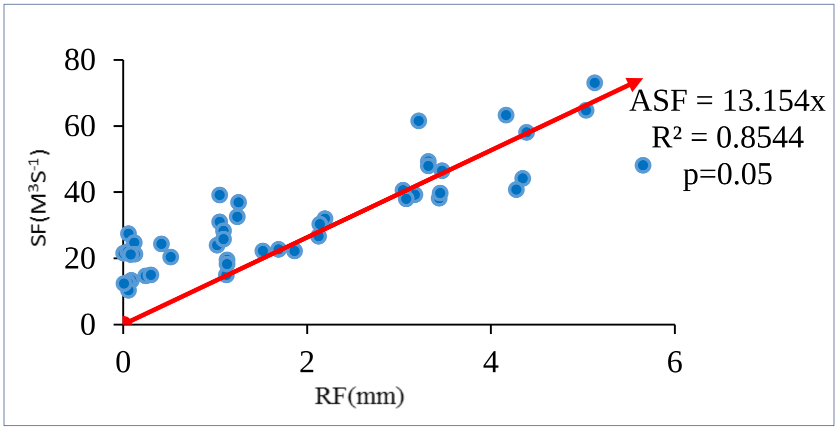


Figure 4: Hydrological effects of average annual rainfall (1972- 2017)

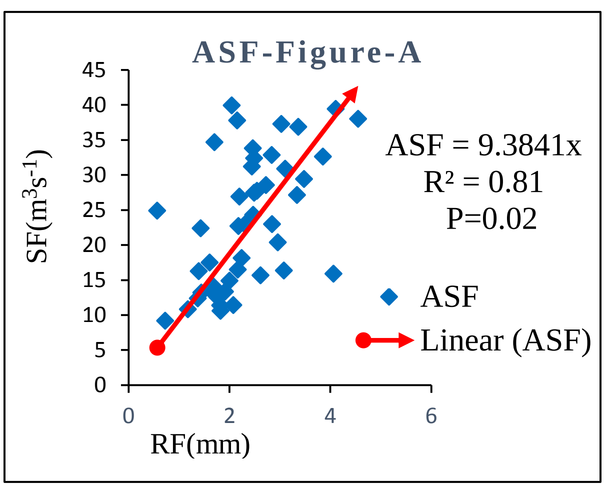
3.2.2. Season hydrological effects of rainfall

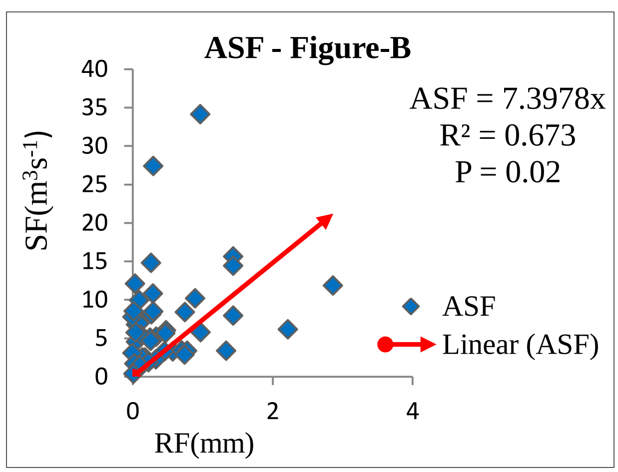
During the summer season, rainfall was at its lowest point, and small amount of stream flow was generated from surface runoff. In addition, the outcomes of linear regression model indicated that there were positive correlation between summer season rainfall and stream flow (R^2=0.87.44, p = 0.05). Hence, 85.44 % of the river basin summer season stream flow is influenced by summer rainfall and 14.56 % of the hydraulic situation of river basin determined by other factors (Figure-5A).

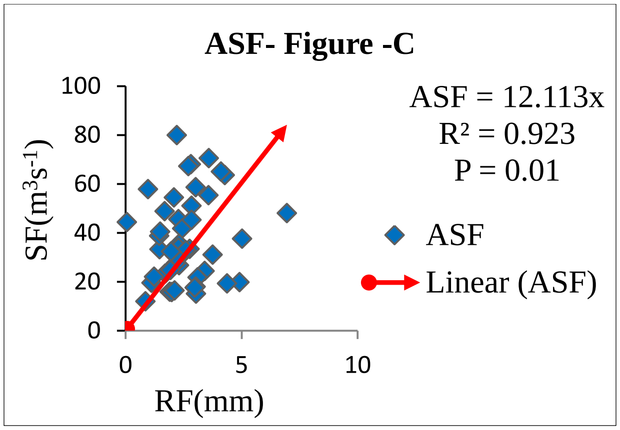
In winter season in the period between 1972 to 2017 showed that the rainfall remain diminished from 2.86 mm to 0.01 mm and the stream flow raised and failed irregularly in amount between 11.84 $m^3 s^{-1}$ to 0.34$m^3 s^{-1}$. In addition, the result of linear regression model pointed out that there was positive correlation between winter season rainfall and stream flow (R^2=0.673, p = 0.02). In other word, 67.3% of the river basin winter season stream flow is influenced by winter rainfall or 32.7 % of the hydraulic situation of the river basin is determine by other factors might be land use land cover change, soil, ground water flow and the like (Figure 5B).

In autumn season in the period between1972 to 2017 showed decreased from 3.59 mm to 1.23 mm. Similarly, the stream flow decreased from 70.57 $m^3 s^{-1}$ to 22.03 $m^3 s^{-1}$. Moreover, the result of linear regression model showed that there were positive correlation between autumn season rainfall and stream flow (R^2=0. 923, p = 0.01). In other words, 92.3% of the river basin autumn season stream flow is influenced by autumn rainfall or 7.7% hydraulic situation of the river basin determined by other factors might be LULC, soil, ground water flow and the like (Figure 5C).

Rainfall and stream flow in spring season in the period between1972 to 2017 showed irregularly decreased. Similarly, the result of linear regression model indicated that there were positive correlation between spring season rainfall and stream flow (R^2=0.56, p = 0.02). In the other word, 56% of the river basin Spring season stream flow is influenced by spring rainfall or 44% of the river basin hydraulic situation is determined by other factors might be soil characteristics, LULC, ground water flow and the like during the spring season (Figure 5D).







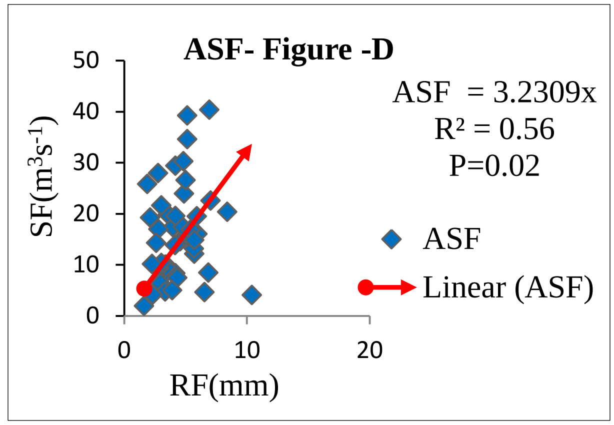


Figure 5. Hydrological effects of Seasonal rainfall (1972-2017).

4. Discussions

4.1. Trend and condition of rainfall and stream flow

According to Rakhee et al. (2019), for the period 1987–2017, 54.38 mm annual decreasing trend rainfall was recorded at the South Africa Astronomical Observatory and at Cape Point the annual rainfall trend also shows a decline in rainfall from 2013 (741.80 mm) to 2017 (325 mm).The rainfall decreased by 279 mm at Cape Agulhas over the 5-year period (2013–2017) for the most recent 30-year period.

According to Amogne et al. (2018), the mean annual rainfall in the study area from 1901 to 1940 was 1185.5mm. This amount had decreased to 1167.21 during 1941-1980 for annual rainfall. Further decrement had been recorded from 1981 to 2013 which became 1087.31mm for annual. This means, mean annual rainfall has decreased, on average by 101.19mm (Amogne et al., 2018). Similarly, during the1972-2017 period in Dawa river basin, the temporal trend of rainfall flow records showed that the average annual rain fall decreased continuously. The rainfall decreased from 4.55 mm in 1972 and 0.72 mm in 2017, with an annual decreased of 0.07 mm.

According to Woldeamlak (2003), in the winter season during the 1960 – 1982 period in Chemoga river basin, the rainfall dwindled from 383 mm in 1960 to 213 mm in 1982, a rate of decrease of 7.4 mm per year. In contrast, the rainfall increased from 278 mm in 1983 to 380 mm in 1999, a rate of increase of 5.9 mm per year. In addition, according to Amogne et al. (2018), the winter season the total amount of winter season Woleka sub-basin rainfall had shown no significant change through time (it was 149.46, 148.57 and 143.59 mm for 1901- 1940, 1941-1980 and 1981-2013 respectively). Similarly, during the 1972 -2017 period in Dawa river basin, in winter season the rainfall decreased from 2.87 mm in 1972 to 0.01 mm in 2017, an annual decreased of 0.064 mm.

According to Woldeamlak (2003), during the 1960 – 1982 period, the summer season Chemoga river basin rainfall pointed out decreasing trends. The rainfall decreased from 1003 mm in 1960 to 929 mm in 1982, an annual decrease of 6.9 mm. Similarly, according to Woldeamlak (2003), during the 1983-1999 period, in Chemoga river basin rainfall of the summer season showed insignificant decreasing trends. In addition, according to Amogne et al. (2018), the summer season Woleka sub-basin rainfall from 1901 to 1940 was 890.11mm but this amount had decreased to 871.98mm during 1941-1980. Further decrement had been recorded in the Woleka sub-basin from 1981 to 2013 which became 797.5mm for summer season. This means, summer season rainfall has decreased, on average by 92.61 mm (Amogne et al., 2018).Similarly, during the 1972 - 2017 period in Dawa river basin, in summer season, the temporal trend of the rainfall flow decreased from 0.32 mm to 0.01 mm.

According to Woldeamlak (2003), in Chemoga river basin, in the winter season the stream flow minimized from 80 mm in 1960 to 47 mm in 1982, a rate of decrease of 1.4 mm per year. In contrast, the stream flow increased from 38 mm in 1983 to 79 mm in 1999; a rate increase of 2.4 mm per year. During the 1972 -2017 period in Dawa river basin, in winter season the stream flow descended from 11.84 m^3s^{-1} in 1972 to 0.34 m^3s^{-1} in 2017, an annual decreased of 0.26m^3s^{-1}.

During 1960 – 1982 period, the summer season stream flow followed decreasing trends. The stream flow decreased from 505 mm in 1960 to 345mm in 1982.In addition, during the 1983 - 1999 period, the stream flow of the wet season shows statistically insignificant changes. Similarly, during the 1972 - 2017 period in Dawa river basin, in summer season, the temporal trend of the stream flow fluctuated between 49.24 $m^3 s^{-1}$ to 12.35 $m^3 s^{-1}$.

4.2. Hydrological effects of Rainfall variability

The river discharge in the Dawa river basin has been decreasing in year from 2000 to 2015 due to the irregular decreasing of rainfall in the study area. But this result is contradicted with the study conducted in Kenya in Thika River basin since 2000 to 2015 (Johnson et al., 2019).According to Johnson et al. (2019), the river discharge in the river basin has been increasing steadily from the year 2000 to 2015 and the major reason for the steady increasing of the stream flow in the river basin is that the consistent increase of rainfall in the basin in the period 2000-2015 (Johnson et al., 2019). This reflects significant regional differences in the effect of rainfall variability on stream flow in the river basin between nations.

Similarly, in the Dawa river basin the rainfall and stream flow situation showed decreasing trends from the year 1980 to 2010.But this result contradicted with the study conducted in the Upstream Regions of the Lancang–Mekong and Nu–Salween Rivers in China and less consistent increasing trends in annual precipitation and stream flow are observed over the investigated periods from 1980 to 2010 in the two upstream regions (Hui and Daming,2015).In addition, the stream flow of the Dawa river basin from 1972 to 2010 showed irregular decreasing trend. But, this result opposed with the study conducted in the lower stream regions of the Lancang–Mekong and Nu–Salween Rivers in China in which the annual streamflow is insignificantly increasing between the mid-1950s and 2010 (Hui and Daming,2015).This implies significant regional differences in the effect of rainfall variability on stream flow in the river basin.

Moreover, from the year 1976- 2011 the registered annual average rainfall in the Dawa river basin portrayed continuous decreasing trend but this result contradicted with the study conducted based on the effect of rainfall variability on the stream flow in the Black Volta river basin from

13 metrological stations considering on the annual average from the periods 1976 – 2011 using the Mann Kendall trend test (Komlavi et al., 2014). The test results showed that about 62% of the stations in the basin presented an increased trend in precipitation while 38% portrayed a decrease trend in precipitation but in the humid zone of the Black Volta, all the stations presented an increase in rainfall except Bui since1954–2005 (Komlavi et al., 2014). This shows significant model differences to test the variables and the different metrological stations used for the study which are found with in different climate zone.

In the Dawa river basin the rainfall and stream flow situation showed decreasing trends from the year 1972 to 1982.The temporal distribution of rainfall in in the period between1972 to 1982 showed decreasing trend from 4.55 mm to 3.08 mm and the stream flow increased from38.00m^3s^{-1} to 16.32 m^3s^{-1}. Similarly, this result agreed with the study conducted in Chemoga river basin (Woldeamlak, 2003).According to Woldeamlak (2003), in the period from 1972-1982, both the rain fall and the stream flow showed a statistically significant decrease trend. In addition, in the periods from 1983-1999, the rainfall increased from 1240mm to 1370mm, but the stream flow continued to decrease from 530mm to 480 mm (Woldeamlak, 2003). This indicates significant model similarity to test the variables and it is suggest that the study area may have the same topographic configuration even though they are found in the different geographical locations.

Moreover, in the Dawa river basin the rainfall and stream flow situation showed decreasing trends from the year 1983 - 1999.The temporal distribution of rainfall in the period between1983 - 1999 showed decreasing trend from 2.18 mm to 0.57 mm; but, the stream flow increased from22.69m^3s^{-1} to 24.86 m^3s^{-1}. Similarity, this result agreed with the study conducted in Chemoga river basin (Woldeamlak, 2003). According to Woldeamlak (2003), the distribution of rainfall in the period between1983 to 1999 showed decreasing trend from 2.18 mm to 0.57 mm; but the stream flow increased from 22.69m^3s^{-1} to 24.86 m^3s^{-1}. This result indicates the use of significant model similarity to test the variables for the study.

5. Conclusions

The effect of rainfall variability and river discharge in the river basin is the focus of this study. In order to examine the river flow effect of rainfall variability, historical rainfall and river flow data from 1972 to 2017 were used. The rainfall data were acquired from the Ethiopian Meteorological Agency, whereas the stream flow data was acquired from the Ethiopian Water Resource Agency. The consequences of rainfall variability on stream flow has analyzed in the study area using linear regression model.

The temporal general trend recorded the period of 1972 to 2017, showed that the summer season rain fall remained on average 0.32 mm to 0.01 mm and the stream flow fluctuated between 49.24 m^3s^{-1} to 12.35 m^3s^{-1}. Similarly, in winter seasons, the rainfall decreased from 2.87 mm in 1972 to 0.01 mm in 2017, an annual decreased of 0.064 mm. While the stream flow descended from11.84 m^3s^{-1} in 1972 to 0.34 m^3s^{-1} in 2017, an annual decreased of 0.26m^3s^{-1}. In autumn seasons, the rainfall decreased from 3.59 mm in 1972 to 1.23 mm in 2017, an annual decrease of 0.05 mm. As a result, the stream flow decreased from 70.56 m^3s^{-1} in 1972 to 22.03 m^3s^{-1} in 2017, an annual decrease of 1.08 m^3s^{-1}. In the spring season the rainfall decreased from 8.45 mm in 1972 to 1.65 mm in 2017, an annual decrease of 0.15 mm. As a result, the stream flow irregularly decreased from 20.36 m^3s^{-1} in 1972 to 1.94 m^3s^{-1} in 2017, an annual decrease of 0.41 m^3s^{-1}.

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ORCID: Fekadu Temesgen http://orcid.org/0000-0003-4447-3734

Compliance with ethical standards

Conflicts of Interest: The author declares that I have no conflicts of interest

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APPENDICES

Appendix 1: Average rainfall data (mm) from 1972 – 2017

Year	J	F	M	A	M	J	J	A	S	O	N	D
1972	0.0613	7.9552	0.094	12.19	12.965	0.71	0	0.258	1.81	7.323	1.667	0.581
1973	0	0.8	0	5.3667	5.4129	0.183	0.277	0.071	3.02	4.981	0.443	0
1974	0	0	4.735	4.4033	8.6516	0.74	0.245	0.994	0.4967	6.032	0.313	0.148
1975	1.429	0	0.471	7.4167	5.8452	0.44	0.297	0.31	2.6833	5.713	0.667	0
1976	0	0.0931	0.477	6.6733	14.05	0.003	0.097	0.016	3.8567	5.103	3.9	0.048
1977	0.0198	0	0.3	9.1333	2.5742	0.203	1.026	0.135	3.0133	9.6	4.307	0
1978	0.1613	6.45	3.048	0.75	4.6129	0.323	0.642	0	2.9	9.413	2.77	0.048
1979	1.61	0.3464	1.79	8.83	6.5484	1.22	0.039	0.065	0.3133	3.968	0.117	0.294
1980	0	0	0	9.3633	11.258	0	0.09	0.503	2.5367	3.445	2.33	0
1981	0	0.8857	16.77	12.283	2.2129	0	0.113	0.271	1.98	7.113	1.167	0
1982	0	2.0429	0.942	10.793	7.9677	0	0.071	0	0.89	7.535	2.833	0.873
1983	0	1.0036	0.113	5.25	3.9774	1.097	0.1	0.883	1.06	4.129	5.55	0
1984	0	0	0.284	5.88	3.9065	0	0.029	0	2.1833	3.194	0.913	0.752
1985	0.0032	0	2.313	6.4	3.7677	0.057	0.01	0.081	0.8667	5.419	2.277	0.352
1986	0	0	0.545	12.643	3.9	1.32	0.097	0.003	2.12	1.506	1.45	0.135
1987	0	0.5321	2.59	5.8333	9.5484	0.733	0	0.042	0.6333	3.452	3.267	0
1988	0	0.0897	1.074	9.8533	1.671	0	0.248	0	0.51	3.865	0	0.077
1989	0.4	0	6.516	5.3333	2.8581	0	0.735	0	1.9533	4.258	0.42	0.394
1990	0.0871	2.7857	4.519	9.0367	1.9161	0.053	0.735	0	1.9533	4.258	0.42	0.394
1991	0.0871	2.7857	4.519	9.0367	1.9161	0.053	0.735	0	1.9533	4.258	0.42	0.394
1992	5.6167	0.0296	1.165	9.0367	1.9161	0.053	0.735	0	1.9533	4.258	0.42	0.394
1993	0.3	2.1857	0.071	8.15	6.1677	0.293	0.213	0	0	4.381	0.1	0.19
1994	0	0	0.99	4.89	6.6968	0.047	0.542	0.071	1.6033	4.226	1.01	0.277
1995	0	0.8714	3.165	9.66	1.6935	0.357	0.294	0.19	1.8033	4.697	1.623	0
1996	0.0581	0.0276	4.735	9.15	2.4452	0.25	0.142	0.003	0.8733	5.871	1.813	0.019
1997	0.0065	0	1.094	3.21	1.3613	1.453	0.106	0	2.2433	6.574	3.537	0.881
1998	1.9581	0.7292	0.371	3.8	4.2032	0.76	0.432	0.165	0.0467	2.206	0.667	0.21
1999	0	0	3.403	0.9033	2.0871	0.067	0.084	0.035	0.22	4.371	0.4	0.055
2000	0.0258	0	0	3.5033	4.3484	0.01	0.071	0.194	0.15	5.465	2.203	0.745
2001	0	0.3464	2.465	7.11	3.0387	0.097	0.103	0.174	1.6567	3.623	1.253	0.071
2002	0.1581	0	3.861	2.2633	3.0161	0.03	0.055	0.081	2.2733	6.658	0.207	3.858
2003	0.3129	0	0.816	8.0767	6.2226	0.07	0.094	0.577	0.2367	1.629	0.707	1.403
2004	1.6065	0.3276	0.884	7.5233	1.8065	0.17	0	0.01	0.6433	4.455	4.233	0.168
2005	1.0935	0.2679	2.362	7.51	10.958	0.153	0.187	0.032	0.09	3.232	1.82	0
2006	0	0.9	3.839	10.06	3.3097	0.043	0.106	0.761	0.17	4.813	1.513	0.513
2007	0.0893	1.471	5.727	3.5194	0.5767	0.374	0.258	0.623	3.1645	0.777	1.513	0.513
2008	0	0	0.874	6.6233	2.7677	0.12	0.223	0.087	1.4633	9.974	3.293	0

2009	0.4645	1.0258	4.24	4.2452	0.0862	0.035	0	1.533	4.1613	1.17	0.416	0.013
2010	0.1032	0.8893	3.91	3.8833	1.3323	0.027	0.119	0.248	1.02	4.129	0.84	0
2011	0	0.0429	0.016	2.0667	4.8032	0.073	0.177	0.035	0.66	3.9	8.597	0.632
2012	0	0	0	6.8967	2.0097	0.033	0.077	0.168	1.76	4.142	3.164	0.148
2013	0.0484	0	0	5.8033	5.8767	1.33	0.039	1.497	5.0161	3.87	0	0.148
2014	0	0.2107	1.893	5.5667	2.629	0.28	1.261	1.061	0.83	5.145	0.014	0.154
2015	0	0	0.774	6.3933	4.6452	0.367	0	0.035	0.83	5.145	0.014	0.154
2016	0.2258	0.4138	0.774	6.3933	4.6452	0.367	0	0.035	0.83	5.145	0.014	0.154
2017	0.2258	0.4138	0.774	6.3933	4.6452	0.367	0	0.035	0.83	5.145	0.014	0.154

Appendix 2: Average Stream flow data (m^3s^{-1}) from1972 – 2017

Year	J	F	M	A	M	J	J	A	S	O	N	D
1972	5.2345	4.2657	2.3657	15.2435	43.45637	46.9824	49.8965	50.83546	68.7809	78.8965	64.031	26.012
1973	5.1345	2.4564	2.0735	14.56432	42.7865	41.591	37.133	38.773	66.757	77.963	59.254	16.664
1974	4.5678	1.2345	1.245	14.384	42.674	47.001	55.811	41.507	62.915	46.893	26.843	7.761
1975	4.7611	1.2013	0.346	13.098	30.323	41.057	39.584	51.567	53.391	76.443	46.149	12.109
1976	4.784	2.107	0.875	6.48	60.221	63.483	65.8763	64.7865	52.6757	75.87243	62.14356	13.3546
1977	4.8762	3.7857	1.3478	5.1238	45.5668	45.7879	62.6574	65.5687	54.78595	43.5658	45.86958	12.13244
1978	4.7645	2.4658	1.2349	3.87958	45.6758	46.8958	47.6758	49.0984	54.6353	31.26453	26.657	11.1876
1979	5.3243	6.3882	2.4685	2.46575	31.4536	34.56473	35.7689	43.9863	53.652	29.09432	16.987	13.4657
1980	4.1326	4.4959	3.588	4.6898	16.987	18.9865	32.9876	43.9843	54.9822	28.9854	15.9876	14.62435
1981	5.6244	3.5668	2.4588	3.58696	5.986	12.9876	32.9875	33.82145	33.98721	20.986	17.9887	16.24152
1982	3.4356	4.6749	3.0013	4.6286	6.0987	16.9876	23.87432	30.987	43.9821	37.983	10.9865	9.142678
1983	2.9836	5.436	3.044	5.402	14.341	15.728	14.536	37.763	63.005	50.96026	51.9873	7.09753
1984	2.0094	4.3456	3.0917	5.19465	16.6879	16.98756	13.7685	33.768	61.564	50.96375	50.8754	8.798534
1985	2.9844	3.4573	4.4567	5.67842	31.356	32.3456	40.56473	48.6857	51.6758	51.4536	49.8454	9.87641
1986	1.9805	2.1235	2.3456	2.45671	34.567	45.8775	46.7685	46.7893	45.45363	52.3657	48.67585	13.00815
1987	0.017	0.017	0.38	1.916	45.652	59.773	36.47	14.442	16.131	59.744	49.288	7.356
1988	1.32	0.9875	13.598	31.8965	42.492	22.1	42.557	49.044	30.22	66.664	19.327	2.375
1989	7.609	10.792	9.192	25.874	36.628	31.141	30.587	35.843	56.409	121.913	61.442	25.892
1990	17.264	10.87	20.649	55.371	41.613	45.066	37.743	34.576	35.874	40.653	29.937	18.744
1991	11.144	12.092	35.897	36.058	31.68	35.98534	30.10634	26.769	38.476	26.766	24.381	19.961
1992	8.661	6.155	2.823	20.107	24.607	17.048	23.086	25.86574	32.98546	25.92132	21.12356	8.97682
1993	7.8745	8.9344	4.7685	11.45573	35.87746	56.346	67.98354	65.527	50.921	38.421	32.02	13.719
1994	7.401	11.864	6.901	9.141	42.42	64.085	57.971	62.306	42.053	34.978	24.729	10.53
1995	6.091	6.06	8.602	26.133	55.993	32.407	50.93	38.89	57.013	85.918	58.611	20.244
1996	6.591	8.9867	11.492	19.6	19.598	112.17	58.088	48.8	40.361	53.112	42.398	20.68
1997	10.856	6.252	4.727	36.816	35.871	14.571	27.107	19.262	12.833	48.409	133.781	65.025
1998	40.431	39.872	20.884	21.222	41.612	41.331	37.243	40.438	42.951	52.725	77.777	22.063
1999	10.149	11.427	12.699	11.086	33.782	24.662	17.816	39.599	34.309	51.821	47.085	3.923