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Detecting the Causes of Stream Flow Change and its Implication for Water Management in the Upper Blue Nile River Basin: Case of Jedeb Catchment.

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Researcher’s Declaration

I, the undersigned, certify the following conditions of authorship I am responsible for the work submitted in this Master Thesis entitled **“Detecting the causes of Stream Flow Change and its Implication for Water Management in the Upper Blue Nile River Basin Case of Jedeb Catchment”**:, and that the original work is my own. I have not submitted this work to any other institution for the award of a degree. All information (including Figures and Tables) or other information which is copied from, or based on, the work of others has its source clearly acknowledged in the text at the place where it appears.

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ADDIS ABABA UNIVERSITY

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DEPARTMENT OF WATER RESOURCES ENGINEERING AND MANAGEMENT

SCHOOL OF GRADUATE STUDIES

Master`s Thesis

On

Detecting the Causes of Stream Flow Change and its Implication for Water Management in the Upper Blue Nile River Basin: Case of Jedeb Catchment.

By

Eyob Temesgen Alemu

A thesis submitted to Addis Ababa University School of Graduate Studies, Ethiopian Institute of Water Resources (EiWR) presented in fulfillment of the requirements for the Degree of Master of Science in Water Resources Engineering & Management (WREM) (Specialization in Surface Water Management (SWM)).

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Eyob Temesgen Alemu

Abstract

Jedeb River is one of the major tributary of Blue Nile River. However, the stream flow trend of Jedeb River has been decreased specially in dry seasons. Climate variability and human activity had been identified as the two main reasons for the decrease in stream flow. Here, climate variability refers to variability in precipitation and temperature and human activity is the activities which includes direct withdrawal of water (for irrigation, domestic and non-domestic use) and land use land cover change. Understanding the individual contributions of climate variability and human activities to changes in runoff is important for sustainable management of regional water resources. To detect the cause of stream flow change, the temporal trends of seasonal stream and annual flow (Dry, less rainy, rainy and annual) during 1980–2014 were first explored by modified Mann-Kendall trend. Annual, less rainy and rainy season's display slightly decreasing trend but not significant, but in dry season significant decreasing trend occur in Jedeb River. Change points from 1980 to 2014 are detected by pittitt test. From the result, the year 1998 is identified as abrupt change year. So that, the stream flow data set is divide into two periods as the pre-change period and post-change period.

Three methods including climate elasticity, hydrological sensitivity and hydrological model method was used to detect and quantify the hydrological runoff response to climate variability and human activities, based on the assumption that climate variability and human activities are the only drivers for stream flow. We found that human activities has 75.8% ,73% and 77.4% contribution for stream flow change by using climate elasticity, hydrological sensitivity and hydrological model method respectively. Whereas climate variability has 24.2%, 27% and 22.6% contribution for decreasing stream flow by using climate elasticity, hydrological sensitivity and hydrological model respectively. From all method human activity was detected as the dominant factor for decreasing stream flow. The study provides scientific foundation to the stakeholder to understand the causes of water resources redaction and useful information for the planning, management and development of water resources.

Key words: Climate elasticity, Hydrological sensitivity, Hydrological model, Modified Mann-Kendall, Pettitt test, Jedeb River

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List of acronyms

amsl	Above mean sea level
95PPU	95 Percent Prediction Uncertainty
acf	Auto correlation function
bcpw	Bias corrected prewhitening
DEM	Digital elevation model
ETo	Potential evapo transpiration
H0	null hypothesis
H1	Alternative hypothesis
HRU	Hydrologic response unit
IQR	Interquartile range
LULC	Land use land cover
MK	Mann-Kendall
mkttest	Mann-Kendall Test without Modifications
NSCE	Nash-Sutcliffe coefficient
PBIAS	Percentage of biasness
R^2	Coefficient of determination
SRTM	Shuffle Radar Topographic Mission
SUFI-2	Sequential Uncertainty Fitting
SWAT	Soil and Water Assessment Tool
SWAT-CUP	Soil &Water Assessment Tool-Calibration & Uncertainty Program
UBNRB	Upper Blue Nile river basin
Var	Variance
w	Plant available water coefficient
Z	Standard score
ΔQc	Change stream flow by climate variability
ΔQH	Change in stream flow by human activity
ε_{Eto}	Potential evapo transpiration elasticity
ε_{P}	Precipitation elasticity

CHAPTER ONE

1 INTRODUCTION

1.1 Background

Jedeb catchment is one of headwater catchments in the Abay/Upper Blue Nile basin originating from Choke Mountain which is located south of Lake Tana. Stream flow of Jedeb river has been changed in dry season (Tekleab et al., 2015).Climate variability and human activity are identified the two major drivers that alter hydrological cycle processes and cause change in spatio-temporal distribution of water availability in Jedeb river. Quantitative evaluation of the individual contribution of climate variability and human activity on runoff has great importance for water resources planning and management in terms of maintaining the ecosystem integrity and sustaining the society development (Wang et al., 2013, Guo et al., 2014). Climate variability is considered to be one of the major drivers behind diminishing water resources availability and changing spatial distribution over the globe. Climate variability describes the way climate elements such as temperature and rainfall depart from the average value in given months, seasons, years, decades or centuries or in other word the fluctuation of climate parameter over years. Consecutive summers, for example, will not all be the same, with some cooler and some warmer than the long-term average. Climate change is the average weather pattern in a place over at least 30 years. Climate change is long term changes in the climate parameters.

Apart from climatic variability, human activities such as modification of land use/land cover (LULC), direct water abstraction ad indirect abstraction are also alter hydrological processes and have exerted global-scale impacts on environment with significant implications on water resources. Climate variability causes alteration in precipitation, evaporation, soil moisture availability and time of flow routing (Dooge, et al., 1999).

The impacts of climate variability on hydrology influences on agriculture, water supply, environmental sustainability and protection from floods and infrastructure. Therefore, determination of the impacts of the climate variability on stream flow at the local scale is urgently needed in order to promote sustainable development and the protection of life and the environment. Human activity also plays an important role in the environment, as it partitions rainfall into the components of the hydrological cycle such as evaporation, runoff and groundwater(Aduah et al., 2017). So, understanding how the two factors (human activity and climate variability) affect river runoff dynamics is essential for water resource management. In addition, the rapid increase of population along with increase in water demand for various sectors poses severe challenges to water resources. Thus, decision and policy makers are drawn towards managing the consequences of hydrological impacts of climate change and human activities for optimal water resources management. Stream flow, the most important component of hydrological cycle undergoes variation which is expected to be influenced by climate change as well as human activities. Since these two affecting conditions are time dependent, having unequal influence, identification of the change point in natural flow regime is of utmost important to separate the individual impact of climate change and human activities on stream flow variability. Subsequently, it is important as well for framing adaptation strategies and policies for regional water resources planning and management. Identifying the dominant driving factors for the stream flow change is vital for sustainable water resources development.

Most of the catchment level hydrological study in Abay river basin deals about assessing the effect of land use and land cover (LULC) change on hydrology and also future climate change impact on hydrology based on Global Climate Models (GCM). This study will quantify the attribution of stream flow change due to climate variability and human activity in Jedeb catchment, upper Abay river basin. Particularly, it quantifies quantitatively the separate contributions of climate variability and human activity on historical Jedeb stream flow change based on the recorded stream flow data but not using future climate data.

Researchers have adopted methodologies like modeling approach (Ma et al., 2009; Bu. J et al., 2018, Aijing et al., 2012, and analytical approach (Yang and Yang, 2011, Zuo et al., 2014; Guo et al., 2014) to detect and quantify the Couse of stream flow change. The main objective of this study is to assess the separate impact that causes stream flow change. In order to quantify the separate contribution of climate variability and human activity on stream flow variation, analytical approach and modeling approach was used. Method of reconstructing nature runoff will be used in modeling approach and climate elasticity and hydrological sensitivity was used in analytical approach (Zhang et al., 2012b).

(Tekleab et al., 2015), studied the monthly trends of the Jedeb river for the period 1973 to 2010 and he conclude that in dry season month the stream flow have significantly decreasing trend. However, the study did not quantify the cause of stream flow change by either climate variability or human activity as well as the seasonal trend of Jedeb stream flow. The aim of this study is to quantify and detect the cause of stream flow change due to human activity and climate variability that affect the catchment hydrology significantly in Jedeb catchment.

1.2 Statement of the Problem

Water is a fundamental element for human life as well as ecological systems. Due to climate variability and intensive human activity, the discharge of many rivers around the world has been changing (Wang et al., 2013).In order to develop the water resource and to assess the sustainability of the stream flow the cause of stream flow change must be quantified separately (Zhang et al., 2012).

Many scholars agree that the main cause of stream flow change are human activity and climate changes/variability (Zhang et al., 2012, Wang et al., 2013). But quantifying the magnitude of individual factors is very important for selecting the dominant factor for alteration of stream flow and to give information for sustainable water resource development and management activities. As far as Jedeb catchment is concerned, few studies have been conducted.(Tekleab et al.,2013,2015) , studied the catchment long term climate and stream flow variability and impacts of land use change using statistical tests and conceptual hydrological model. However, in their studies the influence of climate variability and human activity did not quantified explicitly using of recorded stream flow data and they recommended to future study to quantify the cause stream flow change. Furthermore, many climate and human activity studies have been explored in a bigger spatial scale. However, the effects on meso-scale catchments are not explored in the region. Thus, quantitatively assessing the separate impact of climate and land cover changes on stream flow is significant issue for sustainable development and management of water resource.

1.3 Research Questions

The following research questions are addressed in this study:

- What is the characteristic of the annual and seasonal stream flow trend and the year of its abrupt change for Jedeb stream flow?
- What is the separate contribution of climate variability and human activity for Jedeb seasonal stream flow change?
- What is the implication of quantifying the separate impact of human activity and climate variability on stream flow for water resource management and development?

1.4 Objective of the study

1.4.1 General objective

The general objective of this research is to detect and quantify separately, the cause of stream flow change due to climate variability and human activity on Jedeb stream flow based on recorded observed stream flow data.

1.5 Specific objective

1) To assess and detect the seasonal and annual hydro climate trend and year of change points of Jedeb catchment.
2) To detect and quantify the cause of stream flow change due to human activity and climate variability and also isolating the dominant factor for stream flow with three different methods.
3) To demonstrate the clue/implication of quantifying the cause of stream flow change for water management.

1.6 Significant of the study

Climate variability and human activity are two major drivers that alter hydrological cycle processes and cause change in spatio-temporal distribution of water availability. Stream flow, the most important component of hydrological cycle undergoes variation which is expected to be influenced by climate change/variability as well as human activities. Since these two affecting conditions are time dependent, having unequal influence, identification of the change point in natural flow regime is important to separate the individual impact of climate change and human activities on stream flow variability. This is important for framing adaptation strategies and policies for regional water resources planning and management. This paper aims to estimate quantitatively the contribution of climate variability and human activity to the decrease of stream flow from 1980 to 2014, based on selected technique of data analysis, modeling approach and analytical approach. The findings of this study provide proper direction to decision makers to formulate policies about water resource management and sustainable water resource development. This study will have advantages for sustainable water resource management in Jedeb catchment. And also this paper fill the gap which was recommended by Tekleab et al., (2015) to do further study in quantifying the factors that are responsible for dry season Jedeb stream flow decreasing .

Generally, the major advantages are:

1. To give information to the stakeholders about the past trends of the stream flow and year of abrupt change in order to know the current condition of the stream flow discharge.
2. To give information to the stakeholders which attributes (either human activity or climate variability) have greater contribution on Jedeb seasonal stream flow change in order to formulate adaptation strategy.
3. To give information to scientific society about different methods of quantifying the individual impact of stream flow change

Overall, this study adds to the current body of knowledge with respect to methodologies developed to separate out the individual impacts of climate variability/change and human activities on stream flow with underlying assumptions. This ultimately helps in framing adaptation strategies for conservation and management of water resources.

1.7 Setting of hypothesis

In this paper, climate variability refers primarily to the variation in precipitation and air temperature. On the other hand, human activity impact has both direct and indirect impact on stream flow. Direct impact refers to the water consumption in the catchment of Jedeb River (for irrigation, domestic use..,) and indirect impact refers to the effect of man-made changes in land use and land covers. The study period is splited into two sub-periods (1980–1997 and 1998–2014). The difference of the stream flow between the two sub-periods may be due to impact of climate variability and human activity. Contribution of the two impacts to the decreasing of stream flow of Jedeb River from the period 1980–2014 is assessed in this study. Therefore, the hypothesis are:

H0 = Climate variability and human activity has no impact on Jedeb stream flow.
H1= Climate variability has dominant role in Jedeb stream flow decreasing.
H2=Human activity has dominant role in Jedeb stream flow decreasing.

Where, H0 = null hypothesis, H1 and H2, alternative hypothesis.

1.8 Conceptual framework of the study

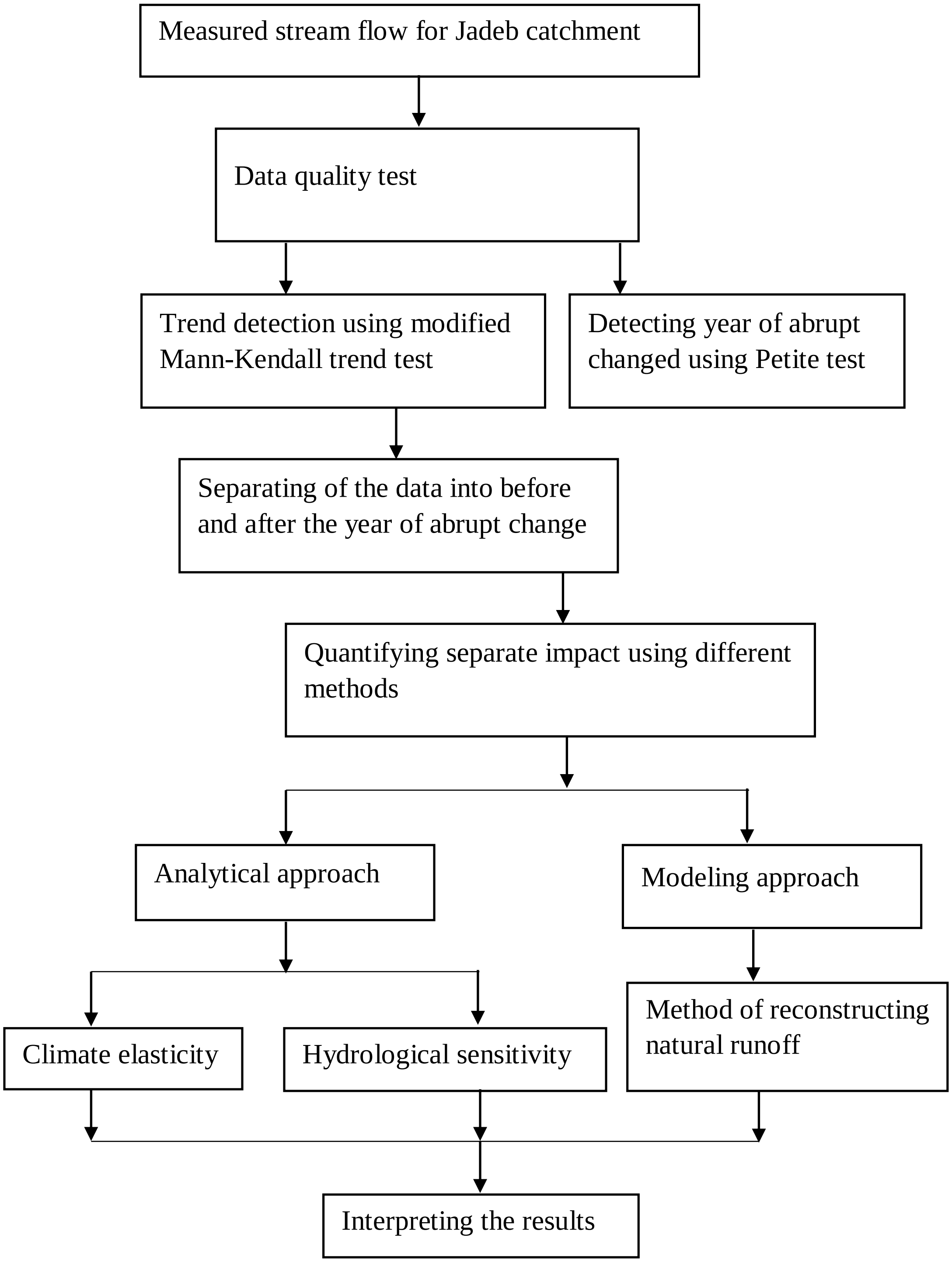

Figure 1.1. Study framework

1.1. Outlines of the Thesis

The paper is organized into six chapters: Chapter one is an introduction part where the background, objectives of the study, research questions, statement of the problem, hypothesis and conceptual framework of the study are discussed. In Chapter two, review of related literature where climate variability and climate change, methods of quantifying the separate impact, climate elasticity, hydrological sensitivity, hydrological modeling, description of the SWAT model, and hydrological model performance evaluation are reviewed. In Materials and Methods (Chapter three), description of the study area, data quality checking, stream flow trend analysis methods, methods used for quantifying the separate impact are elaborated. The fourth chapter describes with the result and discussion which are, the result of hydro climate trend, the result of the three methods of quantifying the cause of stream flow change and calibration and validation results are elaborated. In fifth, conclusion and recommendations of the study are provided. Finally, the references and appendixes are listed.

CHAPTER TWO

2 Literature Review

2.1 Climate, Climate variability and Climate change

Climate, sometimes understood as the "average weather," is defined as the measurement of the mean and variability of relevant quantities of certain variables (such as temperature, precipitation or wind) over a period of time, ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization. Climate in a wider sense is the state, including a statistical description, of the climate system. The climate system is continually changing due to the interactions between the components as well as external factors such as volcanic eruptions or solar variations and human-induced factors such as changes to the atmosphere and changes in land use (Guo et al., 2014).

Climate variability describes the way climate elements such as temperature and rainfall depart from the average value in given months, seasons, years, decades or centuries or in other word the fluctuation of climate parameter over year. Consecutive summers, for example, will not all be the same, with some cooler and some warmer than the long-term average. While these forces can cause differences in the climate from one year to the next, the climate would always be within certain ranges and would keep coming back to average or normal climate In short, climate variability is year-to-year variation of climate component (Wang et al. 2013).

Climate change is the average weather pattern in a place over at least 30 years. Alterations to the earth’s atmosphere that occur over much longer period’s such as decades to millennia are characterized as “climate change. Climate change is long term changes in the climate, so that the average annual temperature or rainfall or other aspect of the weather gets progressively different and the average climate is no longer within the same ranges as usual. Climate change is a long-term continuous change (increase or decrease) to average weather conditions (e.g. average temperature) or the range of weather (e.g. more frequent and severe extreme storms). Long-term means at least many decades above 30 year. Climate change is slow and gradual, and unlike year-to-year variability, is very difficult to perceive without scientific records (DeWaters et al., 2014,; Karl et al., 2009)

2.2 Stream flow trend analysis

Understanding the trends and any abrupt changes in the stream flow could help unravel the causes and effects of historical variations of the water resources. Trend and abrupt change detection of the hydrologic time series can help us understand the causes of historic changes and offer more insights to water resource management and ecological conservation (Zhanga et al., 2014). Many studies were undertaken stream flow and precipitation trend analysis in Abay River Basin. In the upper Blue Nile River Basin (UBNRB), statistically significant increasing long-term mean annual flow at the El Diem gauging station is reported by using Mann–Kendall and Pettit tests for the period 1970 up to 2009 (Gebremicael et al., 2012). However, Tesemma et al., (2010) reported no significant long-term trend in annual stream flow in the UBNRB at El Diem gauging station, but significantly increasing trend is detected at Bahir Dar and Kessie stations for the period 1963 to 2003. The discrepancy of both results might be due to the differences in length of data records considered.

At the sub-basin scale, Gebrehiwot et al., (2013) reported that low flows in the Gilgel Abay sub-basin decreased during the period from1973 to 2001. (Tekleab et al., 2013) studied hydro-climatic trends in the Abay/Upper Blue Nile basin for 13 climatic stations and 9 gauged catchments including the Jedeb catchment using of Mann−Kendall test. In their study, Jedeb River showed decreasing trend in dry season. However, they did not quantify the cause of stream flow variation and also did not determine the magnitude of change in stream flow.

Gebrehiwot et al., (2013) studied stream flow trend analysis in 12 catchment of upper Abay river basin for the period 1960 to 2004 except the current study area and Chomoga watershed. They reported decreasing trend at high stream flow for the Birr and Guder sub-basins and decreasing low stream flow trends for Gilgel Abay and Muger watersheds.

2.3 Human activity and land use land cover impact on hydrology

Human activity is the composite all phenomena like land use land cover change, water abstraction for different activities like irrigation, domestic and non-domestic water use and reservoir regulation. Human activities have gradually increased and their consequential impacts on the hydrological cycle on different spatiotemporal scales, such as river basins, have become widely recognized (Wang et al., 2009; Ma et al., 2010; Yang et al., 2017). However, land use land cover change is the conversion of one land cover class in to other land cover class. For example forest to agriculture, grass land to urban, shrub land to forest etc (Woldesenbet et al., 2017; Yalew et al., 2016). Recent studies mainly focused on human activities rather than land use land cover change in order to control and manage the water resource because of human activity compose of land use land cover change and abstraction of water from the catchment (Ma et al., 2010; Saidi et al 2018; Dey et al., 2017; Guo et al., 2014; Yang et al., 2017).

2.4 Major cause of stream flow change

Climate variability and human activity had been identified as the two main reasons for the change in flow. Here, climate variability refers to changes in precipitation and temperature. Impact of human activity includes direct withdrawal of water (referred to as direct abstraction from the river (primary) or groundwater and indirect impact due to man-made changes in land use and land cover in the catmint (Ma et al., 2010). According to different researchers the change in LULC of Jedeb catchment is significantly changed due to human activity (Yalew et al., 2016,Tekleab et al., 2013).

Water resources and hydrological dynamics in river basins are altered by changes in climate and human activity. Human activity and climate changes are main drivers to influence river flows and water resources (Aijing et al., 2012).

The Nile basin, having the world's longest river (6700 km) and catchment area of 3.3 million km^2, is characterized by the limited water resource where climatic and hydrological extremes such as floods and droughts hit the basin population severely and regularly associated with scarce hydro-climatic data(Taye et al., 2015). The direct and indirect impacts brought by both human activity and climate change exacerbate the water scarcity of the Nile basin as they are the key factors that can modify the hydrology and water availability of the basin (Mekonnen et al., 2017). In general, the investigations of the contribution of climate parameter and land use land cover change on stream flow trend variation at sub-catchment level in previous studies were largely unexplored, though it is a very relevant issue for sustainable use of water resources management and development at sub-catchment scale.

Although, substantial progress has been made in assessing the impacts of human activity and climate variability on the hydrology of UBNRB, most studies focused on single aspects i.e., either analyzing the statistical trend of precipitation and stream flow or analyzing impacts of single factor LULC or climate change on the flow. Impacts by combined effects of LULC and climate changes are not well understood because their contributions are difficult to separate and vary regionally (Tekleab et al., 2013, Gebremicael et al., 2013).

2.4.1 Contribution of human activity on stream flow

Human activity includes direct withdrawal of water (referred to as direct abstraction from the river (primary) or groundwater and indirect impact due to man-made changes in land use and land cover in the catchment. Land-use practices and management of water resources are interdependent. Changes in land cover as a result of farming, grazing, logging and tree planting, and urbanization have affected the water balance and transformed the water-flow pathways in the terrestrial hydrological cycle (Ma et al., 2009). According to the study by Tekleab et al., (2015), the land use in Jedeb catchment has been subject to change from 1986 to 2014 The major change was an increase of the cultivated area at the expense of the open grazing area and a slight increase in plantation forest cover due to eucalyptus plantations. This is supported by a recent study by Yalew et al. (2016), who showed that 46% of the Jedeb catchment experienced transition from one land cover to another over 52 years. At the time of study, about 70% of the land is used for agriculture and 30% is covered by forest plantation.

Yalew et al. (2016) also identified the potential land-use change drivers in the Jedeb catchment of the Abay basin by combining statistical analysis, field investigation and remote sensing. They reported that major drivers for land-use change in the study area were population, slope, livestock and distances from various infrastructures (roads, markets and water). The study indicated that farmers seem to increasingly prefer plantations of trees such as eucalyptus by replacing croplands perhaps mainly due to declining crop yield, soil fertility, income generation and climate variability. Tekleab et al., (2015) quantified the impacts of land use land cover change on the hydrology of the Jedeb catchment using stream flow change detection point and conceptual hydrological model but did not quantify the separate impact of land use land cover dynamics and climatic variability explicitly.

Mekonnen et al., (2017) assessed the response of stream flow to land use land cover (LULC) change using spastically tool and hydrological model SWAT at El Diem gauging station near Ethio-Sudan border. They provided a strong indication that changes in LULC altered the water balance in the UBNR basin. They showed that LULC change due to deforestation and expansions of cultivated area has increased surface run-off but reduced base flow. Woldesenbet et al., (2017) revealed that, in the Tana sub-basin, the expansion of cultivation land and decline in woody shrub are the major contributors to the rise in surface run-off and to the decline in the ground water component. Similarly, they reported that decline of wood land and expansion of cultivation land are the major contributors to the increase in surface run-off and water yield in the Beles sub-basin.

2.5 Contribution of climate variability on stream flow change

Climate variability alters the hydrological cycle in a direct way by influencing the distribution of precipitation, variations of evapo-transpiration and stream flow. Recent studies showed that climate variability has altered water flows and resources indifferent river basins across the world (Taye et al., 2015; Ma et al., 2009; Shao et al., 2018). Climate variability, including changes in precipitation regime, temperature, vapor pressure, and wind speed, can cause changes in stream flow directly or indirectly (Shao et al., 2018).

Most of the climate related studies in Abay river basin analyzed the effect of future climate change on hydrology and water resource based on Global Circulation Models (Worqlul et al., 2017; Taye et al., 2015; Setegn et al., 2011). But very few studies were undertaken to determine and quantify the attribution of past stream flow change in catchment and basin level stream flow trend change (Mekonnen et al., 2017).

Taye et al., (2015) used two conceptual hydrological models to assess the impact of climate change on hydrological extremes for the Lake Tana basin. They used the climate scenarios from the A_2 (medium–high) and B_2 (medium–low) emission scenarios. Gebremicael et al., (2012), investigated the response of stream flow change to historical climate change using statically tool and hydrological model at El Diem Ethio−Sudan border and they reported that increasing of rainfall intensity and extreme rainfall events in the UBNRB leads to the increasing of surface run-off and decreasing of base flow during the simulation period in the UBNRB.

2.6 Detecting the separate impact of climate variability and human activity on stream flow change

Investigations and studies on the impact of climate variability and human activity on water resources and hydrology have recently drawn considerable interest, and progress has been made in this field (Zhang et al. 2011, 2017, 2018; Bao et al. 2012; Wang et al. 2013, 2016; Ahn and

Merwade 2014; Zhao et al. 2014; Liu et al. 2017; Dey and Mishra 2017; Naz et al. 2018; Li et al. 2018).

Previous studies showed that changes in runoff are significant in various regions around the world (Gedney, N., et al., 2006). One cause is the effects of climate variability, which may alter hydrological processes under the global warming conditions. Other causes relate to human activities including land-use and land-cover change, afforestation, deforestation, urbanization, irrigation, water diversion, and domestic and industrial water consumption. However, it is difficult to estimate whether the changes in runoff are caused by climate change or anthropogenic factors, yet the detection of the dominant factor is central to policy making for adaptive and sustainable regional water resources management. Hence, it is important to detect and separate the effects of climate change and human activities and to determine the dominant factors which lead to runoff changes. Although several studies have recently been conducted on this topic, separating the effects of climate change and human activities in hydrology is still a challenge, and the impacts of the two factors on the water cycle still need further investigation at the local scale (Aijing et al., 2012).

In recent years, a number of studies have been conducted to distinguish effects of climate variability and human activity on watershed hydrology (Guo et al., 2014, Yang et al., 2017).The methods that use to quantify the separate impact can be divided into four types: simple regression techniques, modeling-based approach, conceptual model, and climate elasticity mode (Ervinia et al., 2017,Aijing et al., 2012). Hydrological modeling is used to simulate stream flow under natural and impacted conditions. The conceptual approaches include applications of Budyko hypothesis and analytical approach includes climate elasticity and hydrological sensitivity methods. Climate elasticity, hydrological sensitivity and hydrological model is the most common methods to quantify the cause of stream flow change due to human activity and climate variability.

2.6.1 Climate Elasticity Method

Changes in stream flow characteristics can be influenced by climatic variability and human activity. The individual impacts of climate variability and human activities are, therefore, necessary to frame different adaptation measures due to climate change in watersheds and to realize the future water use pattern for different human activities. Researchers have adopted deferent methodologies. This method is one of the analytical approach and commonly used to separate the individual impact of human activity and climate variability on water resource. Elasticity has been used to examine sensitivity of stream flow to variation in climate parameter and human activity. The concept of climate elasticity was first introduced by (Schaake et al., 1990) and developed by (Sankarasubramanian et al., 2001; Ma et al., 2010; Saidi et al 2018; Dey et al., 2017) to evaluate the sensitivity of stream flow to climate variability. Climate elasticity measures the contribution of climate parameter variability on stream flow alteration, and assumes that the remaining change of stream flow would come from human influence. It represents the proportional change in stream flow divided by the proportional change in a climatic variable (X), such as precipitation or potential evapotranspiration. As a result precipitation and potential evapotranspiration incorporate all climate parameter.

Liu et al., (2012) applied climate elasticity method in the Danjiangkou Reservoir to quantify the individual impact (the headwater source of the central route of China's South to North Water Diversion Project), and concluded that the contribution of climate variation and human activities to the reduction in stream flow were about 84.1– 90.1 % and 9.9–15.9 %, respectively. Saidi et al., (2018) applied climate elasticity to quantifying and detect the impacts of climate variability and human activities on the stream flow change of an Alpine river and conclude that, climate variability accounted for 85% for Alpine river decline and the remaining 15% is human activity for Alpine river decline. Wu et al., (2017) use climate elasticity to do detecting and quantify the quantitative hydrological response to changes in climate and human activities and conclude that climate change was estimated to account for 46.1%–60.8% (mean 54.1%) of the total decrease in runoff, whereas human activities accounted for 39.1%–53.9% (mean 45.9%). Ma et al., (2010) use climate elasticity to assess and detect the contribution of climate variability and human activity for decline in stream flow in the Miyun Reservoir catchment. They concluded that, climate variability was accountable for about 51% of the decrease in reservoir inflow and the remaining 49% is human activity accountable for Miyum reservoir inflow. Liang et al., (2013) use this method to evaluate and detect the relative contribution of climate variability and human activity for decrement of stream flow in a sediment concentrated region in the Middle Yellow River. They reported that climate variability has contributed 40.9% for yellow river flow decreasing and also human activities accounted for 59.1% for yellow river decreasing.

2.6.2 Hydrological Sensitivity Method

This method is one of the analytical approach and commonly used to separate the individual impact of human activity and climate variability on water resource. The hydrological sensitivity method, developed by Dooge et al., (1999) and developed by (Wang et al., 2013; Zue et al., 2014; Saidi et al., 2018; Dey et al., 2017) to describe first-order effect of changes in precipitation and potential evaporation on stream flow. It has been also adopted to study hydrologic responses to changes in climate and hence separate the effect of climate change on stream flow from that of human activities. A general approach can be summarized for these methods, usually climate variability is estimated first and the remaining effect is attributed to other factors such as human activities (Zhao et al., 2010). Hydrological sensitivity can be described as the percentage change in mean annual runoff in response to the change in mean annual precipitation and potential evapotranspiration in short, Hydrological sensitivity method refers to changes in mean stream flow with respect to changes in climate variables (precipitation, potential evapotranspiration) and is often expressed in percentage (Guo et al., 2014; Zuo et al., 2014). The driving principle of this method is hydrological water balance model. The basic assumption in this method is similar to the hydrological modelling which is that before the change point, the change in the stream flow is due to only climate variability/change and after the change point both climate change and human activities are responsible for changes in stream flow

Guo et al., (2014) applied hydrological sensitivity to quantify the impact of climate variability and human activities on runoff changes for the upper reaches of Weihe River. They concluded that the human activities contributed around 59 to 77 % to the reduction in runoff and the remaining is climate variability. Saidi et al., (2018) applied this method to quantify impacts of climate variability and human activities on the stream flow of an Alpine river and conclude that climate variability accounted for 85% and the remaining 15% is human activity. Dey et al., (2017) applied this method in separating the impacts of climate change and human activities on stream flow and conclude that hydrological sensitivity is one of the effective methods to achieve best result. Zuo et al., (2014) applied hydrological sensitivity to identify the influence of climate change and human activities on stream flow in the Wei River Basin, China and they concluded that human activity contributed 50% for Wei stream flow decline whereas climate variability contributed 50% for Wei stream flow decline.

2.6.3 Hydrological Model Method

In modeling approach hydrological model, the water balance model SWAT will be used to quantify the contributions of the separate impact of human activity and climate variability on historical stream flow change. Hydrological modeling is being used for analyzing the impacts of climate variability and human impacts on runoff by simulating runoff processes using representative hydro-meteorological data for study area. Selection of hydrological model should be done in such a way that it must be able to address specific research question within the available information resources such as data availability on different variables/process, number of stations for accounting spatial changes across a watershed, complexity of model structure.

Hydrological models are increasingly important to investigate the hydrological system dynamics and to predict the potential impacts of changes in the catchment on the discharge regime at various spatial and temporal scales. In addition, hydrologic model are important to simulate the catchment or river basin hydrological process. There are different type of hydrological model depend on their characteristic such as conceptual model, distributed model, lumped model and empirical model (Kormann et al., 2016, Li et al., 2012, Yang et al., 2017).Several studies used hydrological models globally as well as in the upper Abay river basin in order to determine the impact of climate and land usechange on hydrology, to simulate the sedment load,to quantify the separate impact of stream change etc(Worqlul et al., 2018, Dagnenet F. Mekonnen, 2017, Taye et al., 2015, Setegn et al., 2011,Weldesebet etal.,2017).

But in the Jedeb catchment, there are few study undertaken by using hydrological model and statistical tool (Tekleab et al., 2015; Tekleab et al., 2013). Tekleab et al., (2013,2013), modeled the rainfall–runoff process in Chemoga and Jedeb catchment using stable isotope data and field observations. They used lumped conceptual distributed model to understand the rainfall–runoff processes of Chemoga and Jedeb catchments.and also analyses the stream flow trend of upper Abay River basin including my study area The same conceptual monthly hydrological model is used to assess the impact of land use land cover on hydrology by identifying changes in the model parameters over different periods to infer LULC change.Yalew et al., (2016), identified the potential land-use drivers in the Jedeb catchment of the Abay basin by combining statistical analysis, field investigation and remote sensing.

2.6.4 Selection of Models

The selection of a model for a specific hydrological situation has implications in water resources planning, development, and management. The selection is usually based on data availability, spatial representation, computational cost, and model robustness (Pechlivanidis et al., 2011). Some of the factors and criteria involved in the selection of a model include the following:

- The purpose and the benefits of the model-output, e.g., continuous hydrograph of discharges, forecast of floods, water quality, and water resource management;
- The climate and physiographic characteristics of the basin;
- The lengths of the records of the various types of data;
- The quality of the data both in time and space;
- The availability and size of the computers for both the development and operation of the model;
- The possible need for transferring model parameters from smaller catchments to large catchments;
- The ability of the model to be updated on the basis of current hydro-metrological conditions.

In light of all these, the Soil and Water Assessment Tool (SWAT) is selected for rainfall-runoff modeling in the current study. SWAT is a semi-distributed hydrological model widely used for over 250 peers reviewed journal articles existed by 2007 on SWAT-related work (Gassman et al., 2007). SWAT was also successfully used to model Ethiopian highland watersheds in previous studies. SWAT is selected as an important tool for the current study due to the following reasons:

1. It considers many components of the hydrologic balance like precipitation, surface runoff, infiltration, evapotranspiration, lateral flow from the soil profile, and return flow from shallow aquifers (Gassman et al., 2007).
2. It considers sediment yield, crop biomass, crop rotations, grassland/pasture systems, forest growth, planting, harvesting, tillage, nutrient applications, pesticide applications, biomass removal and manure deposition of grazing operations, continuous manure application options to confined animal feeding operations, conservation and water management practices, and pollutants transport (Gassman et al., 2007). These applications of SWAT can be used in the future once its hydrological application to the area is verified.

3. It has automated sensitivity, calibration, and uncertainty analysis components, data generator and Geographic Information System (GIS) interface (Gassman et al., 2007). The weather generator routine of SWAT considers the problem of missing data for the area.
4. It is physically based and can model ungauged watersheds that have no monitoring data and can quantify the impact of changes in management practices (Neitsch et al., 2011).
5. It is computationally effective and can simulate processes in very large basins or a variety of management strategies without excessive investment in time and money (Neitsch et al., 2011).

2.6.5 Comparisons of SWAT with other Models

Borah and Bera in 2003 and 2004 compared SWAT with the Dynamic Watershed Simulation Model (DWSM), and Hydrologic Simulation Program - Fortran (HSPF) model for their applicability for hydrology, sediment, and chemical routines at watershed-scale. In the 2003 study, they reported that SAWT is a promising model for continuous simulations in predominantly agricultural watersheds. In the 2004 study, they found that SWAT and HSPF could predict yearly flow volumes and pollutant losses adequately for monthly predictions except for months having extreme storm events and hydrologic conditions. In contrast, DWSM reasonably predicted flow hydrographs, sediment load and chemicals at small time intervals.

Van Liew et al., (2003) compared the stream flow predictions of SWAT and HSPF on eight nested agricultural watersheds within the Little Washita River basin in southwestern Oklahoma. They concluded that SWAT was more consistent than HSPF in estimating stream flow for different climatic conditions and may thus be better suited for investigating the long-term impacts of climate variability on surface water resources (Van Liew et al., 2003). According to Singh et al., (2005),the average daily flow, sediment loads, and nutrient loads simulated by SWAT were closer to measured values collected at five sites than HSPF during both the calibration and verification periods for the upper North Bosque River watershed in Texas. Singh et al., (2005) found that SWAT flow predictions were slightly better than corresponding HSPF estimates for the 5,568 km^2 Iroquois River watershed in eastern Illinois and western Indiana, primarily due to better simulation of low flows by SWAT.

CHAPTER THREE

3 Methodology and Materials

3.1 Study area

The Jedeb catchment is one of tributaries of the Upper Abay river basin and it is located in the northwestern highlands of Ethiopia, within 10°18'N to 10°39'N and 37°44'E to 37°53'E (Fig. 2.1). They originate from the Choke Mountains at an elevation of 4000 m a.s.l. and drain to the Abay/Blue Nile basin. It covers an area of 300 km^2. The climatic condition is generally moderate climate, with mean annual temperature of 14 °C and rainfall of 1300 mm considering Robugebeya, Amanuel and Debre Markos stations.

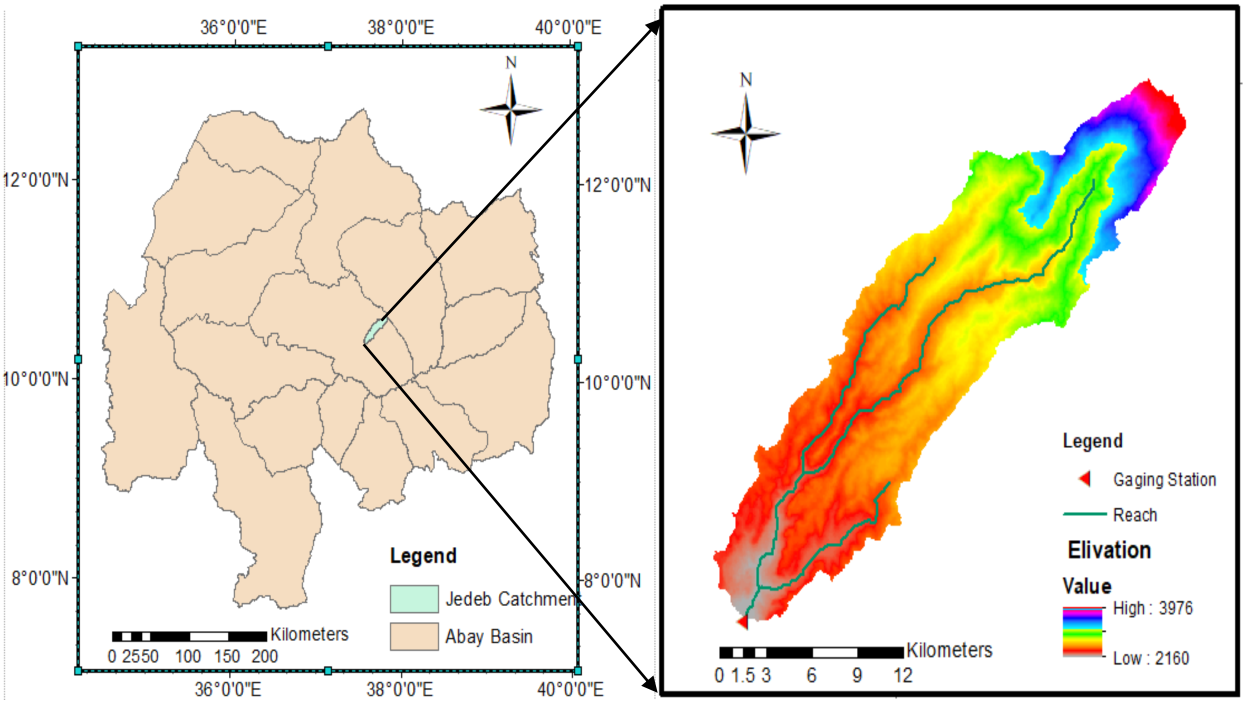

Figure 2.1. Location of the study area

3.2 Material

3.2.1 Hydro-Meteorological data

The stream flow dataset recorded at Yewla station is collected for the period 1980–2014 from the Ethiopian Ministry of Water Resources and Energy. The data recorded using manual water-level measurements daily at 06:00 and 18:00 hours. Daily climate data at the Debre Markos, Rob Gebeya and Amanuel stations were obtained from the Ethiopian National Meteorological Agency.

3.2.2 Land use land cover data

The land use land cover maps of Jedeb catchment for the year 2013 is collected from Ethiopian Geospatial Institution developed from Landsat satellite images. The LULC data represent the land use land cover feature of the study region for the period after the year of abrupt change in stream flow.

3.2.3 Soil data

The SWAT model requires soil data to determine the hydrological parameters of each soil category within each sub watershed (SW) and hydrological response unit (HRU). The input soil layers in the Arc SWAT model is extracted from the Food and Agriculture Organization (FAO) of the United Nations which archived at the Ministry of Irrigation, Water Resources and Energy.

3.2.4 Potential evapotranspiration

The FAO Penman-Monteith method is recommended as the sole ETo method for determining reference evapotranspiration. The method, its derivation, the required meteorological data and the corresponding definition of the reference surface. The daily PE (millimeters) is calculated using the Penman method modified. For this research, the preferred method to calculate reference evapotranspiration is the Penman-Monteith method (Equation 3.1) as presented in the United Nations Food and Agriculture Organization’s report FAO-56 (Allen et al., 1998). FAO-56 Penman-Monteith method (Allen et al., 1998):

$$\mathbf{ET}_{\mathbf{0}} = \frac{\mathbf{0.408} * \Delta * (\mathbf{R_a} - \mathbf{G}) + \boldsymbol{\gamma} * \left(\frac{\mathbf{900}}{\mathbf{Tmean + 273}}\right) * \mathbf{U}_{\mathbf{2}} * (\mathbf{e}_{\mathbf{s}} - \mathbf{e}_{\mathbf{a}})}{\Delta + \boldsymbol{\gamma} * (\mathbf{1} + \mathbf{0.34} * \mathbf{U}_{\mathbf{2}})} \qquad \text{… (Equation 3.1)}$$

Where; ET_0 is reference evapotranspiration rate (mm/day), R_a is net radiation at the crop surface ($MJ/m^2/day$), G is soil heat flux density ($MJ/m^2/day$), T_{mean} is daily air temperature at 2m height (^0C), U_2 is wind speed at 2m height (m/s), e_s is saturation vapor pressure (KPa), e_a is actual vapor pressure (KPa), $e_s - e_a$ is saturation vapor pressure deficit (KPa), Δ is slope vapor pressure curve ($KPa/^0C$), and γ is psychrometric constant ($KPa/^0C$).

3.2.5 Field observation

Field visit was held on during the dry season to observe direct human activities like direct abstraction of water for irrigation and to observe the land use land cover condition of the catchment.

Figure 3.1. Field visit, Dry season irrigation practice in the study region

Figure 3.2. Field visit, Jedeb river gauging site at Yewla station

3.3 Missing data Estimation

The continuity of a record may be broken with missing data due to many reasons such as damage or fault in a rain gauge during a period, recording error etc. The missing data can be estimated by using the data of the neighboring stations and with it station. If the total annual rainfall at any of them region gauges differs from the annual rainfall at the point of interest by more than 10%, the normal-ratio method is preferable (Woldesenbet, T.A et al 2016). Because this method is more advanced than station average method and simple, it used for filling missed rainfall data in this study. On the other hand, if the missing data is below 10% regression model have been used by creating a linear relationship between the data. In this study both Regression model and normal ratio method have been used to compute the missing data. Below equation is used to compute missing data by using normal ratio method.

$$Pt = \frac{1}{n}\sum_{i=1}^{n} Pi\frac{Nt}{Ni} \text{..............Equation 3.2}$$

Where *Pt* is the precipitation at the target station location, *Pi* is the precipitation at neighboring station, *Nt* is the average annual rain at target station, *Ni* is the average annual rain at neighboring stations, and *n* is the number of neighboring stations.

3.4 Data Quality Test

Before going to do any analysis, the data should be tested to assure the reliability of the data. Outlier and consistency tests are commonly used data quality test approaches.

3.4.1 Consistency test

The double mass curve is used to check the consistency of many kinds of hydrological data by comparing data for a single station with that of a pattern composed of the data from several other stations in the area. Double mass curve is a simple, visual and practical method, and it is widely used in the study of the consistency and long-term trend test of hydro meteorological data (Gao, et al, 2017). The theory of the double-mass curve is based on the fact that a plot of the two cumulative quantities during the same period exhibits a straight line so long as the proportionality between the two remains unchanged, and the slope of the line represents the proportionality. This method can smooth a time series and suppress random elements in the series, and thus show the main trends of the time series.

Some of the common causes for inconsistency of record include:

- Shifting of a rain gauge station to a new location,
- The neighborhood of the station undergoing a marked change.
- Personal/recorder errors.

3.4.2 Outlier test

The identification of outliers has been the primary emphasis of quality control work; outliers are observations very distant from the mean value that can be due to measurement errors or to extreme meteorological events in observed metrological data. When outliers are undoubtedly erroneous measurements those extreme data can be rejected and the problem is converted into one of missing data treatment. In one hand, extreme data carry very valuable climatological information that should not be dismissed, yet statistical parameters are highly affected by presence of outliers. An alternative that would combine keeping the information of extreme data and showing consideration for effects of outliers would be to censor outliers by means of replacing them by some threshold value that keeps the information of an extreme event and yet does not have such an important influence on non-resistant statistics. Outliers were identified as those values trespassing a maximum threshold for each time series defined by

$$P_{out} = q_{0.75}+3IQR\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{Equation 3.3}$$

Where $q_{0.75}$ is the third quartile and IQR the interquartile range. The IQR has been used in quality control of climate data (Eischeid et al. 1995) because it is resistant to outliers. Values over P_{out} were substituted by this limit. This way of proceeding reduces the bias caused by outliers and yet keeps the information of extreme events (Zhang et al., 2004).

3.5 Stream flow Trend Analysis

Stream flow data for the period 1980 to 2014 is used to analyze the trend on runoff. The data is obtained from Ministry of Irrigation, Water Resources and Energy. To understand the stream flow trend, the data is categorized annually and into three seasons such as dry seasons (October, November, December, January, February), small rainy season (March, April, May), Main rainy season (June, July, August, September). Modified Mann-Kendall trend analysis is applied for evaluation of trends in stream flow. The Mann-Kendall trend test is a nonparametric trend tests which assumes no distribution of the data. The null hypothesis of the test is that there is no trend in the data and the alternative hypothesis is that the data represents a monotonic trend.

Modified Mann-Kendall trend test by using “Modifiedmk” R package Test coded by Sandeep Kumar Patakamuri is nonparametric test which has been recommended as an excellent tool for trend detection. This R package is one of the most popular trend detection method used in the scientific society. It is useful for detection of statistically significant trend in variables like rainfall and stream flow. Statistically significant decreasing or increasing trends or none are extremely important parameters for watershed modeling, studying catchment characteristics and for water resources planning strategies in the long term for any region.

This R package trend test is selected because it is simple, robust, can cope with missing values, and the data need not conform to any particular distribution. This R package propose two hypothesis, the null hypothesis, Ho is the data has no trend and the alternative hypothesis H_1 is that the data follow a trend over time.

The"Modifiedmk" R package test with different function by Sandeep Kumar Patakamuri is commonly used and suitable to identify trends in hydrological data, as it is not affect by the distribution, outliers and missing values of time series data. Below equations are the algorism in this package.

$$S= \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} Sgn(X_j - X_i) \qquad \text{……. Equation 3.4}$$

Where x_j and x_i are the monthly values in month*' j and i , j >i ,* respectively and

$$\boldsymbol{Sgn(X_i - X_j)}=\begin{Bmatrix} \mathbf{1} \; \boldsymbol{if} \; \boldsymbol{x_j - x_i > 1} \\ \mathbf{0} \; \boldsymbol{if} \; \boldsymbol{x_j - x_i = 0} \\ \mathbf{-1} \; \boldsymbol{if} \; \boldsymbol{x_j - x_i < 0} \end{Bmatrix} \qquad \text{………….. Equation 3.5}$$

A positive value of S indicates an increasing trend while a negative value shows a decreasing trend.

$$Z=\begin{Bmatrix} \boldsymbol{(s-1)/(v(s)^{0.5} \; if \; s > 0} \\ \boldsymbol{0 \; if \; s = 0} \\ \boldsymbol{(s+1)/(v(s)^{0.5} \; if \; s < 0} \end{Bmatrix} \qquad \text{…………..........Equation 3.6}$$

$$V(s) =\frac{1}{18}[n(n-1)(2n+5) \qquad \text{………………… Equation 3.7}$$

H_0 will be rejected at the significance level of α when the absolute value of *Z* is bigger than $z_{(1-(\alpha/2))}$.

There are different function are existed in "modifiedmk" R package to perform trend for different criteria. Those are, bbsmk, bbssr, bcpw, mkttest, mmkh, mmky, pwmk, etc. from those Bias Corrected Prewhitening ("bcpw") function are used for the serially correlated data.

The “Modifiedmk” R package, accepts the null hypothesis if $-Z < Z_{cr} < Z$, where Z_{cr} is critical value of the normalized statistics Z at 5% confidence level (1.96). Positive and negative values of those parameters (z and s) indicate an “upward trend” and “downward trend”, respectively. Before going to trend analysis the data must be checked whether the data is serially correlated or not.

3.5.1 Autocorrelation test

In a time series data, if the observations at a given time is influenced by its previous observations, then the data is said to be serially correlated. Trend detection studies give erroneous results if the serial correlation issue is not addressed. Auto correlation in a data can be tested by using “acf()” function available in 'stats' package available with R. When serial correlation is detected in the data, it is suggested to use variance correction approach and apply modified versions of Mann Kendall test suggested by Hamed and Rao (1998) and Yue and Wang (2004). Before going to do trend by using “modifiedmk” package, the data has been checked for autocorrelation to eliminate the influence of serial correlation.

3.6 Quantification of the relative contribution to changes in stream flow

For a given watershed, both climate variability and human activities could impact the stream flow. In addition, the human influences can be further divided into two parts: direct water abstraction (i.e. the water abstracted for irrigation, industry, and domestic uses) and indirect impact (due to land use land cover change.). Therefore, the total changes in stream flow (ΔQ_{tot}) can be regarded as

$$\Delta Q_{total}=\Delta Q_C+\Delta Q_H \qquad \text{.......... Equation 3.8}$$

Where, ΔQ_{tot} is the total changes in observed stream flow; ΔQ_C, ΔQ_H are changes in stream flow due to climate variability and human activity, respectively.

Numerous methods have been utilized for separating the individual impact of climate variability and human activities on stream flow. These methods can be categorized as experimental approaches, hydrological modeling, conceptual approaches, and analytical approaches. The experimental approaches include time trend and paired catchment observations and analysis whereas hydrological modeling is used to simulate stream flow under natural and impact conditions. The conceptual approaches include applications of Budyko hypothesis (decomposition and sensitivity method) and Tomer-Schilling framework, analytical approach includes climate elasticity and hydrological sensitivity methods.

For a certain river basin, the following steps can be adopted to quantify the effects of climate variability and human activities. Firstly, the change points are determined by the standard statistical methods, e.g. Mann–Kendall (MK) trend test (Kendall 1975), and changing point can be determine by Pettit's test (Pettit 1979; Kiely et al. 1998), and the period before the change is regarded as a baseline period. Therefore the period that shows the impact of climate variability and human activities are separated from the baseline period. This is followed by application of methods that summarize the effect of climate variability. The remainder of the effect is then attributed to other factors such as human activities (Zhao et al. 2010). To detect the cause of stream flow change the following process was employed.

Firstly, understanding the monotonic stream flow trend of Jedeb River was undertaken by using of modified Mann-Kendall trend analysis which is coded in R programming as "modifiedmk" by Sandeep Kumar Patakamuri., (2018), in order to know whether the stream flow trend is increasing or decreasing. Then, the recorded data is separated in to two base period and changed year by using abrupt change detection method "Trend" R package coded by (Thorsten Pohlert.,2018). Base period data is a stream flow data ware not significantly changed by human activity and climate variability or the year before abrupt year. On the other hand, stream flow data after abrupt year is the data affected by both climate variability and human activity so this is called as changed period. The total change in stream flow is the difference between the stream flows after abrupt year (changed period) minus the base period. Analytical approach i.e. (hydrological sensitivity, climate elasticity) and modeling approach i.e. hydrological model was implemented to detect the cause of stream flow change.

After quantifying each factor (human activity and climatic variability), the dominant factors that responsible for alteration of stream flow will be selected.

The climate in these study has a distinct seasonality with three seasons: rainy season, June-September, October–February (dry season), and March– May (less dry season).

3.7 Analytical Approach

1 .**Climate elasticity method**

The climate elasticity method was applied to evaluate the impacts of climate variability on stream flow (ΔQ_C) based on the fact climate variability is the function of precipitation and potential evapotranspiration.

The concept of stream flow elasticity was first introduced by (Schaake et al., 1990) and modified by (Sankarasubramanian et al., 2001, Fu et al, 2007, Ma et al., 2010, Saidi et al., 2018, Dey et al., 2017)to evaluate the sensitivity of stream flow to climate change. It represents the proportional change in stream flow divided by the proportional change in a climatic variable (X), such as precipitation or potential evapotranspiration, and is expressed as

$$\varepsilon = \frac{\boldsymbol{\alpha Q/Q}}{\boldsymbol{\alpha x/x}} \text{.............. Equation 3.9}$$

As a result precipitation and potential evapotranspiration incorporate all climate parameter, precipitation elasticity and potential evapotranspiration elasticity of stream flow were defined by (Schaake et al.,1990) as

$$\varepsilon p\ (P,Q) = \frac{dQ/Q}{dP/P} \text{.......... Equation 3.10}$$

$$\varepsilon Eo\ (Eo,Q) = \frac{dQ/Q}{dEo/Eo} \text{.......... Equation 3.11}$$

Where, $\varepsilon(Q,P\ )$ the precipitation elasticity the stream flow. εEo (Eo,Q the potential evapotranspiration elasticity. P and Q were precipitation and stream flow, respectively.

So, the annual stream flow percentage change due to climate variability (dQ/Q)c

$$\left(\frac{dQ}{Q} \right)_C = \varepsilon p * \frac{dP}{p} + \frac{dEto}{Eto} * \varepsilon Eto \quad \text{.............Equation 3.12}$$

Where, dP/P is the annual precipitation percent of change; is equal to the ratio of change in precipitation between the two period and the mean precipitation before changing period. dEto/Eto is the annual potential evaporation present of change; is equals to the ratio of change in potential evapotranspiration between the two period and the mean evapotranspiration before changing period, εp is the precipitation elasticity of stream flow, εEto is the potential evapotranspiration elasticity of stream flow.

The estimator of the climate elasticity parameters is the product of the correlation coefficient and the ratio between coefficients of variations (Sankarasubramanian et al., 2001).

For example, the estimator of precipitation elasticity of stream flow is expressed as

$$\varepsilon_P = \rho_{Q,P} \left(\frac{CQ}{CP}\right) \text{........... Equation 3.13}$$

$$\varepsilon_{PE} = \rho_{Q,PE} \left(\frac{CQ}{CPE}\right) \text{............ Equation 3.14}$$

Where ρ_Q,P is the cross correlation coefficient of Q *and* P and ρ_Q,P is the cross correlation of Q and PE; C_Q is the coefficient of variation of Q; C_P is the coefficient of variation of P; CPE is the coefficient of variation of PE. After obtaining dQ/Q, the remaining is the stream flow change due to human activity.

Theoretically, the value ε_{PE} and ε_P in dicates that,10% increase or decreas erainfall and potential evapotranspiration, will increase or decrease the value of stream flow by 10 time (ε_P and ε_{PE}.)

3.7.1 Framework for climate elasticity

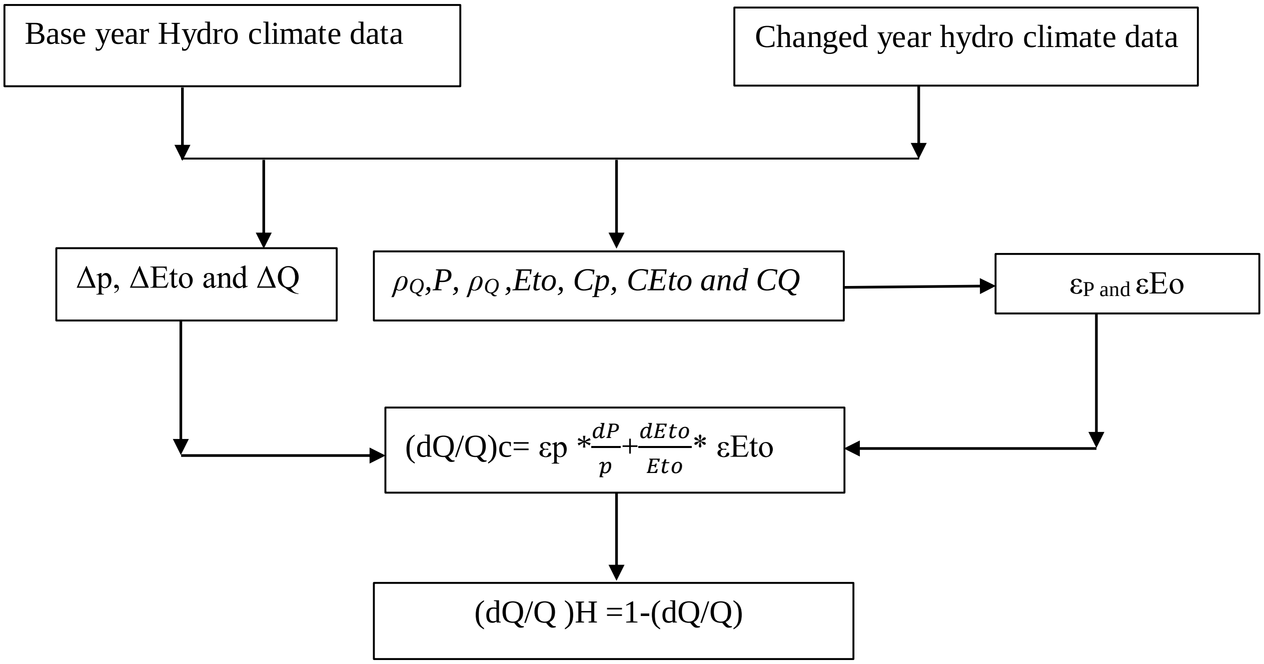

Figure 3.4. Conceptual frame work of climate elasticity

3.7.2 Hydrological Sensitivity Method

Currently, Hydrological sensitivity method is widely used to detect the cause of stream flow change (Saidi et al., 2018, Liang et al., 2013, Dey et al., 2017)

The hydrological sensitivity is described by (Wang et al., 2013) as the percentage change in the mean annual stream flow in response to a change in annual precipitation *P* and the potential evapo transpiration PE.

The sensitivity of stream flow to climate change is best understood using historical data. For a river basin, the composition of changes of mean annual stream flow between two periods can be estimated as:

$\Delta Q = \Delta Q_C + \Delta Q\mathrm{H}$………..Equation 3.15

Where, ΔQ_C is the changes in mean annual stream flow due to climatic variation; ΔQ_H is the Changes in mean annual stream flow due to human activities. The impact of human activities ΔQ_H

on the stream flow is the sum of the direct abstraction of water from catchment and the indirect impact such as land use/cover change.

The impact of climatic variation on the stream flow ΔQ_C can be approximately estimated as follows (Gue et al., 2014):

$$\Delta Q_C = \Delta Q_P + \Delta Q_{PE} = (\varepsilon_p * \Delta P + \varepsilon_{pe} * \Delta PE) \text{……………..Equation 3.16}$$

where ΔQ_P is the contribution of the change in P to the change in Q; ΔQ_{PE} is the contribution of the change in PE to the change in Q; ΔP is the changes in P between two periods; Δ_{PE} is the changes in PE between two periods; ε_P is the sensitivity coefficient of the stream flow to P; ε_{PE} is the sensitivity coefficient of the stream flow to PE; Hydrological sensitivity coefficients are expressed as follows (Dooge et al. 1999; Arora 2002):

$$\varepsilon_p = 1 + \frac{F'(\Phi)}{1 - F(\Phi)} \text{………… Equation 3.17}$$

$$\varepsilon_p + \varepsilon_{pe} = 1 \text{………… Equation 3.18}$$

Where $\Phi = \frac{PE}{P}$, is the aridity index; F is the function of ϕ; F' is the derivative of F with respect of ϕ.

F and *F* are calculated as (Zhang et al. 2001):

$$F(\Phi) = \frac{1 + w\Phi}{1 + w\Phi\frac{1}{\Phi}} \qquad \text{……… Equation 3.19}$$

$$F'(\Phi) = \frac{\Phi^{-2} + 2w\Phi^{-1} + w - 1}{1 + w\Phi + \frac{1}{\Phi}} \qquad \text{….. Equation 3.20}$$

Where, *w* is the plant available water coefficient related to vegetation type. According Tekleab et al., (2011), *w* varies between 0.5 and 2 for upper Abay river basin. They recommend that in Jedeb catchment w=1.5. For forests, the best-fit value is 2 whereas for pasture and crops it is 0.5.

Where, ET is the annual evapotranspiration (mm); P is the annual precipitation (mm) and $F(\phi)$ is the function mentioned above .

Theoretically, the value ε_{PE} and ε_P in dicates that,10% increase or decreas erainfall and potential evapotranspiration, will increase or decrease the value of stream flow by 10 time (ε_P and ε_{PE}.)

3.7.3 Frame work to do hydrological sensitivity

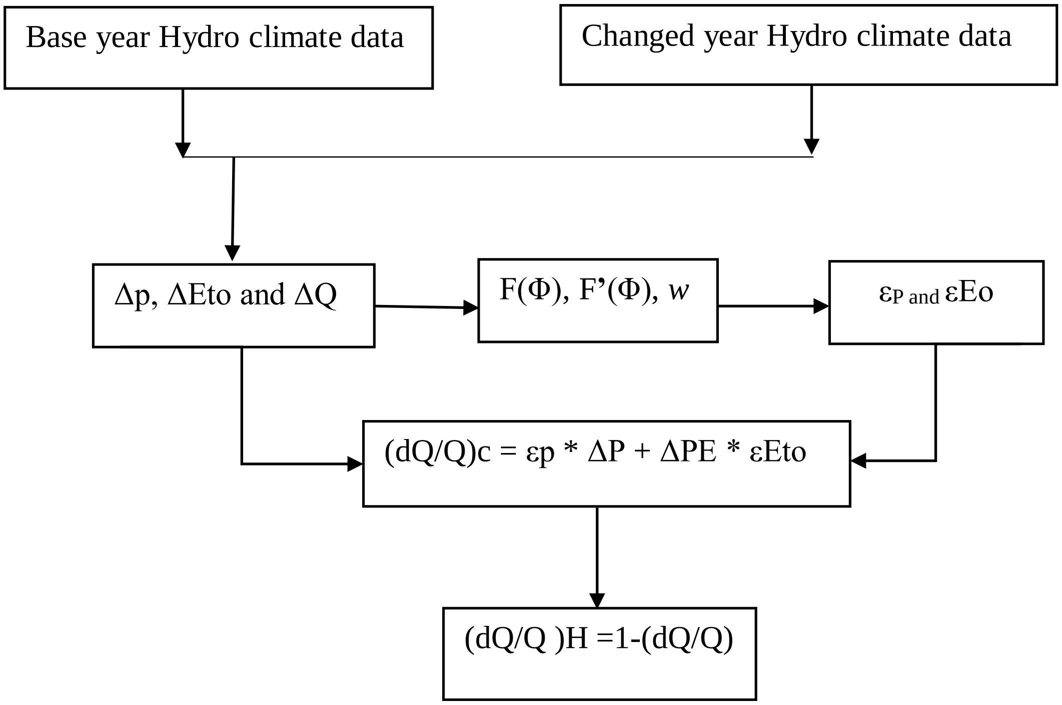

Figure 3.5. Conceptual frame work for hydrological sensitivity

3.8 Modeling Approach

3.8.1 Method of reconstruction of natural runoff

To evaluate the impacts of climate change/variability and human activities on runoff variation, the method of reconstructing natural runoff based on hydrological models is used. The relative contribution of climate change and land use and land cover dynamics on stream flow variation is quantified using method of reconstructing nature runoff. Hydrologic model is needed to link both climatic forcing and land cover impact on hydrological response (Guo et al., 2014).

Various methods has been applied to quantify the separate contributions of land use land cover change and climatic parameters to current stream flow change, with their own merits and drawbacks.

In this research SWAT hydrologic model was used in order to simulate current stream flow at catchment scale. Several physically based distributed parameter models SHE, HEC-HMS, HEC

2000, HBV and SWAT have been developed to predict runoff, erosion, sediment and nutrient transport from rural and agricultural watersheds (Yang et al., 2017) under various management regimes. Among these models, soil and water assessment tool (SWAT) is used successfully for simulating runoff, sediment yield and water quality of large basin (Mekonnen et al., 2017; Yang et al., 2016; Arnlod et al., 1998).

The hydrological model is first calibrated based on observed runoff in the changed period, and natural runoff during the pre-change period is reconstructed by changing only meteorological input without any change in the calibrated parameters and consideration of local human activities.

3.8.2 Description of SWAT Model

The SWAT model is a physically based continuous time, spatially distributed model designed to simulate water, sediment, nutrient and pesticide transport at a catchment scale on a daily time step. It uses hydrological response units (HRUs) that consist of specific land use, soil and slope characteristics. The HRUs are used to describe the spatial heterogeneity in terms of land cover, soil type and slope class within a watershed. The model estimates relevant hydrological components such as evapo-transpiration, surface runoff and peak rate of runoff, groundwater flow and sediment yield for each HRU. Arc SWAT ArcGIS extension is a graphical user interface for the SWAT model. The water balance equation is the base of the hydrologic cycle simulation in SWAT (Arnold et al., 2012):

$$SW_t=SW_O+\sum_{i=0}^{t}(R_{day}+Q_{surf}+E_a+W_{seep}-Q_{gw}) \quad \text{………………Equation 3.21}$$

Where SW_t is the final soil water content (mm), SW_0 is initial soil water content on day i (mm), t is the time (days), R_{day} is the amount of precipitation on day i (mm), Q_{surf} is the amount of surface runoff on day i (mm), E_a is the amount of evapotranspiration on day i (mm), w_{seep} is the amount of water entering the vadose zone from the soil profile on day i (mm), and Q_{gw} is the amount of return flow on day i (mm).

3.8.3 Surface Runoff Estimation

Surface runoff occurs when the rate of water application to the ground surface exceeds the rate of infiltration. To estimate surface runoff volume, two methods are available in the SWAT model. These are the SCS-curve number (SCS, 1972) and the Green and Ampt infiltration method (Green and Ampt, 1911). SCS- Curve number is used for this study as it uses daily rainfall rate as an input for runoff volume estimation (Equation 3.20). The SCS-curve number equation is given as:

$$\boldsymbol{Q_{surf}} = \frac{(\boldsymbol{R_{day}} - \boldsymbol{I_a})^2}{(\boldsymbol{R_{day}} - \boldsymbol{I_a} + \boldsymbol{S})} \qquad \text{……. Equation 3.22}$$

Where; Q_{surf} is accumulated runoff or rainfall excess (mm), R_{day} is the rainfall depth for the day (mm), I_a is the initial abstraction including surface storage, interception, and infiltration prior to runoff (mm), S is the retention parameter (mm).

The initial abstractions, I_a is commonly approximated as *0.2S* and Equation 3.20 becomes

$$\boldsymbol{Q_{surf}} = \frac{(\boldsymbol{R_{day}} - \mathbf{0.2}\,\boldsymbol{S})^2}{(\boldsymbol{R_{day}} - \mathbf{0.8}\,\boldsymbol{S})} \qquad \text{……. Equation 3.23}$$

Here, $Q_{surf} > 0$, whenever $R_{day} > 0.2S$.

SCS defines three antecedent moisture conditions: I-dry (wilting point), II-average moisture and III-wet (field capacity). The moisture condition I curve number is the lowest value the daily curve number can assume in dry conditions. The curve numbers for moisture conditions I and III are calculated with Equations 9 and 10, respectively.

$$CN_1 = CN_2 - \frac{20 * (100 - CN_2)}{(100 - CN_2 + \exp[2.533 - 0.0636 * (100 - CN_2)])}$$

$$\boldsymbol{CN_3} = \boldsymbol{CN_2} * \mathbf{exp}\,[\mathbf{0.00673}\,(\mathbf{100} - \boldsymbol{CN_2})] \qquad \text{.... Equation 3.24}$$

Where CN1 is the moisture condition I curve number, CN2 is the moisture condition II curve number, and CN3 is the moisture condition III curve number.

The retention parameter is defined by the equation

$$\boldsymbol{S} = \mathbf{25.4}\left[\frac{\mathbf{1000}}{\boldsymbol{CN}} - \mathbf{10}\right] \qquad \text{……………….Equation 3.25}$$

Where: *CN* is the SCS-curve number for the day. *SCS*-curve number is the function soil permeability, land use, and the antecedent soil water conditions and its value range from 0-100.

SWAT includes two methods for calculating the retention parameter; the first one is retention parameter varies with soil profile water content and the second method is the retention parameter varies with accumulated plant evapotranspiration. The soil moisture method (Equation 3.20) over-estimates runoff in shallow soils. But calculating daily CN as a function of plant evapotranspiration, the value is less dependent on soil storage and more dependents on antecedent climate. The runoff will only occur when Rday > 0.2S. The retention parameter varies with soil profile water content according to the following equation:

$$\boldsymbol{S = S_{max} * \left(1 - \frac{SW}{SW + \exp\ (w_1 - w_2 * SW)} \right)} \quad \text{…. Equation 3.26}$$

where S is the retention parameter for a given moisture content (mm), S_{max} is the maximum value the retention parameter can achieve on any given day (mm), SW is the soil water content of the entire profile excluding the amount of water held in the profile at wilting point (mm of water), and w1 and w2 are shaped coefficients.

The maximum retention parameter value, Smax, is calculated by solving Equation 13 using CN1.

$$\boldsymbol{S_{max} = 25.4 * \left(\frac{1000}{CN_1} - 10 \right)} \quad \text{…. Equation 3.27}$$

The daily curve number value adjusted for moisture content can be calculated by rearranging Equation 11 and inserting the retention parameter calculated for that moisture content:

$$\mathrm{CN} = \frac{25400}{(\mathrm{S} + 254)} \quad \text{……………….Equation 3.28}$$

3.8.4 Ground water flow

To simulate the groundwater, SWAT partitions groundwater into two aquifer systems: a shallow, unconfined aquifer which contributes return flow to streams within the watershed and a deep, confined aquifer which contributes return flow to streams outside the watershed (Arnold et al., 1993). In SWAT the water balance for a shallow aquifer is calculated with Equation 3.27.

$$\mathbf{aq_{sh,i} = aq_{sh,i-1} + W_{rchrg} - Q_{gw} - W_{revap} - W_{deep} - W_{pump,sh}} \cdots \text{ Equation 3.29}$$

Where, aqsh, i is the amount of water stored in the shallow aquifer on day i(mm), aqsh,i-1 is the amount of water stored in the shallow aquifer on day i-1(mm), Wrchrg is the amount of recharge entering the aquifer on day i (mm), Qgw is the groundwater flow or base flow, or return flow, into the main channel on day i (mm), Wrevap is the amount of water moving in to the soil zone in response to water deficiencies on day i (mm), Wdeep is the amount of water percolating from the shallow aquifer in to the deep aquifer on day i (mm), and Wpump, sh is the amount of water removed from the shallow aquifer by pumping on day I (mm).

3.8.1 Model Calibration and Validation

The SWAT-CUP is a computer program for the calibration of SWAT models. The program is linked to five different algorithms such as Sequential Uncertainty Fitting (SUF2), Particle Swarm Optimization, (POS), Generalized Likelihood Uncertainty Estimation (GLUE) (Beven and Binley, Parameter Solution (ParaSol), and Mark chain Monte Carlo (MCMC) procedures to SWAT. It enables to conduct sensitivity analysis, calibration, validation, and uncertainty analysis of SWAT models. SUFI-2 (sequential uncertainty fitting) can provide the widest marginal parameter uncertainty intervals of model parameters among the five approaches. After sensitivity analysis was carried out, the calibration of SWAT model is done automatically and manually. The calibration is carried out using the output of the sensitivity analysis of the model and by changing the more sensitive parameter at a time while keeping the remaining parameters constant.

3.8.1 Sensitivity Analysis

Explores how changes in parameter values affect the overall change in the output of the model. This can be done by using simple sensitivity analysis, where only one parameter is changed or more complex arrangements that explore the relationships between multiple parameters. The SWAT-CUP will used to select the sensitive parameter.

3.9 Model Performance Estimation

In order to assess the performance SWAT model stream flow simulation over the basin, the statistical indicators, categorical and graphical evaluation techniques were selected for this work to measure the goodness-fit of SWAT model simulations with the observed ones.

3.9.1 Statistical Indicators

3.9.1.1 The Nash-Sutcliffe model Efficiency (NSE)

Nash-Sutcliffe coefficient measures the efficiency of the model by relating the goodness-of-fit of the model to the variance of the measured data (Equation 30), Nash-Sutcliffe efficiencies can range from $-\infty$ to 1. An efficiency of 1 corresponds to a perfect match of simulated discharge to the observed data. An efficiency of 0 indicates that the model predictions are as accurate as of the mean of the observed data, whereas an efficiency less than zero ($-\infty < \text{NSE} < 0$) occurs when the observed mean is a better predictor than the model. Besides, due to the frequent use of this coefficient, it is known that when values between 0.6 and 0.8 are generated, the model performs reasonably. A value between 0.8 and 0.9 tells that the model performs well and a value between 0.9 and 1 indicates that the model performs extremely well (Nash and Sutcliffe, 1970). NSE (Nash and Sutcliffe, 1970), which is used to assess hydrological models' goodness-of-fit.

$$\boldsymbol{NSE} = \mathbf{1} - \left[\frac{\sum_{i=1}^{n} (\boldsymbol{Q}_{m} - \boldsymbol{Q}_{s})^{2}}{\sum_{i=1}^{n} (\boldsymbol{Q}_{m,i} - \bar{\boldsymbol{Q}}\boldsymbol{m})^{2}}\right] \quad \text{…… Equation 3.30}$$

Where; $Q_m$is the measured discharge, Q_s is the simulated discharge, and $\bar{Q}m$ is the average measured discharge.

3.9.1.2 The coefficient of determination (R^2)

R^2 describes the proportion of the variance in measured data by the model. It is the magnitude linear relationship between the observed and the simulated values. R^2 ranges from 0 (which indicates the model is poor) to 1 (which indicates the model is good), with higher values indicating less error variance, and typical values greater than 0.6 are considered acceptable .The R^2 coefficient is calculated using the following equation (Equation 31):

$$\boldsymbol{R}^{2} = \left[\frac{\sum (\boldsymbol{Si} - \boldsymbol{Sav})(\boldsymbol{Oi} - \boldsymbol{Oav})}{\sqrt{\sum (\boldsymbol{Si} - \boldsymbol{Sav})^{2}}\sqrt{\sum (\boldsymbol{Oi} - \boldsymbol{Oav})^{2}}}\right]^{2} \quad \text{… Equation 3.31}$$

Where, S_i – simulated value, S_{av} – average simulated value, O_i – observed value, and O_{av} – average observed value.

3.9.1.3 The percent of bias error (PBIAS)

PBIAS is used to estimate the model error as stated in Equation 3.30.It measures the average tendency of the simulated data to be larger or smaller than the observations. The optimum value is zero, where low magnitude values indicate better simulations. Positive values indicate model underestimation and negative values indicate model overestimation and given as;

$$\boldsymbol{PBIAS}\,(\%) = \frac{\sum_{i=1}^{n} (\boldsymbol{O}_{i} - \boldsymbol{S}_{i})}{\sum_{i=1}^{n} (\boldsymbol{O}_{i})} * \mathbf{100} \quad \text{…….Equation 3.32}$$

Where; $O_i$denotes the observed value at the month j, $S_i$is the simulated value

3.10 Procedure by Modeling Approach

In order to quantify the separate contribution of climate change and land use and land cover dynamics on stream flow variation, method of reconstructing nature runoff will be used(Zhang et al., 2012b)

1. The recorded stream flow data should be separated into base period and changed period using Pettit test. Pettit test detects the year of abrupt change when the stream flow change significantly from recorded stream flow data.
2. Total variation in runoff is the difference between the recorded stream flow data after changed period minus the base period. This variation comes due to climate variability or human activity.
3. Simulate stream flow for the changed period using calibrated and validated SWAT model. After that, stream flow is simulated for base year period, by only changing the climate parameter but with same calibrated parameter and land use land cover data to that of changed period. The difference between simulated stream flow of base year and simulated changed year the result is stream flow variation due to climate variability. The remaining from total change is due to human activity.

So percentage of stream flow change due to climate change is
(Change due to climate variability/total change) *100, the percentage of stream flow change due to human activity is (Change due to human activity/total change) *100.
Finally, we can distinguish the separate impact of human activity and climate variability on stream flow in Jedeb catchment. The above method is used widely in different scholars (Dagnenet F. Mekonnen, 2017, Wang et al. 2013, Zhang et al., 2012b).

Table 3.1. Data used for water balance swat model.

Data type	Data description	Scale	Data sources
Topographic map	Digital elevation map (DEM)	30m	SRTM
Land use map	Land use raster map & legends	30m	Ethio Geospatial Institute
Soil map	Soil raster map & soil properties	900m	HWSD v2

Meteorology/ Weather data	Rainfall, max & min temperature, relative humidity, wind speed, & sunshine hours.	Daily	National Meteorological Agency of Ethiopia
Hydrological data	Stream flow	Monthly	MIWRE

3.11 Framework in modeling approach

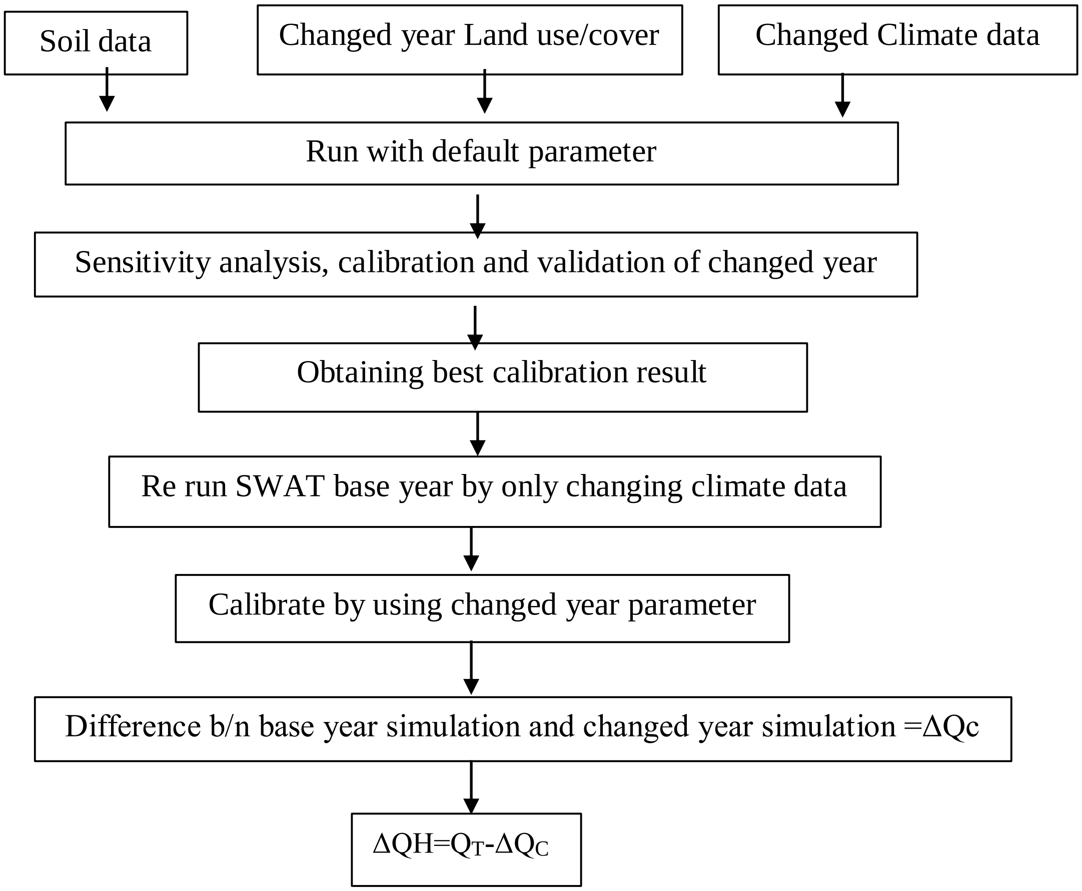

Figure 3.6. Conceptual frame work for hydrological model

3.11.1 Standard of Model Performance Evaluation

Comparing modelled and observed runoff time series since the main aim of a rainfall-runoff model is to simulate the runoff series on the basis of rainfall record. To evaluate the model simulation outputs relative to the observed data, model performance evaluation is necessary. There are various methods to evaluate the model performance during the calibration and validation periods. For this study, four methods were used (NSE, R2 and PBIAS).After manual and automatic calibration, the monthly stream flow was compared against the observed data.

Table 3.2. Model performance evaluation parameters

Statics	Very good	Good	Satisfactory(fair)	Unsatisfactory(poor)
R^2	$0.86<R^2<=1$	$0.75<R^2<=0.86$	$0.65<R^2<=0.75$	$R^2 <=0.65$
NSE	0.75<NSE<=1	0.65<NSE<=0.75	0.5<NSE<=0.65	NSE<=0.5
PBIAS	PBIAS<±10	±10<PBIAS<±15	±15<PBIAS<±25	PBIAS>±25

CHAPTER FOUR

4 Results and Discussions

4.1 Data quality Test

Before conducting any analysis the data should be tested to assure the reliability of the data. Outlier and consistency tests are widely used approaches for checking the data quality.

4.1.1 Consistency test

Double mass curve is used to check the consistency of annual rainfall station of Robu Gebeya, Debre Markos and Amanuel stations. The results are shown below.

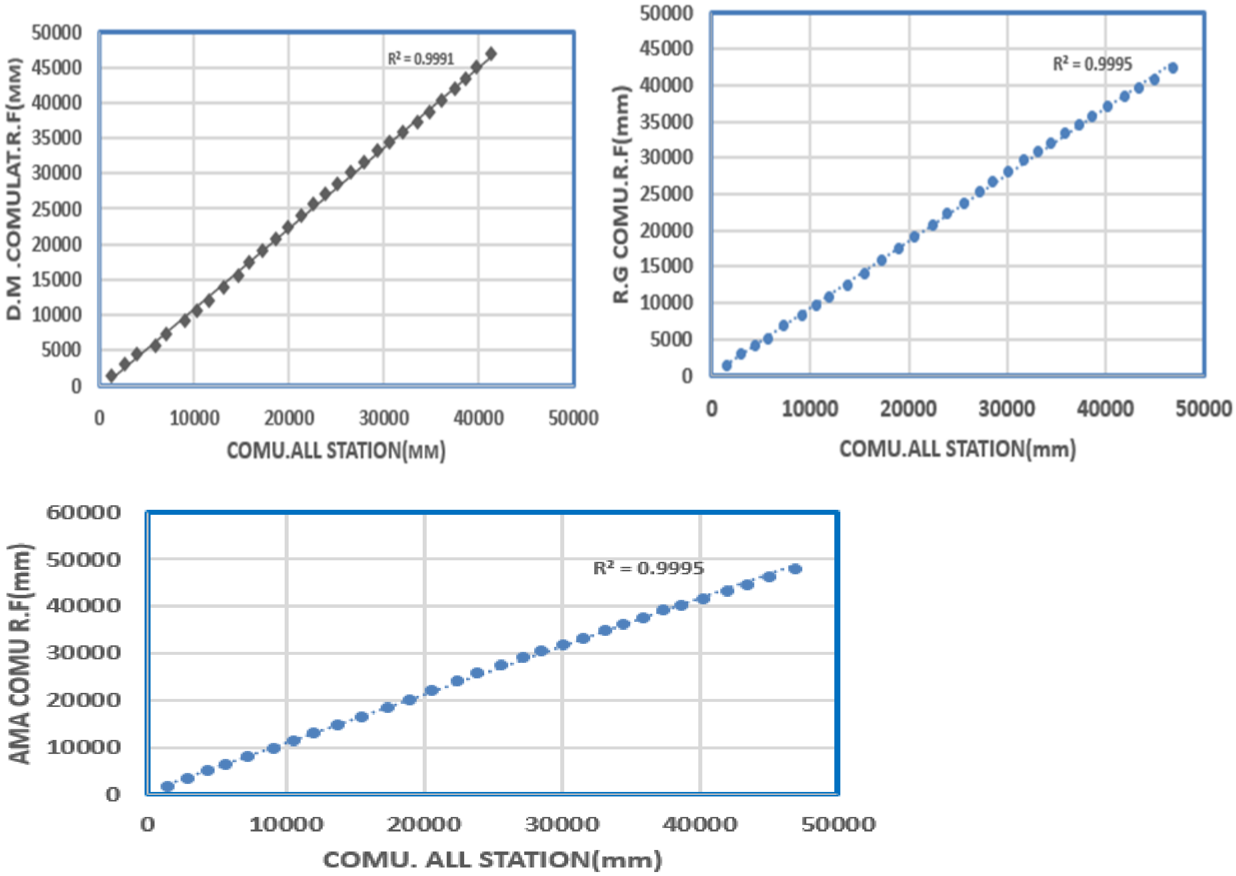

Figure 4.1. Consistency test using double mass curve. D.M stands for Debre Markos, AMA stands for Amanuel and R.G stands for Robu Gebeya stations.

From the result we observe that, the graphs shows straight line from the origin without changing its slope. So the data is consistent.

4.1.2 Outliers test

The identification of outliers has been the primary of quality control work; outliers are observations very distant from the mean value that can be due to measurement errors or recording error in observed hydro metrological data. In other words, an outlier is an observation that diverges from an overall pattern on a sample. In the current study, outlier test for climate data is undertaken in daily time scale. From below figure 4.2 the value above upper outlier line is the value deviate from is mean. So, it is out of the limit and fill by the maximum of the outlier.

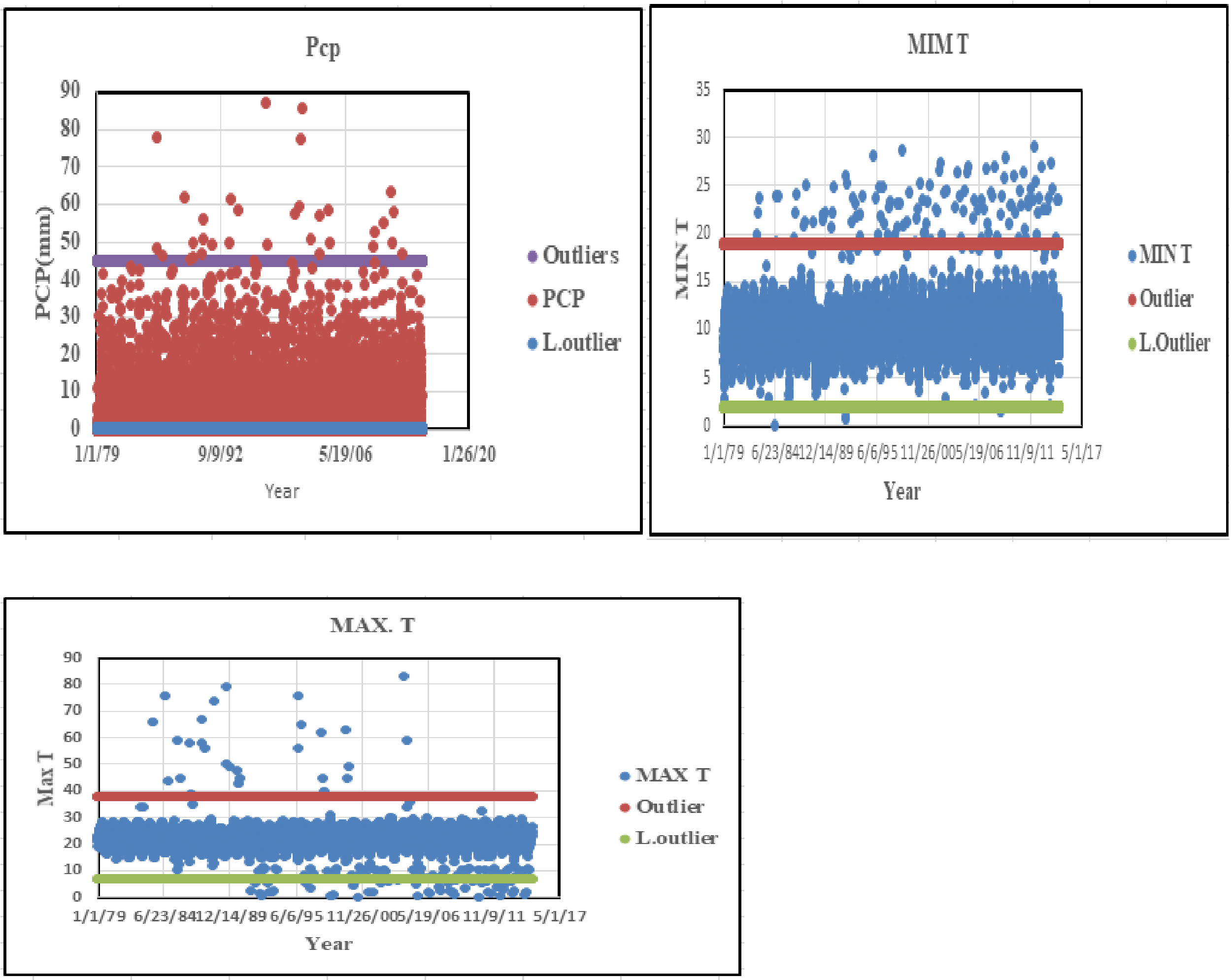

Figure 4.2. Outlier test of climate data

4.1.2.1 Stream flow outlier test

In Jedeb stream flow data, outlier test was undertaking monthly data time scale. From below figure 4.3 shows that the stream flow above upper outlier line is out of the limit and filed by the maximum of upper outlier value.

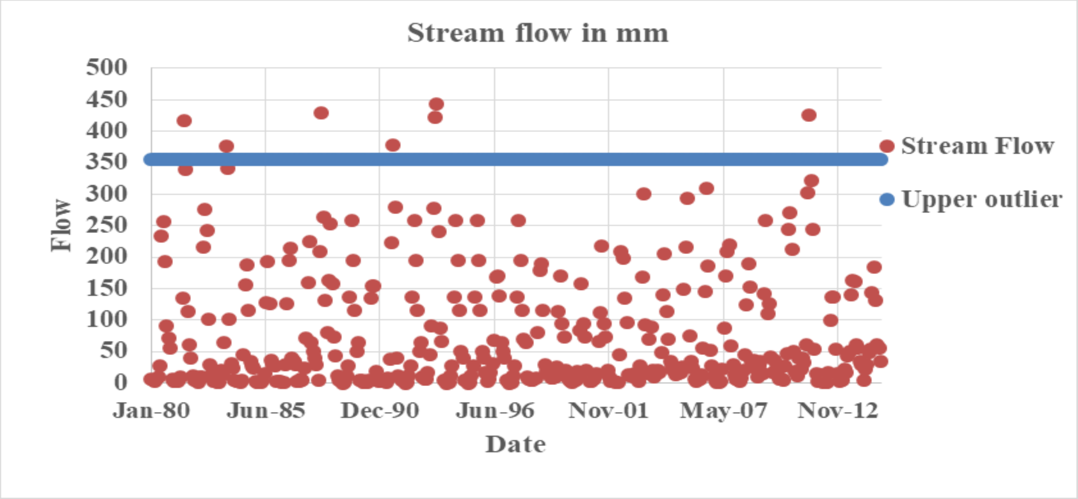

Figure 4.3. Outlier test of stream flow data

4.1 Jedeb Stream flow trend analysis

Data from 1980 to 2014 is used to analyze the seasonal and annual stream flow trend. To understand the stream flow trend, the data is classified in to 3 seasons, those are dry seasons (October, November, December, January, February), small rainy season (March April may), small rainy season (June, July, August, September). The trend analysis is conducted using modified Mann-Kendall trend analysis which is coded in R programming language as”modifiedmk” by Sandeep Kumar Patakamuri.

4.1.1 Auto-correlation test

In a time series data, if the observations at a given time is influenced by its previous observations, then the data is said to be serially correlated. Trend detection studies might give erroneous results if the serial correlation issue is not addressed. Auto correlation in a data can be tested by using “acf()” function available as 'stats' package in R programming language. When serial correlation is detected in the data, it is suggested to use variance correction approach and apply modified versions of Mann Kendall test suggested by Hamed and Rao (1998) and Yue and Wang (2004). For detail code for “modifiedmk” and “acf()” in R studio is existing in appendix 2.

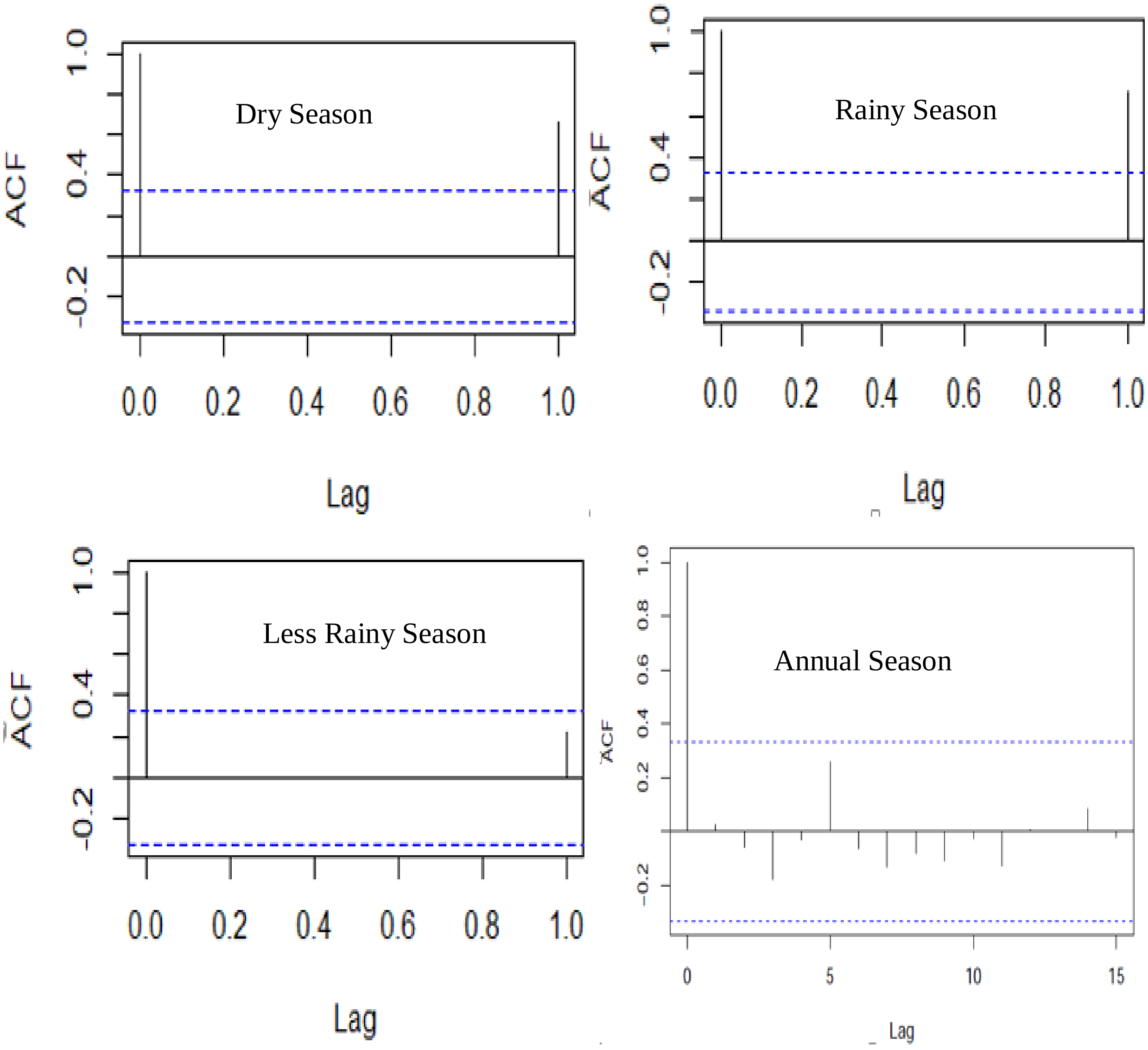

Figure 4.4. Auto correlation result for dry, rainy, less dry and annual seasons

As can be seen from the above result in dry season and rainy season, the data has serially correlated but in small rainy season and annual scale the data did not show serial correlation. So if the data is serially correlated data we have to do “prewitning” to eliminate the serially correlate effect. But “modifiedmk” R package has different package function that are useful for data’s that exhibit serially correlate or data’s has not exhibit serially correlate.

4.1.1.1 Annual season trend Analysis

The annual stream flow trend of Jedeb River is detected by "mkttest" (Mann-Kendall trend test of time series data without modifications) function due to the fact that the data is free from serial autocorrelation. The detail code description is existing appendix 4 and 3.

4.1.1.2 Dry season flow Trend Analysis

For dry season, the data show serially correlation. So, Hamed and Rao, (2009) approach is used to detect trends. It is implemented in R package as bias corrected prewhitening ("bcpw") function. The detail code description is existing appendix.

4.1.1.3 Small rainy season trend analysis

As small rainy season stream flow showed no significant serial autocorrelation, Mann-Kendall approach without modification is used. "Mkttest" R package is applied in order to analyze significant trend for small rainy season stream flow. The detail code description is existing appendix 3 and 4.

4.1.1.4 Rainy season rainfall

From autocorrelation result in main rainy season the data is serially correlated, as a result "prewitning" is needed before assessing the trend. Therefore, "bcpw" function is used to evaluate trend analysis. The detail code description is existing appendix 5 and 6.

Table 4.1.Stream flow trend for annual and seasonal time series

Trend parameters	Annual	Dry season	Small rainy season	Main rainy season
Z-Value	−1.02	−0.02	−1.62	−1.22
Sen's slope	−3.31	0.003	−0.11	4960.0
Var(S)	4956.33	5390.0	5390	−0.06
p-value	0.31	−2.94	0.105	0.146

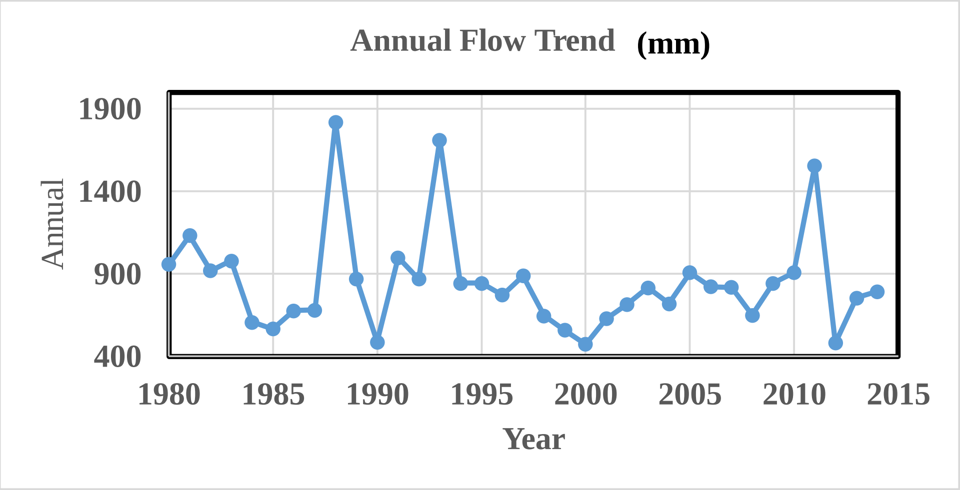

Figure 4.5. Annual stream flow trend

For the above result, for annual time series, the value of Z is -1.022, this value is less than 1.96 in significant limit of 5%, so in annual the stream flow Jedeb river shows slightly decreasing trend but not statistically significant.

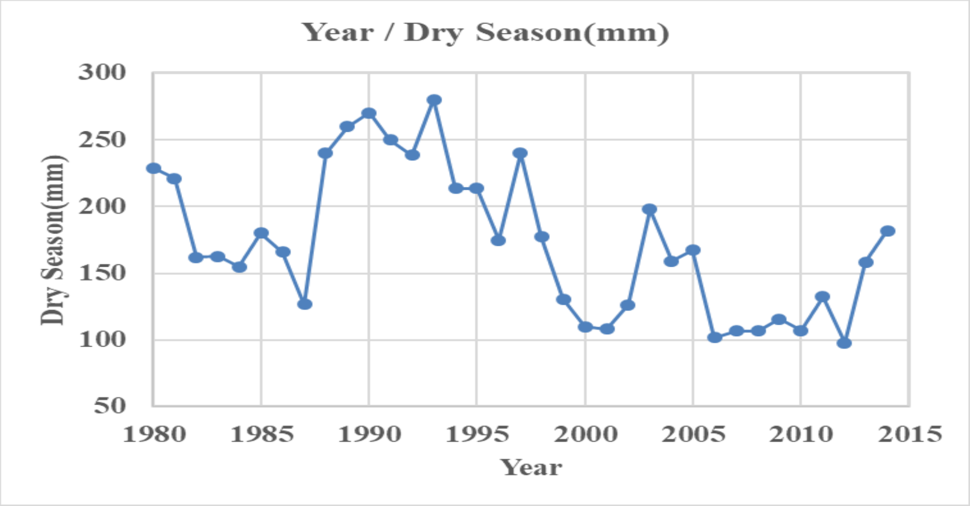

Figure 4.6.Dry season stream flow trend detection

For this dry season, the value of Z is -2.942, this value is greater than 1.96 in significant limit 5%, so, in dry season the stream flow shows significantly decreasing trend. The above dry season stream flow trend is executed in (mm) in order to similar the value with rainfall and potential evapotranspiration value. Below figure 4.7 is the stream flow in m3/s for demonstrate the value.

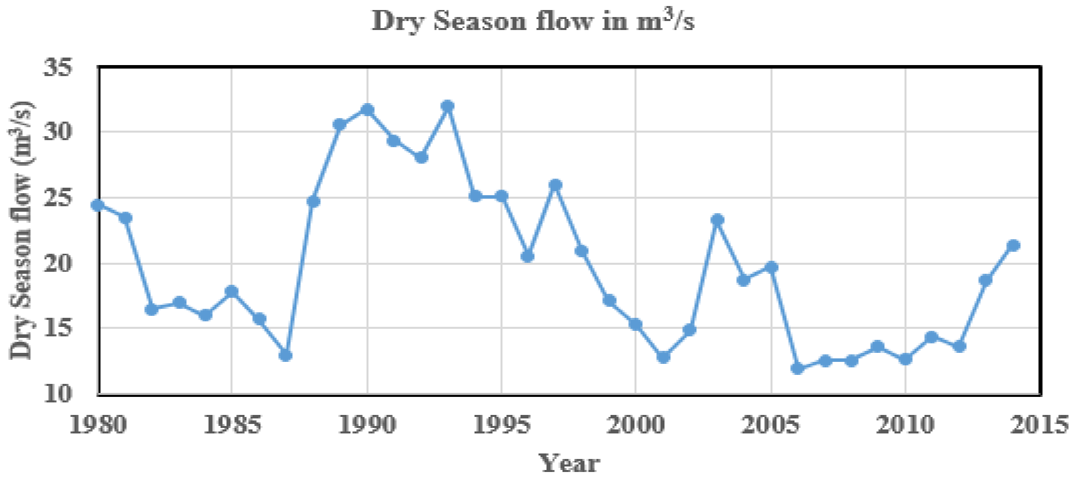

Figure 4.7.Dry season stream flow trend in m3/s

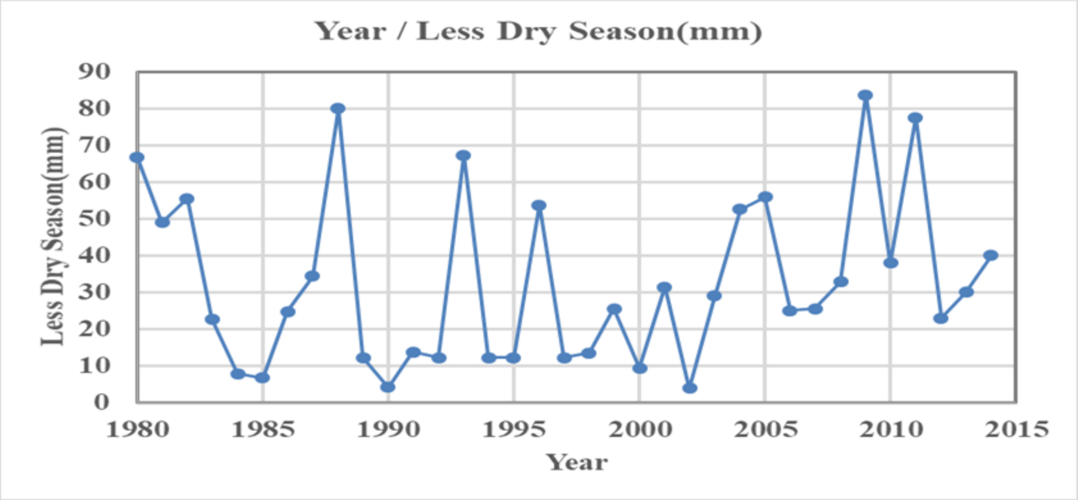

Figure 4.8. Less rainy season stream flow trend detection

So, from the above figure 4.8 result 4.8 Z= -1.62, indicates that the stream flow has decreasing trend in less dry season but not significantly.

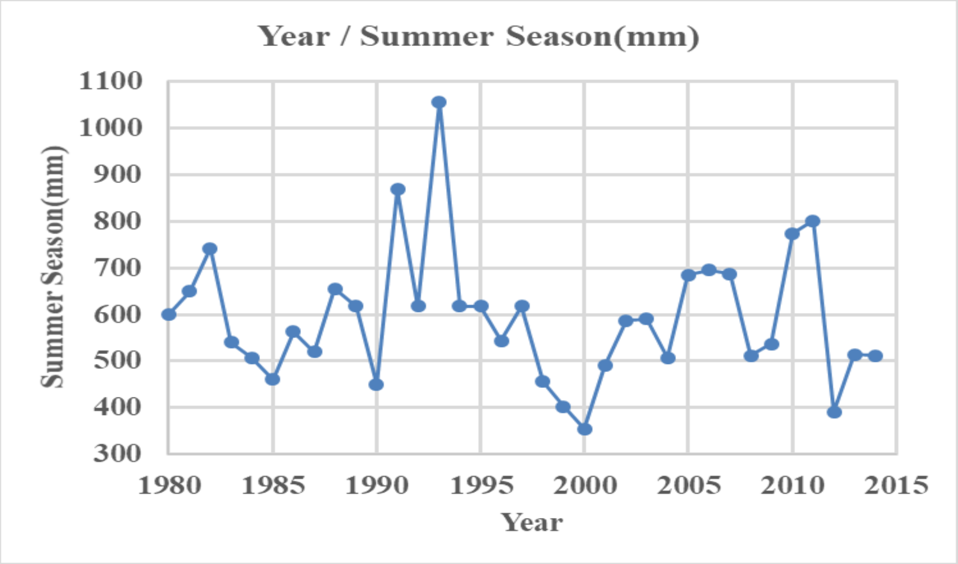

Figure 4.9. Summer season stream flow trend detection

From the above result figure 4.9 Z= -1.22, indicates that the stream flow has slightly decreasing trend in main rainy season but not statistically significant. To be statistically significant increasing trend the value of Z should be greater than 1.96.

Generally, from the above result in small rainy season and main rainy season the stream flow trend is slightly decreasing but not statistically significant, but in dry season, the stream flow showed significant decreasing trend. The reasons for the decline in stream flow is quantified in the subsequent sections.

4.2 Trend analysis for climatic parameters

Autocorrelation result of dry season rainfall and potential evapotranspiration are shown in Figure 4.10.

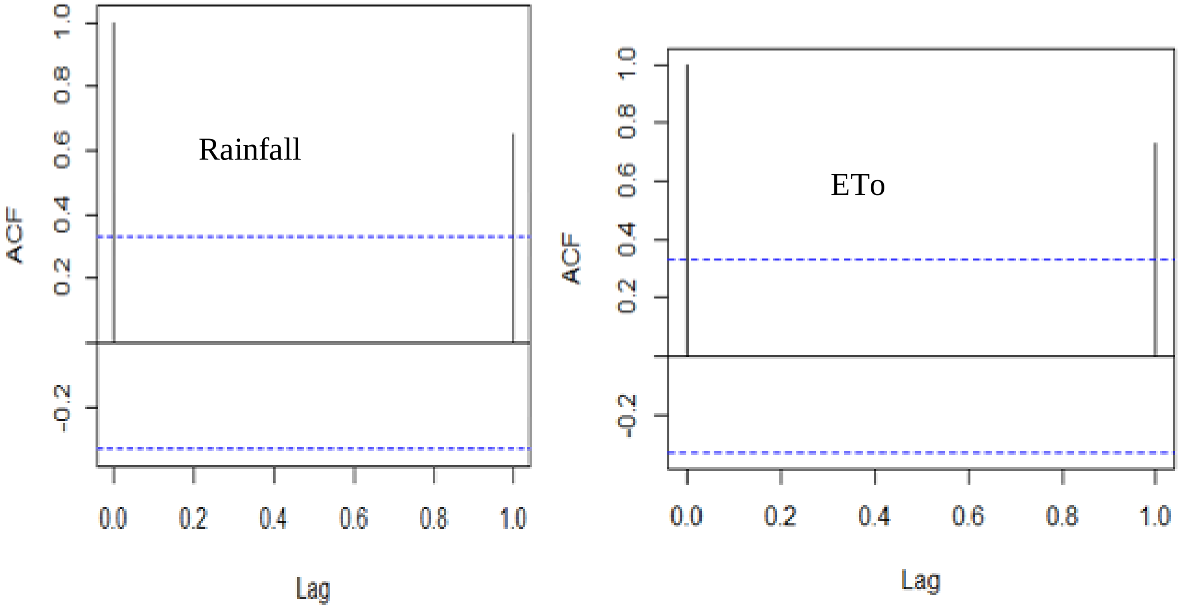

Figure 4.10. Autocorrelation result of dry season rainfall and potential evapotranspiration.

As we see from the above result the dry season rainfall and potential evapotranspiration showed serial autocorrelation so we use “bcpw” function to detect the trend.

4.2.1 Dry season rainfall trend

Table 4.5. Trend result of precipitation data

Z-Value	Sen's Slope	p-value	Var(S)
−0.208	−0.187	0.836	4550.3

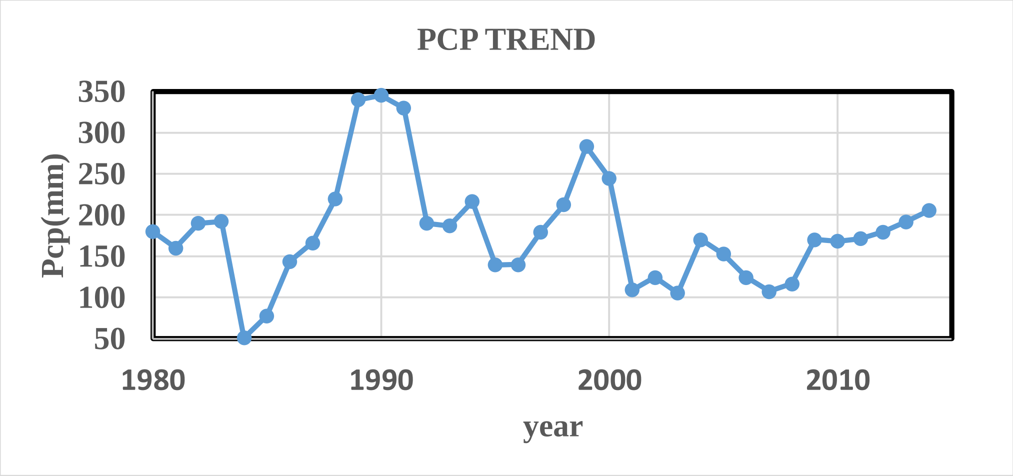

Figure 4.11. Dry Season rainfall trend

4.2.2 Potential Evapo transpiration trend for dry season

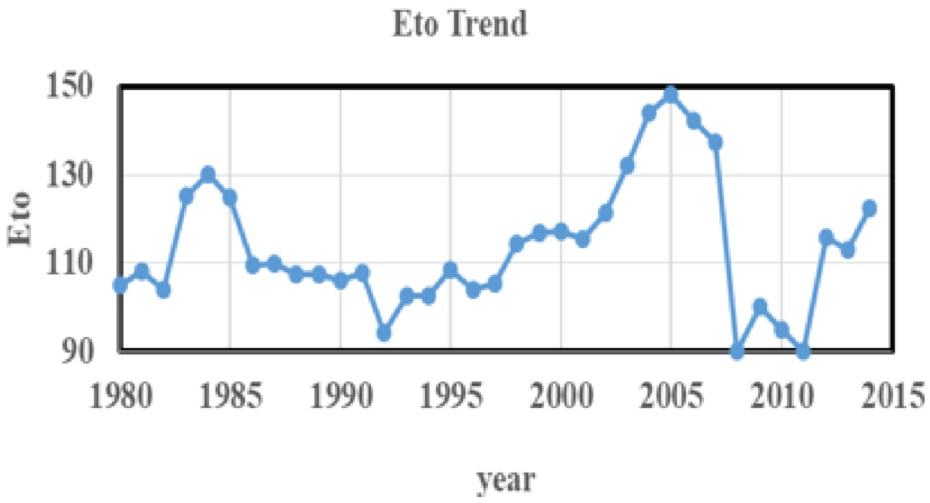

Figure 4.12. Dry season potential evapotranspiration trend

Table 4.6. Trend result for potential evapo transpiration

Z-Value	Sen's Slope	P-value	Var(S)
1.13	0.25	0.26	4550.3

4.3 Detecting the year of abrupt change

After detecting the stream flow trend, the next activity is to determine the year of abrupt change from the recorded time series; this means the year where the stream flow is abruptly changed. To analyze the individual impact of human interaction and climate change on stream flow with respect to natural or undisturbed condition, it is most important to identify the change points or periods of influences. It is the major challenging step to find out the change point (time) in hydrologic regime by using hydrological modeling and elasticity methods. In both approaches, the period before the point of inflection is assumed to have negligible impacts due to human activities and after inflection, both climate change and human activities cast a measurable influence in stream flow. "Trend" R package is used to detect the year of abrupt change by implementing Pettit test. Inside Trend package there is "pettitt.test" function is implemented to detect the change point.

4.3.1 Pettit's test for change-point detection

The H_0 hypothesis using Pettit test is no change in the mean of the time series while Ha is an alternative hypothesis that the mean of the data showed change.

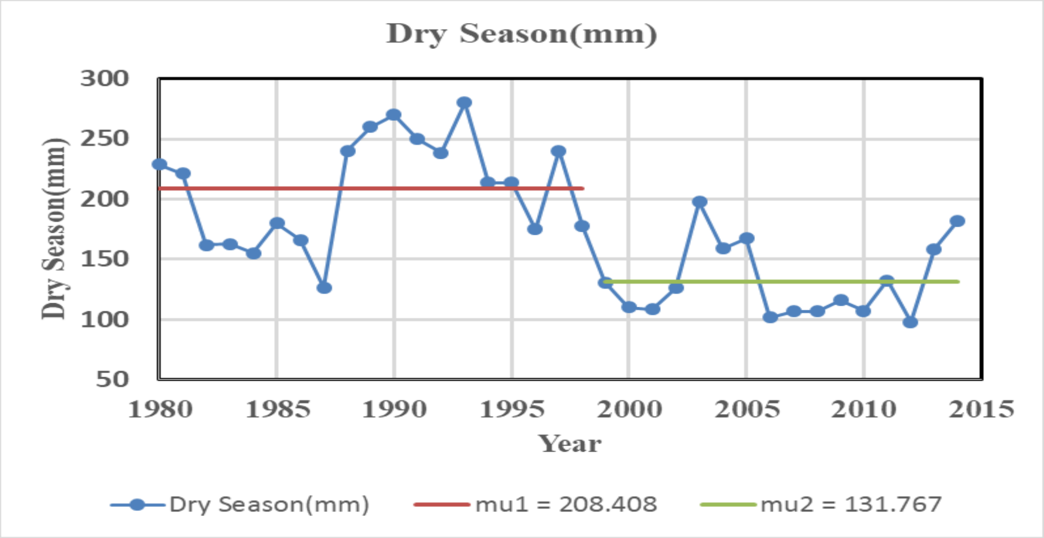

Figure 4.13. Year of abrupt change for dry season stream flow.

The above change point detection for dry season flow is executed in mm unit, below figure 4.14 shows, to demonstrate the change point detection when the flow value in m3/s unit.

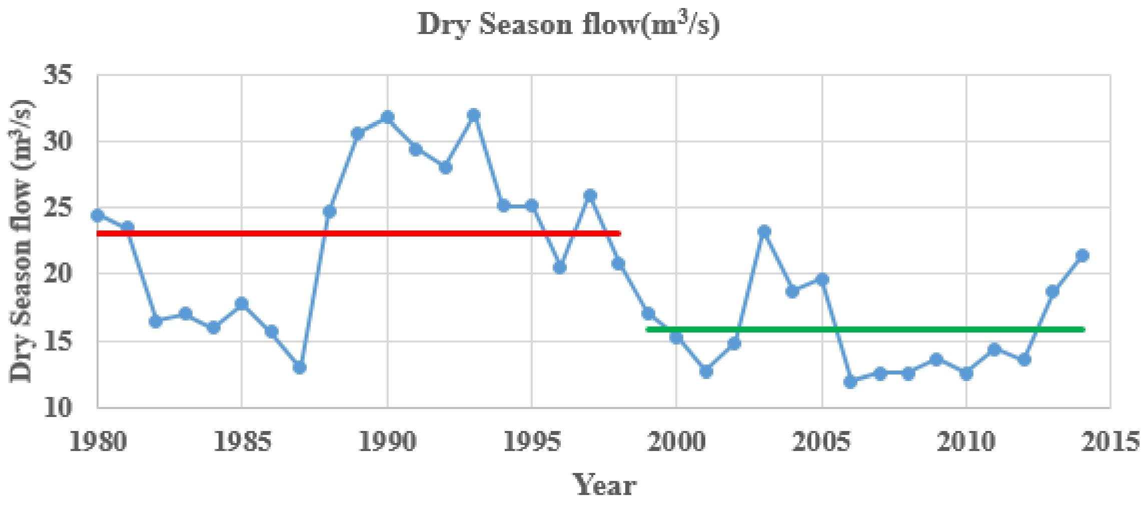

Figure 4.14 dry season stream flow abrupt change detection

As the computed *p*-value is lower than the significance level alpha=0.05, one should reject the null hypothesis H_0, and accept the alternative hypothesis Ha. The year of abrupt change for dry season stream flow is at 1998 (see Fig. 4.13). So, from this the stream flow data is divided in to two period for dry season.

- Base year from (1980-1997)
- Changed year from (1998-2014)

This means the flow data from 1980 -1997 in dry season has no deviate from the mean as a result this period said to be base year period. On the other hand the flow data from 1998-2014 in dry season the flow mean deviate from mean of base year (1980-1997) so this period is changed period as we can see figure 4.12.

Generally

- The average dry season stream flow of base year(1980-1997) is 191.811mm
- The average dry season stream flow of changed year(1998-2014) is 136.968 mm

So the total change in Q(mm) is:

$$\Delta Q_t = Q_{\text{base year}} - Q_{\text{changed year}}$$

$$\Delta Q_t = 191.811 - 136.96$$

$$\Delta Q_t = 54.84\text{mm}$$

So, this 54.84mm variation of stream flow in dry season is obtain from the result of human activity and climate variablity.so, those two factors should be quantify separately in order to detect the dominant factor for decreasing of Jedeb stream flow in dry season. So, to do this we use three different methods (climate Elasticity, Hydrological sensitivity and Hydrological model).

4.4 Areal rainfall determination

.A rain gauge station represents a rainfall at a single location. This point rainfall should be converted to aerial precipitation, the depth of rainfall considering the enclosed area is important in hydrological analyses and it is one of very important parameter in hydrology. Computation of average areal rainfall is done by Theissen polygon method. Rainfall varies in intensity and duration horizontally from place to place, hence the rainfall recorded by each metrological station should be weighted according to the area assumed to represent. Below equation is used to estimate areal rainfall.

$$\hat{\boldsymbol{P}} = \sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \left(\frac{\boldsymbol{A_i\ P_i}}{\boldsymbol{A_i}} \right)$$

in which $\hat{P}$ is the average areal rainfall, Pi is the rainfall measured at station i, n the number of rain gages, and Ai is the area at station i. The mean $\hat{P}$ has the same units as the Pi.

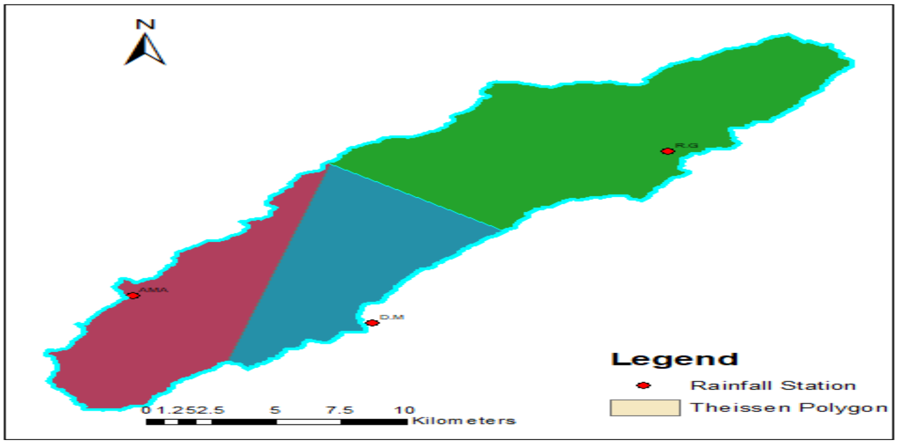

Figure 4.13 Thiessen polygon created for areal precipitation estimation

4.5 Detecting and quantifying the cause of stream flow change

According to the change point analysis of the “pettitt. test” function in R studio, the study period was split into two sub periods: the first sub-period (1980–1997) (i.e. ‘‘base year’’ or natural period), the second sub-period (1998–2014) changed year. Observed runoff during the natural period is taken as benchmark value, the difference between observed base period and observed runoff in the post-change period was assumed to the result of both climate variability and human activities (Wang et al., 2008; Ma et al., 2009; Liu et al., 2010). There are different methods used to detect and quantify the cause of stream flow change from those:

4.5.1 Climate Elasticity

By using of general equation 3.12, the effect of individual impact can easily quantify: the stream flow was changed in to mm from m3/s.

Table 4.7. Observed Jedeb hydro climate data of the two period.

Period	Q (mm)	P (mm)	ETo (mm)
Total period 1980-2014	165.17	179.64	112.31
Base year 1980-1997	191.81	191.61	108.99
Changed year 1998-2014	136.96	166.97	115.82
Difference (mm)	54.84	24.64	−6.82
Difference (%)	28.59	12.8	6.26

Correlation Coefficient (Q and P) = 0.72, Correlation Coefficient (Q and ETo) = −0.7, Coefficient of variance of dry season flow is 0.311, Coefficient of variance of precipitation 0.417, Coefficient of variance evapotranspiration 0.082.

So, the precipitation elasticity and potential evapotranspiration elasticity can calculated

$\varepsilon_P = \rho_{Q,P} \left(\frac{CQ}{CP}\right)$

=0.72*(0.311/0.417)

= 0.581= this mean 10% increase/decrease precipitation will increase/decrease 5.81 % decrease/increase stream flow.

$\varepsilon_{PE} = \rho_{Q,PE}\,(\frac{CQ}{CPE}) =$

=-0.7*(0.311/0.082)

−2.66= this mean 10% increase/decrease ETo will increase/decrease 26.68 % decrease/increase stream flow.

By using general equation:

$$(\frac{dQ}{Q})_C = \varepsilon p * \frac{dP}{p} + \frac{dEto}{Eto} * \varepsilon Eto$$

$$(\frac{dQ}{Q})_C = 0.581*(\frac{24.64}{191.6} + \frac{-6.826}{108.99} * -2.66)$$

$$= 0.24 = 24\%$$

This means by using climate elasticity method, the climate variability is contributing 24% for the decline in dry season stream flow. The remaining 76% is attributed to human activity. From the observed stream flow data between the two periods, 54.84 mm of stream flow variation occurs due to climate variability and human activity. By multiplying the total change in stream flow with the relative percentage obtained by climate elasticity, the amount of decline in stream flow is obtained As a result, 13.16 mm is attributed to climate variability and 41.67 mm attributed to that of human activity.

4.5.2 Hydrological sensitivity method

From general equation 3.16,

Table 4.8. Observed data of Jedeb river stream flow from two period

ΔP (between two period)	ΔEto (between two period)	Pave (for base period)	Eto ave (for base period)
24.64	-6.826	180.5	112.3

$$\varepsilon_p = 1 + \frac{F'(\Phi)}{1 - F(\Phi)}$$

$$\varepsilon_p + \varepsilon_{pe} = 1$$

Where $\phi = \frac{PE}{p}$, is the aridity index; $F(\phi)$ is the function of ϕ; $F'(\phi)$ is the derivative of F with respect of ϕ.

F(Φ) and ***F'** (Φ)* are calculated as :

$$\mathrm{F}(\phi) = \frac{1+w\Phi}{1+w\Phi\frac{1}{\Phi}} = \text{ After substituting the above value,}$$

$$\mathrm{F}(\phi) = 0.546$$

$$\mathrm{F}'(\phi) = \frac{\Phi^{-2}+2w\Phi^{-1}+w-1}{1+w\Phi+\frac{1}{\Phi}} = \text{after substituting the above value}$$

$$\mathrm{F}'(\phi) = 0.63$$

Where, *w* is the plant available water coefficient related to vegetation type. According (Tekleab., 2011) for Jedeb catchment w=1.5.

So, by using the above relationship

$\varepsilon p=1+(0.63/(1-0.546)$

=1.864. This mean 10% increase/decrease precipitation will increase/decrease 18.64 % decrease/increase stream flow

$\varepsilon_{Eto}=1-1.864$

= -0.864. This mean 10% increase/decrease potential Eto will increase/decrease 8.64 % decrease/increase stream flow

So, the contribution of climate variability on stream flow decreasing is

$$\Delta Q_{C} = \Delta Q_{P} + \Delta Q_{PE} = (\varepsilon_{p}*\Delta P+\varepsilon_{pe}*\Delta PE)$$

$$\Delta Q_{C} = (1.864*24.6)+(-0.86 * -6.82)$$

$$=27\%$$

This means by using hydrological sensitivity method, the climate variability is contributing 27% for the decline in dry season stream flow. The remaining 73% is contributed due to human activity. From the observed stream data between the two periods, 54.84 mm of stream flow variation occurs due to climate variability and human activity. Based on hydrological sensitivity method, 14.8 mm of stream flow is decreased due to climate variability and 40 mm of stream flow is decreased due to human activity.

4.6 Modeling Approach

4.6.1 Method of reconstruction of natural runoff

Arc SWAT 2012 was used to simulate the recorded stream flow of changed period (1998 to 2014) and again to reconstruct the stream flow by using of base year climate data to distinguish the effect of climate parameter for stream flow change.

4.6.2 Model Setup

The SWAT model was set up on the basis of the available geospatial data (DEM, land use, and soil maps) and hydro-metrological data.

4.6.3 Projection

All spatial datasets were projected to the same spatial references, for this study UTM 37 North and WGS84 datum (WGS_1984_UTM_37N). Projections were done using ArcGIS 10.5`s raster and vector standard world project tool. ArcSWAT requires all data to be in the same projection before any GIS processing can take place. The UTM (Universal Transverse Mercator) projection was chosen as it is widely used in the world.

4.6.4 Basin and Sub basin Delineation

The first step in creating SWAT model input is a delineation of the basin from a DEM. The ArcSWAT model provides three spatial levels: the basin, the sub-basins, and the hydrologic response units (HRUs). Each level was characterized by a parameter set and input data.

The ArcSWAT proposes the minimum, maximum, and suggested size of the sub basin area in hectares to define the minimum drainage area. Generally, the smaller the threshold area, the more detailed the drainage networks and a number of sub basins and HRUs. In addition, more processing times and spaces are needed. The stream definition and the size of sub-basins were carefully determined by selecting an appropriate threshold area required to form the origin of the streams.

As a result, there are 11 sub basins and 154 HRU of the Jedeb catchment having a total area of 300.52Km^2.

4.6.4.1 Slope and DEM

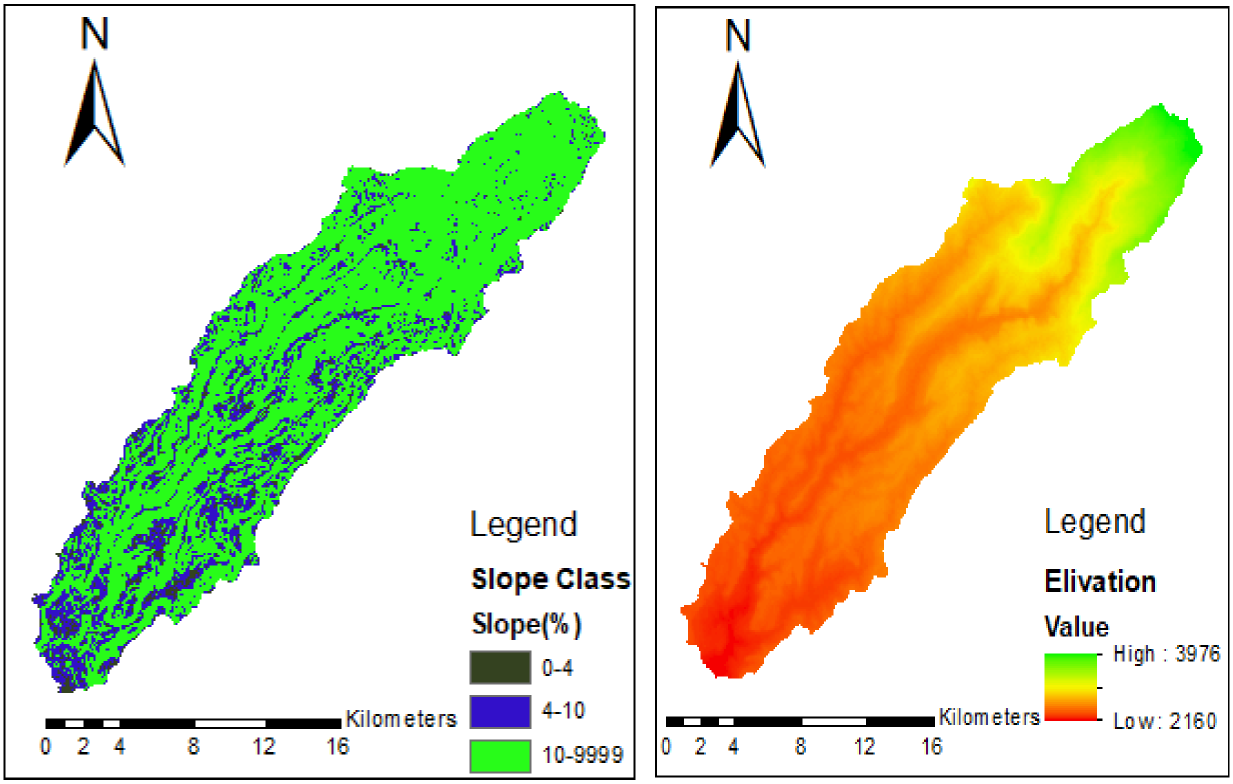

Figure 4.14. Slope and elevation of Jedeb catchment

4.6.4.2 Soil map and LULC

The soil types in these catchments are Haplic Nitisols, which are a deep soil with silty-clay texture; Haplic Luvisols, well-drained soil with clay to silty clay texture; and Eutric vertisols (moderately deep soil), with clay loam to clay texture. According to 2013 LULC map from Ethiopian Geospatial Institute, the land use land cover of the study area consist of forest, agricultural land, wet land, bare land, shrub land and grassland.

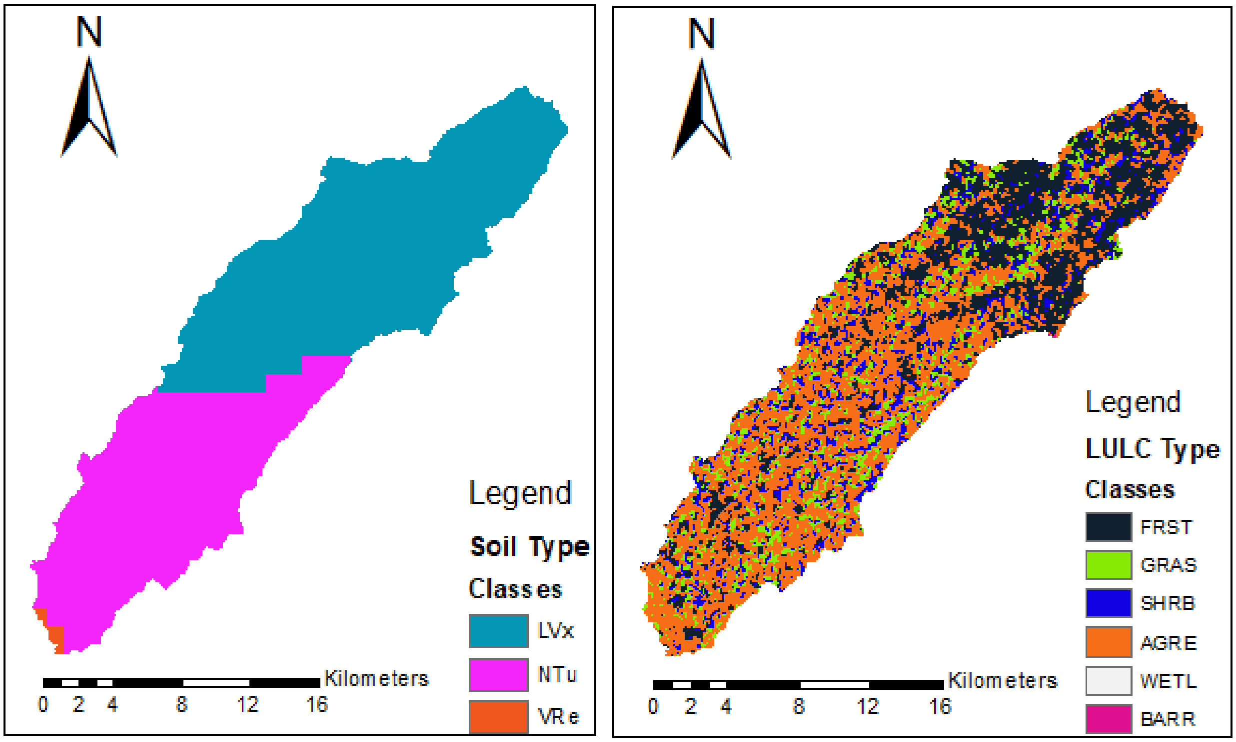

Figure 4.15. Soil and LULC class of Jedeb catchment. *(FRST=Forest,GRAS=Grasland,SHRB=shireb land,AGRE=Agricultural land,,WETL=Wetlad,,BARR=Barl land),(Lvx= Haplic Luvisols,Ntu= Haplic Nitisols,VRe= Eutric vertisols)*

4.7 Sensitivity Analysis, calibration and validation

4.7.1 Sensitivity analysis

After simulating the stream flow for changed period using SWAT model, sensitivity analysis is performed using 26 SWAT-CUP parameters. Global Sensitivity Analysis (GSA) is used to carry out a sensitivity analysis of the parameters chosen for the calibration process. In this process, multiple regression system regresses Latin hypercube generated parameters against objective function to determine the sensitivity of the parameters. As statistical measurements, t-stat and p-value were used.

A ranking of the “most sensitive” parameters, determined by means of an LH-OAT analysis is given in Table below 4.9. Parameter ranked as 1 is considered as very highly sensitive and ranked as 26 is highly sensitive. Table 4.9 shows that the parameters representing the soil properties, management, surface runoff, groundwater, and evaporation are more sensitive than others, and accurate estimation of these parameters is important for stream flow simulation with the SWAT model in the watershed.

The ranking of the parameters from different SWAT CUP parameters are, Effective channel hydraulic conductivity (mm/hr) CH-K2.rte, curve number (CN2), ground water delay(days) GW_DELAY.gw), the Saturated hydraulic conductivity (Sol_K), was top three very high sensitivity parameters for all products. This is due to the fact that the curve number depends on several factors including soil types, soil textures, soil permeability, land use properties, etc. table below shows that calibration parameters existing in swat cap.

Table 4.9. SWAT CUP calibration parameters with default value

Parameters	**Name**	**min**	**max**
r__CN2.mgt	SCS runoff curve number	-0.25	0.25
v__ALPHA_BF.gw	Base flow alpha factor (days)	0	1
v__GWQMN.gw	Threshold depth for ground water flow occur (mm)	0	5000
v__CH_N2.rte	Manning’s “n” value for main channel	0	0.3
v__GW_REVAP.gw	Ground water ‘revap’ coefficient	0.02	0.2
r__BIOMIX.mgt	Biological mixing efficiency	0	1
v__SURLAG.bsn	Surface runoff lag coefficient (days)	0	24
v__EPCO.hru	Plant uptake compensation factor	0	1
v__ALPHA_BNK.rte	Baseflow alpha factor for bank storage	0	1
r__SOL_CBN().sol	Organic carbon content	-0.25	0.25
v__GWHT.gw	Initial groundwater height (m)	0	25
r__SOL_K().sol	Saturated hydraulic conductivity	-0.25	0.25
v__SHALLST.gw	Initial depth of water in the shallow aquifer (mm)	0	5
r__SOL_AWC().sol	Available water capacity of the soil layer (mm H2O/mm soil)	-0.25	0.25
v__CH_K2.rte	Effective channel hydraulic conductivity (mm/hr)	-0.01	500
r__HRU_SLP.hru	Average slope steepness	0	1
r__RCHRG_DP.gw	Threshold depth of water in the shallow aquifer for revap to occur(mm)	0	1
v__GW_DELAY.gw	Groundwater delay (days)	30	450

v__SLSOIL.hru	Slope length for lateral subsurface flow	0	150
r__USLE_K().sol	USLE equation soil erodibility (K) factor	-0.25	0.25
v__SURLAG.bsn	Surface runoff lag coefficient (days)	0	24
v__REVAPMN.gw	Threshold depth of water in the shallow aquifer for revap to occur(mm)	0	100
r__ESCO.hru	Soil evaporation compensation factor	0	1
v__CH_S2.rte	Average slope of main channel	-0.01	10

4.8 Calibration

Calibration is held on for the period 1998 to 2007 using of most sensitive parameters obtained from sensitivity analysis. The last fitted parameter are shown in Table 4.10.

Table 4.10. Best calibration parameters compare with before calibration parameters.

Rank	Parameters	Fitted value	Min value	Max value	before calibration	
					Min value	Max value
1	V__CH_K2.rte	391	-0.01	400	-0.01	500
2	R__CN2.mgt	0.218	0.21	0.25	-0.25	0.25
3	V__GW_DELAY.gw	395.37	300	450	30	450
4	R__RCHRG_DP.gw	0.258	0	1	0	1
5	R__USLE_K(..).sol	-0.119	-0.25	0.25	-0.25	0.25
6	R__SOL_K(..).sol	0.112	-0.25	0.25	-0.25	0.25
7	V__GW_REVAP.gw	0.188	0.15	0.22	0.02	0.2
8	V__CH_S2.rte	0.576	-0.01	10	-0.01	10
9	R__HRU_SLP.hru	0.61	0	1	0	1
10	V__REVAPMN.gw	84	0	100	0	100
11	V__GWHT.gw	15.39	0	25	0	25
12	R__SOL_CBN(..).sol	-0.19	-0.25	0.25	-0.25	0.25
13	R__SOL_AWC(..).sol	-0.16	-0.25	0.25	-0.25	0.25

4.9 Validation

Validation is conducted for the period 2008 to 2014 without changing the calibrated parameter in order to make sure the simulation is valid for independent period. The visual inspection for calibration and validation is shown in Figure 4.9.

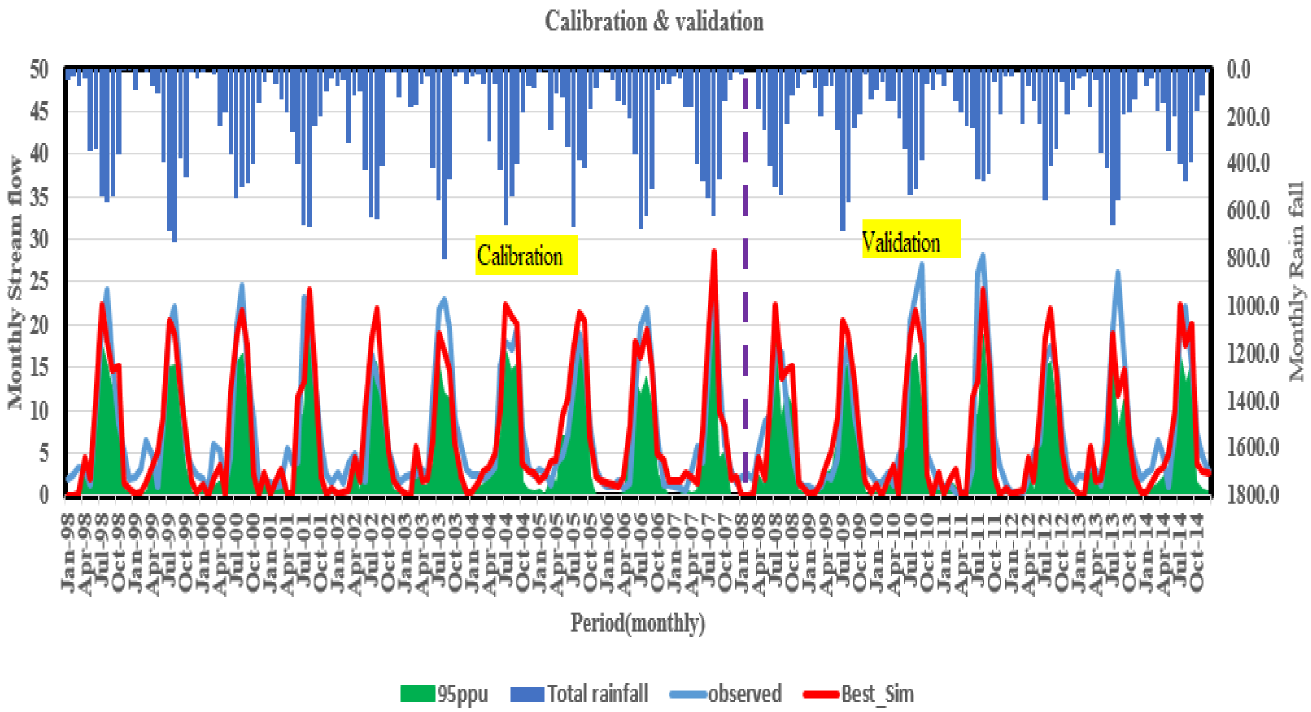

Figure 4.15.SWAT calibration and validation plot with observed stream flow and precipitation.

4.9.1 Model performance evaluation result

To evaluate the model simulation outputs relative to the observed data, model performance evaluation is necessary. There are various methods to evaluate the model performance during the calibration and validation periods. For this study, three methods were used (NSE, R^2 and PBIAS) .Below table 4.11 shows that the model performance values for calibration and validation period

Table 4.11. Model performance value of Jedeb simulation result

Factors	NSE	R^2	PBIAS
Value	0.77	0.79	4.6%

4.10 Simulated base year

In order to quantify the contribution of climate variability, the calibrated SWAT model for the changed year period is simulated for base period by using climate variability for base period. But all other parameters remained constant. This is the principle of reconstruction. Figure 4.16 below shows that the simulation result of base year period by making the land use land cover constant to changed period.

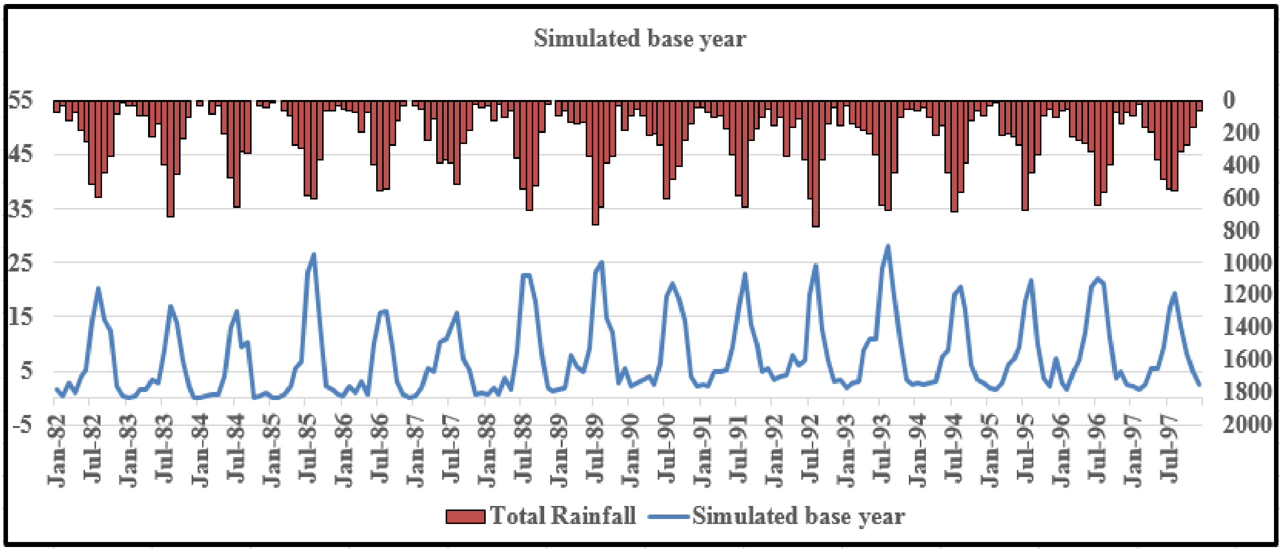

Figure 4.16. Simulated base year with a constant LULC to changed period.

The result of the simulated stream flow of changed year and base year stream flow with constant land use land cover is tabulated in Table 4.12.

Table 4.12. Result of the simulated stream flow of changed year and base year

Parameter result	Simulated stream flow of changed period	Simulated stream flow using base period climate	Difference in two periods	Average natural period
Average stream flow (mm)	90.904	134.024	43.12	191.81

From the above result the contribution of climate variability can easily be determined.

The climate variability contribution to stream flow change using modeling approach in percentage is:

$$\Delta Qc=\Delta Q/Qnatural$$

$$=43.12/191.81$$

$$=0.224=22.4\%$$

So, the contribution of climate variability for reduction in stream flow is 22.4% while the remaining 77.6% is attributed to human activity.

From the observed stream flow data between the two periods, 54.84 mm of stream flow variation occurs due to climate variability and human activity. Using hydrological model method, 12.28 mm of stream flow is decreased due to climate variability and 42.55 mm of stream flow is decreased as a result of human activity. In summary, the three methods revealed that, human activity is the dominant factor for decrease in stream flow in Jedeb River during dry season (Table 4.13).

Table 4.13. Summary of the percentage of the relative contribution using the three approaches

Methods	Human Activity	Climate variability
Climate Elasticity	75.8 %	24.2 %
Hydrological Sensitivity	73 %	27 %
Hydrological Model	77.4 %	22.6 %

4.11 Discussions

4.11.1 Stream flow trend

The stream flow trend of Jedeb catchment in dry season has shown significantly decreasing trend but in annual season, less dry and summer season, the stream flow trend is not shown significantly decreasing trend. In spite of no significant trends in dry seasonal precipitation and evapotranspiration, significant decreasing trends in dry season runoff can be found Jedeb River. This infers, to some degree, that runoff in the catchments may be affected by other factors (mainly human activities) apart from the climate variability. Usually, those human activities (direct abstraction from the river (primary) or groundwater and land use and land cover change in the catchment) are considered as the reasons leading to decrease the flow. The change points of runoff in the catchments happened in the 1998s, which corresponds to the fact that the land use land cover and climate parameter was changed after 1998. (Yalew et al., 2016) reveal that, Cultivated Land

and Plantation Forest increased from 54.4% and 0.3% in 1986 to 69.5% and 3.4%, respectively, in 2009. On the other hand, Natural Woody Vegetation and Grassland decreased from 14.6% and 24.4% to 11.6% and 21.2%, respectively, in 2009.Teklead et al (2015) agreed that the stream flow of Jedeb River is showed significantly decreasing trend in dry months like January and February.

4.11.2 Distinguishing Dominant factor for stream flow decline

In this study the dominant factor for declining stream flow Jedeb River in dry season flow was human activity. This human activity include direct abstraction of water from the catchment and land use land cover change of the catchment. In dry season the rain fall raining on the catchment is too minimum as a result the source of the flow of the Jedeb River is mainly ground water recharge to the river. Due to the fact that the land use land cover change was changed from forest to agricultural land and from grass land to agricultural land according to (Yalew et al., 2016). Due to this the deep percolation of water in rainy season should be decrease trough time to time and the direct runoff extreme events is increase, as a result the contribution of ground water in dry season was decrease time to time. So that the stream flow of Jedeb river in dry season is exhibit decreasing trend. This decreasing of dry season stream flow has negative effect in dry season irrigation of the society, in ecology life in the catchment as well as in upper Blue Nile river basin. To overcome this problem it should be planting bare land by indigenous plan to increase deep percolation to ground water and good water resource management should be implemented throughout the catchment as well as in upper Abay river basin.

4.12 Methods of quantifying human activity and climate variability

As mention in different researchers, upper Blue Nile basin has three seasons; namely dry season, less dry season and summer season. In less dry season and rainy season the stream flow has shown a slightly decreasing trend but not significant. This is why the climate parameters like evapotranspiration and rainfall was not show decreasing trend. However, the stream flow trend in dry season shows that there is significant decreasing trend occur, this mean the contribution of ground water to stream flow in dry season was decrease due to human activity like land use land cover change. This decreasing stream flow in dry season was significantly changed after 1998 year due to human activity and climate variability. Human activity and climate variability has no equal contribution on stream flow change.so quantifying the separate impact is very important to take action for water resource management. Climate elasticity, hydrological sensitivity and hydrological model is the commonly methods to quantify and detect the separate factors for stream flow change. All three methods has near result to quantify and detect the separate impact. From the result climate variability has 22% up to 27% contribution for stream flow change where as human activity has 78% up to 73% contribution for stream flow change in all three method. From the result human activity like LULC change, abstraction for irrigation, domestic water use has dominant role for Jedeb stream flow change. On the other hand climate variability has an effect for Jedeb stream flow change slightly. Those are increasing of potential evaporation and decreasing of dry season rainfall are the most common climate elements that contribute for Jedeb stream flow change. As a result those three method used for quantifying the contribution of climate variability and human activity display near to the same result. Specially hydrological model and climate elasticity has exactly the same result to quantify the separate impact of climate variability and human activity impact on stream flow. Wang et al., (2013);,Sadidi et al (2018);,Dey et al.,(2017) use the above methods to detect and quantify the dominate factor for stream flow change and they get the same result.

4.13 Implication for water management

The quantification of individual impacts of climate variability and human activities on stream flow are, necessary to frame different adaptation measures due to climate variability in watersheds and to realize the future water use pattern for different human activities. The rapid increase of population along with increase in water demand for various sectors poses severe challenges to water resources. Thus, decision and policy makers are drawn towards managing the consequences of hydrological impacts of climate change and human activities for optimal water resources management. The individual impacts of climate change and human activities are, therefore, necessary to frame different adaptation measures due to climate change in watersheds and to realize the future water use pattern for different human activities. Hydrologic cycle and its components are getting affected by climate change and human activities which alter the spatio-temporal distribution of water. Stream flow, one of the most vulnerable components, undergoes variability that poses alarming consequences for water demand by different sectors. Therefore, it is essential to understand the behavior of stream flow under the influence of climate variability and human activities separately for developing adaptation strategies and policies for water resources planning and management.

The practical recommendation based on this review is in helping the policy and decision makers to design the plans of adaptation and mitigation more effectively under the information of water availability and its variability due to climate change and human activities. These changes are vulnerable and would incur huge expenditure to develop new infrastructure in underdeveloped nations. Increase in the water related risks such as floods or droughts or changing spatial and temporal characteristics of rainfall will further increase the stress and will continue whatever may be the mitigation strategies adopted. For sustainable societal progress, water managers need to come up with improved infrastructure and services more resilient to the changing patterns of climate as well as human activities. Excessive deforestation or installation of dam with improper regulation of water will lead serious threats to the riverine ecosystem and biodiversity of the command area. Combined influence of the attributes on stream flow may have average and unidirectional effect. So, in designing strategies and decision making policy, the individual impacts are more important compared to the combined impact.

Generally the implication of detecting stream flow change for water management

- If the policy makers are aware of the fact that the contribution of the human activities are the major drivers behind the changes in stream flow behavior, they may regulate the policies accordingly human activity. So that the river may restore to a better level and ecosystem may get improved.
- In order to differentiate different basin or catchment, which one is affected by climate variability and which one is affected by human activity for planning of adaptation strategy and for distribution of equitable water resource.

CHAPTER FIVE

5 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In this study, the cause of stream flow change in Jedeb River is detected and quantified using climate elasticity, hydrological sensitivity and hydrological model approaches. Climate variability and human activity had been identified as the two main reasons for the decrease in stream flow. Hydro climate data from1980 to 2014 of Jedeb catchment is used to detect the cause of stream flow change. The stream flow trend is first analyzed using modified Mann-Kendall trend analysis codded in R package. The Jedeb catchment showed significantly decreasing trend in stream flow during the dry season. The year of abrupt change in stream flow is assessed using Pettit test codded in R package. The year 1998 is detected as the year of abrupt change in stream flow at Jedeb catchment. The difference in mean stream flow before and after the year of abrupt change is attributed to both climate variability and human activity. Human activity is identified as the dominant driver for the change in dry season stream flow. Human activities contributed 75.83% and 73%, 77.6% to change in stream flow change using climate elasticity, hydrological sensitivity and hydrological model method respectively. Whereas, climate variability contributed 24.17%, 23% and 22.6% to decrease in stream flow using climate elasticity, hydrological sensitivity and hydrological model respectively.

All the three methods (climate elasticity, hydrological sensitivity and hydrological model) indicated similar dominant factor for the change in stream flow at the study catchment. Therefore, all the three approaches are applicable to identify the relative contribution for the change in stream flow. From climate variability parameters, increase in potential evapotranspiration has dominant role that decline in rainfall for reduction of stream flow at Jedeb catchment.

Generally we conclude that:

- All three methods (climate elasticity, hydrological sensitivity and hydrological model) have near to the same result in quantifying the separate impact of climate variability and human activity.so we can use one of them to detect the dominant factors for stream flow change

- Human activity (land use land cover change, domestic and non-domestic water use, abstraction for irrigation etc.) was detected as a dominant factor for stream flow decrease in Jedeb catchment.
- From climate variability parameters, potential evapotranspiration has dominant role that rainfall for reduction of stream flow of Jedeb catchment.
- Soil and water conservation activities mainly in bare land area and high slope areas should be undertake in the Jedeb catchment, to increase dry season stream flow and its sustainability.

5.2 Recommendations

From this study we recommend that:

- For sustainable water resources management and development, measures which enhance soil infiltration rate is highly recommended in order to reduce flood risk during high flow period and hydrological drought during dry season.
- The quantification of the cause of stream flow change was implemented in single catchment (i.e Jedeb catchment) in this study. So that this study did not represent upper Blue Nile river basin.it is recommended to do in all catchments of upper Abay river basin as well as all over Ethiopia to detect the cause of stream flow change and to maintain regional water resource development.
- In addition to climate elasticity, hydrological sensitivity and hydrological model methods, other methods like regression analysis, histogram matching approach and Budyko hypothesis
- Further studies considering the impact of future climate change and land use land cover dynamics on stream flow is most welcome.

5.3 Limitations

In this study quantifying and detecting the climate variability and human activity for stream flow change is conducted. But human activity is general phenomena that comprise LULC change, abstraction for irrigation, domestic and non-domestic water use etc. and also climate variability comprise variation in rainfall, temperature, relative humidity, solar radiation, wind speed. So quantification of detail human activity element and climate variability element is vital in order to get exactly detect and quantify the root cause of stream flow change. So, further study should be needed to detect the exact cause of stream flow change due to human activity element and climate variability element.

CHAPTER 6

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7 APPENDICES

Appendices 1. Average yearly observed stream flow data and climate data

Base Year	Dry(FLOW) mm	Dry(pcp) mm	Dry(Eto) mm	Changed Year	Dry(flow) mm	Dry(pcp) mm	Dry(Eto) mm
1980	218.7	180	105.0	1998	177.4	212.6	114.5
1981	221.2	160	108.0	1999	145.6	283.4	116.8
1982	162.0	190	104.0	2000	130.1	245	117.3
1983	162.5	192.2	125.0	2001	108.3	109.1	115.6
1984	70.0	50.9	130.0	2002	126.2	124.6	121.5
1985	90.0	77.9	125.0	2003	197.8	105.5	132.1
1986	110.0	143.9	109.6	2004	159.1	170.3	144.1
1987	126.6	166.2	110.0	2005	167.4	152.6	148.3
1988	210.1	220	107.4	2006	101.6	124.3	142.2
1989	260.0	340	107.3	2007	106.7	107.5	137.5
1990	270.0	345.6	106.0	2008	106.7	116.6	90.1
1991	250.0	330	107.9	2009	115.8	170.4	71.3
1992	238.4	190	94.1	2010	107.3	168.2	79.2
1993	240.1	186.8	102.4	2011	122.4	171.3	87.7
1994	213.5	216.3	102.4	2012	115.5	179.4	115.6
1995	213.5	139.6	108.6	2013	158.5	192.1	113.0
1996	174.8	140	104.0	2014	181.9	205.6	122.3
1997	221.0	179.7	105.2				
Avg.	191.8	191.617	109.0	Avg.	137.0	167.0	115.8

Appendix 2. Auto correlation computation in R

```
> Stream flow<-read.csv (file. Choose (), header = T)
> X1<- Stream flow $Dry.Season.mm.
> X2<- Stream flow S$Less.Dry.Season.mm.
> X3<- Stream flow $Summer.Season.mm.
> acf(x1,lag.max = 1)
> acf(x2,lag.max = 1)
> acf(x3,lag.max = 1)
```

Appendix 3. Modifiedmk R package function descriptions

“Bcpw” function Description

Description of the function

Hamed (2009) proposed a prewhitening technique in which the slope and lag-1 serial correlation Coefficient are simultaneously estimated. The lag-1 serial correlation coefficient is then corrected for bias before “prewhitening”.

Usage

bcpw(x)

H0: There is no trend in the series

Ha: There is a trend in the series

Arguments

x - Time series data vector

Value

Z-Value - Mann-Kendall Z-statistic after bias corrected “prewhitening”

Prewhitened Sen’s Slope - Sen’s slope of the “prewhitened” data

Sen’s Slope - Sen’s slope for the original data series ’x’

P-value - p-value after “prewhitening”

S - Mann-Kendall ’S’ statistic

Var(s) - Variance of ’S’

Tau - Mann-Kendall’s Tau

Appindex 4 “mkttest” R function description and code.

Mann-Kendall Trend Test of Time Series Data without Modifications

Description of the function

The Mann-Kendall trend test is a nonparametric trend test used to identify monotonic trends present in time series data.

Usage

mkttest(x)

Arguments

x - Time series data vector

Value

Z - Mann-Kendall Z statistic

Sen's slope - Sen's slope

S - Mann-Kendall S statistic

Var(s) - Variance of S

P-value - Mann-Kendall p-value

Tau - Mann-Kendall's Tau

```
> Stream flow<-read.csv(file.choose(),header = T)
> library("modifiedmk", lib.loc="~/R/win-library/3.6")
> mkttest(x4)………… (From this x1 is assign to Annual season in R studio")
>bcpw(x2) ……. (From this x3 is assign to less dry season season in R studio")
```

Appendix 5 "Bcpw" function coad in R studio

```
> Stream flow<-read.csv(file.choose(),header = T)
> library("modifiedmk", lib.loc="~/R/win-library/3.6")
> bcpw(x1)………… (From this x1 is assign to dry season in R studio")
>bcpw(x3) ……. (From this x3 is assign to summer season in R studio")
```

Appendix 6. Description and code of pittitt.test R function

Usage

pettitt.test(x)

x a vector of class "numeric" or a time series object of class "ts"

In this function, the test is implemented as given by Verstraeten et. al. (2006), where the ranks *r[1], ..., r[n]* of the *X[i], ..., X[n]* are used for the statistic:

$U[k] = 2 * \sum r\_i - k (n + 1) \quad k = 1, ..., n$

The test statistic is the maximum of the absolute value of the vector:

$U* = \max |P[k]|$

.The probable change-point *K* is located where *U** has its maximum. The approximate probability for a two-sided test is calculated according to

$p =2 \exp[-6K^2 / (T^3 + T^2)]$

```
> x1<-Stream flow$Dry.Season.mm.
```

```
> library ("trend", lib.loc="~/R/win-library/3.6")
> pettitt.test (x1) ……(from this x1 is assign to dry season in R studio”)
Pettitt's test for single change-point detection
data:  x1
U* = 250, p-value = 0.0004056
Alternative hypothesis: two.sided
Sample estimates:
Probable change point at time K=19
```

Appendices 7. Stream flow simulation result

year	Simulated (base year)mm	year	Simulated changed year(mm)
1982	145.3810025	1998	153.1015365
1983	83.28855187	1999	82.213056
1984	16.70970334	2000	56.5628223
1985	37.99500905	2001	41.76743134
1986	52.48967134	2002	72.65829246
1987	76.88481049	2003	77.46575843
1988	124.331328	2004	96.79145548
1989	208.96704	2005	127.9572669
1990	222.5205089	2006	118.8764852
1991	216.8682492	2007	137.4142426
1992	180.2213351	2008	153.1015365
1993	180.4745862	2009	82.213056
1994	150.368577	2010	56.5628223
1995	143.737023	2011	41.76743134
1996	136.9624131	2012	72.65829246
1997	167.1916485	2013	77.46575843
Avg.	134.0244661	2014	96.79145548
		Avg.	90.90404116

Appendix 8.Sample Final HRU distribution from swat simulation

```
SWAT   model  simulation   Date: 7/5/2019 12:00:00 AM   Time: 00:00:00
MULTIPLE HRUs  LandUse/Soil/Slope OPTION        THRESHOLDS : 5 / 5 / 5 [%]
Number of HRUs: 154
Number of Sub basins: 11
```

```
___________________________________________________________________________
________________________________________________
                                                                Area [ha]
Area[acres]

Watershed                                                      30052.0000
74259.9946


___________________________________________________________________________
________________________________________________
                                                                Area [ha]
Area[acres] %Wat.Area
LANDUSE:
                                Forest-Mixed --> FRST           7971.9417
19699.0666     26.53
                                   GRASSLAND --> GRAS           3505.1027
8661.2840     11.66
                                   SHRUBLAND --> SHRB           3646.5205
9010.7346     12.13
                   Agricultural Land-Generic --> AGRE          14928.4351
36888.9095     49.68

SOILS:
                                                 LVx           17345.2677
42861.0238     57.72
                                                 NTu           12546.7323
31003.6028     41.75
                                                 VRe             160.0000
395.3680      0.53

SLOPE:
                                             10-9999           22861.1846
56491.1302     76.07
                                                4-10            6197.7169
15314.8684     20.62
                                                 0-4             993.0985
2453.9960      3.30
___________________________________________________________________________
________________________________________________
___________________________________________________________________________
________________________________________________
                                                                Area [ha]
Area[acres] %Wat.Area %Sub.Area

SUBBASIN #                                                 1     6627.5000
16376.8839     22.05

LANDUSE:
                                Forest-Mixed --> FRST           2191.9903
5416.5176      7.29     33.07
                                   GRASSLAND --> GRAS            683.1365
1688.0645      2.27     10.31
```

```
                                   SHRUBLAND --> SHRB            736.4167
1819.7224      2.45     11.11
                   Agricultural Land-Generic --> AGRE           3015.9565
7452.5793     10.04     45.51

SOILS:
                                                  LVx           5894.8354
14566.4331     19.62     88.95
                                                  NTu            732.6646
1810.4508      2.44     11.05

SLOPE:
                                              10-9999           5513.2100
13623.4176     18.35     83.19
                                                 4-10           1087.2747
2686.7102      3.62     16.41
                                                  0-4             27.0153
66.7561      0.09      0.41
HRUs
 1                  Forest-Mixed --> FRST/LVx/10-9999           1930.5869
4770.5767      6.42     29.13    1
 2                     Forest-Mixed --> FRST/LVx/4-10            261.4034
645.9409      0.87      3.94    2
 3                        GRASSLAND --> GRAS/LVx/4-10            117.0757
289.2999      0.39      1.77    3
 4                     GRASSLAND --> GRAS/LVx/10-9999            467.0048
1153.9922      1.55      7.05    4
 5                        GRASSLAND --> GRAS/NTu/4-10             21.6930
53.6045      0.07      0.33    5
 6                     GRASSLAND --> GRAS/NTu/10-9999             77.3630
191.1679      0.26      1.17    6
 7                        SHRUBLAND --> SHRB/LVx/4-10             90.7629
224.2798      0.30      1.37    7
 8                     SHRUBLAND --> SHRB/LVx/10-9999            536.8422
1326.5639      1.79      8.10    8
 9                        SHRUBLAND --> SHRB/NTu/4-10             19.6897
48.6543      0.07      0.30    9
 10                    SHRUBLAND --> SHRB/NTu/10-9999             89.1219
220.2246      0.30      1.34   10
 11       Agricultural Land-Generic --> AGRE/LVx/4-10            472.5911
1167.7961      1.57      7.13   11
 12    Agricultural Land-Generic --> AGRE/LVx/10-9999           2018.5685
4987.9837      6.72     30.46   12
 13        Agricultural Land-Generic --> AGRE/NTu/0-4             27.0153
66.7561      0.09      0.41   13
 14    Agricultural Land-Generic --> AGRE/NTu/10-9999            393.7228
972.9087      1.31      5.94   14
 15       Agricultural Land-Generic --> AGRE/NTu/4-10            104.0589
257.1347      0.35      1.57   15
__________________________________________________________________________
________________________________________________
__________________________________________________________________________
________________________________________________
```

```
                                                                Area [ha]
Area[acres] %Wat.Area %Sub.Area

SUBBASIN #                                             2         12203.7500
30156.0764     40.61

LANDUSE:
                                Forest-Mixed --> FRST             4404.0207
10882.5552     14.65     36.09
                                   GRASSLAND --> GRAS             1170.0719
2891.3062      3.89      9.59
                                   SHRUBLAND --> SHRB             1499.5922
3705.5672      4.99     12.29
                   Agricultural Land-Generic --> AGRE             5130.0653
12676.6478     17.07     42.04

SOILS:
                                                 LVx             10121.1220
25009.7985     33.68     82.93
                                                 NTu              2082.6280
5146.2779      6.93     17.07

SLOPE:
                                             10-9999             10595.1743
26181.2054     35.26     86.82
                                                4-10              1508.5696
3727.7509      5.02     12.36
                                                 0-4               100.0061
247.1202      0.33      0.82
HRUs
 16                Forest-Mixed --> FRST/LVx/10-9999              3851.9697
9518.4097     12.82     31.56    1
 17                   Forest-Mixed --> FRST/LVx/4-10               317.2865
784.0309      1.06      2.60    2
 18                Forest-Mixed --> FRST/NTu/10-9999               204.7454
505.9360      0.68      1.68    3
 19                   Forest-Mixed --> FRST/NTu/4-10                30.0191
74.1786      0.10      0.25    4
 20                   GRASSLAND --> GRAS/LVx/10-9999               893.1183
2206.9399      2.97      7.32    5
 21                      GRASSLAND --> GRAS/LVx/4-10               102.4429
253.1416      0.34      0.84    6
 22                       GRASSLAND --> GRAS/NTu/0-4                10.5006
25.9476      0.03      0.09    7
 23                      GRASSLAND --> GRAS/NTu/4-10                32.5020
80.3141      0.11      0.27    8
 24                   GRASSLAND --> GRAS/NTu/10-9999               131.5081
324.9630      0.44      1.08    9
 25                      SHRUBLAND --> SHRB/LVx/4-10               135.5923
335.0554      0.45      1.11   10
 26                   SHRUBLAND --> SHRB/LVx/10-9999              1000.7275
2472.8477      3.33      8.20   11
```

```
 27                       SHRUBLAND --> SHRB/NTu/0-4             19.2512
47.5706      0.06      0.16   12
 28                      SHRUBLAND --> SHRB/NTu/4-10             83.7551
206.9632      0.28      0.69   13
 29                   SHRUBLAND --> SHRB/NTu/10-9999            260.2660
643.1303      0.87      2.13   14
 30    Agricultural Land-Generic --> AGRE/LVx/10-9999          3280.2796
8105.7348     10.92     26.88   15
 31       Agricultural Land-Generic --> AGRE/LVx/4-10           539.7052
1333.6386      1.80      4.42   16
 32        Agricultural Land-Generic --> AGRE/NTu/0-4            70.2543
173.6019      0.23      0.58   17
 33       Agricultural Land-Generic --> AGRE/NTu/4-10           267.2664
660.4287      0.89      2.19   18
 34    Agricultural Land-Generic --> AGRE/NTu/10-9999           972.5598
2403.2438      3.24      7.97   19
____________________________________________________________________________
_________________________________________________
```