ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

DEVELOPMENT OF WATER ALLOCATION SYSTEM FOR GENALE DAWA RIVER BASIN UNDER CLIMATE CHANGE AND FUTURE DEVELOPMENT SCENARIOS

A thesis submitted to the School of Graduate Studies in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering.

(Major Hydraulic Engineering)

By

Markos Abiy Hailemichael

Advisor

Belete Berhanu. (PhD)

Addis Ababa University Ethiopia

June 2020

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Approval by Board of Examiners

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CERTIFICATION

I, the undersigned, certify that I read the thesis entitled, “Development of water allocation system for Genale Dawa river basin under climate change and future development scenarios" and hereby recommend for acceptance by the Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering.

Belete Birhanu (Ph.D)

Advisor

AUTHOR'S DECLARATION

I, the undersigned, hereby declare that this thesis entitled, “Development of water allocation system for Genale Dawa river basin under climate change and future development scenarios” is my own work, and that all the sources I have used or quoted have been indicated or acknowledged by means of completed references.

Markos Abiy

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ABSTRACT

Population growth, urbanization, and industrialization are occurring at an ever-increasing phase. These processes result in an increased demand for water in all sectors. Water is not only influenced by human activities, but also by natural factors, such as climate change. It is in the Genale Dawa Basin that the higher percentage of people under the poverty line in the country (NAPA 7).The region is known with subsistence farming and pastoral livelihood facing frequent drought and rainfall declining abruptly and Climate change is expected to worsen the problem of rainfall variability, and associated drought and flood disasters. The objective of this thesis is to model the water resources system to develop a water allocation system for the Genale Dawa river basin under climate change and future development scenarios using a computer-based modeling tool Water Evaluation and Planning System Model (WEAP). Records of hydrology, meteorology, and irrigation water supply for the study area are statistically tested and arranged as an input file source to suit the model. Meteorological and CORDEX Africa RCM 8.5 climatic data were corrected with multi-regression and distribution mapping (DM) method respectively and the two data were also correlated with each other. The model calibration, validation, and its statistical measure were seen and therefore the result shows that it's good and the model can simulate the current and future scenarios. The results of this analysis revealed the study found No quantity of unmet demand in the in reference Scenario from the years 1990 to 2018 for all cumulative demands. Similarly in the coming future Development scenario I Short term analysis period (2019–2030) and long term analysis period (2031–2050) among the total water requirement the unmet Demand for domestic and livestock water demand in each period became 13.72% and 15.72% of the total Water demand . Although for the Climate change scenario II for constant total cumulative water demand of 759.6Mm^3 in Short term and long term period 10.97% and 9.48% of the total demand is Unmet in the analysis respectively. And For Scenario III (combination scenario) both the future development and climate change effect on sectional demand are considered and analyzed. Based on the simulation results from the total demand in short term period (2019 – 2030) and long term period (2031- 2050) the total unmet demand is found to be 10.97% and 12.73% of the total demand is Unmet respectively.

Key Words: Water Evaluation and Planning System Model (WEAP), CORDEX Africa, Regional Climate Model (RCM), Distribution Mapping (DM)

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LIST OF ABBREVIATION

DEM	Digital Elevation Model
DM	Distribution Mapping
GCM	General Circulation Model
GIS	Geographic information system
ICTZ	Inter-Tropical Convergence Zone
IPCC	Intergovernmental Panel on Climate Change
Kc	Crop coefficient
MoWIE	Ministry of Water, Irrigation and Electricity
NAPA	National Adaptation Program of Action
NMSA	National Meteorological Services Agency
NSE	Nash-Sutcliffe Efficiency
OIDA	Oromia Irrigation Developments Authority
RCM	Regional Climate Model
RCP	Representative Concentration Pathway4
RMSE	Root Mean Square Error
SEI	Stockholm Environment Institute
SRES	Special Report on Emission Scenario
WEAP	Water Evaluation and Planning System

1. INTRODUCTION

1.1.Background of the study

In the developing world the processes of population growth, urbanization, and industrialization are occurring at an ever-increasing phase. These processes result in an increased demand for water in the sectors of agriculture, power generation, industry, and urban water supply.

Water is not only influenced by human activities, but also by natural factors, such as climate change. Hence, the impact of climate change on water resources is the most crucial research agenda at the worldwide level today (IPCC, 2007). This change affecting certain components of the hydrological cycle, especially precipitation and temperature, and this alters the spatial and temporal availability of water resources. It can change flow magnitude; variability and timing of the foremost flow event are among the most event are among the most frequently mentioned hydrological issues (Habtom, 2009). Climate variations can also affect the use of agricultural land associated with irrigation water demand systems (knife, 1999).

As water resources within the rural river basins are exploited to their limits, problems with pollution and resource degradation arise. To mitigate the damages to water resources and their environment additional limits are imposed on water abstraction.

Due to changing water supplies and increased water demands, tools and methods for water allocation have become an important area of study and the Water resources allocation is facing major challenges due to increased variation in water availability caused by climate change and an increasing water demand resulting from future developments in the river basins (Dan.Y, 2017).

To address this need, the study assessed the impact of climate change and future development expansion on available water resources of using a decision support system known as the Water Evaluation and Planning (WEAP) Model. WEAP is a systematic framework developed for the evaluation of climate change and other drivers that water managers commonly challenging (Dan.Y, 2017). Indeed, the WEAP model is one of the useful tools for integrated water resources management and it can be used as a database, forecasting, and also as a policy analysis tool, depending on the focus of the study. In this regard, the applicability of WEAP was assessing the impact of climate change as well as the future developments expected on water allocation of the basin.

1.2.Statement of the Problem

Ethiopia is highly vulnerable to the potential impacts of climate change with low capacity to reponed or adapt it (Thornton et al. 2006). Extreme events including drought and floods occurrence become a frequent phenomenon with a frequency of 3-5 years in Ethiopia and resulted to record 5 major national level drought and too many local droughts (World Bank 2009).

It is in the Genale Dawa Basin that the higher percentage of people under the poverty line in the country. The region is known with subsistence farming and pastoral livelihood facing frequent drought and rainfall declining abruptly. More than 91% of the population in the Basin lives in rural areas, where accessibility of basic needs hardly any (NAPA priority7), and Climate change is expected to worsen the variability of rainfall and increase in temperature, which leads to frequent drought and flood episode's (NMA 2006).

The Genale Dawa Basin is a highland –lowland system with a risk of natural resource degradation, particularly water and land, due to a rapid increase in the demand for water and high variability. The Basin has an area of 172,889 km^2 and an annual flow of 6.10 billons cubic meters of annual flow (NAPA priority7). Therefore, this study will have profound importance and contribution to the national efforts on allocating the water under expected future Development and climate change scenarios.

1.3.Objectives of the Study

1.3.1. General Objective

The main aim of this thesis is to model the water resources of the basin and to develop a water allocation system for the Genale Dawa river basin under climate change and future development scenarios using a computer-based modeling tool Water Evaluation and Planning System Model (WEAP).

1.3.2. Specific Objectives

The specific objectives of the proposed study are

→ To analyze the capability of the Genale Dawa river basin water resource under the climate change scenario

→ To analyze the capability of the Genale Dawa river basin water resource under future development scenarios

→ To analyze the capability of the Genale Dawa river basin water resource under both scenarios

1.4.Research Questions

→ How climate change and developments in the Genale Dawa River Basin affects the water availability in that basin.

→ Can Genale Dawa River Basin water resources fulfill the existing and future water demands under both scenarios?

1.5.Significance of the study

The study will assist the decision and policymakers, administrators, planners, and water resources professionals, who are responsible for the management of water resources, to assist them in formulating and implementing effective and efficient water allocation systems in the basin to better manage the water demand and supply cases and better understand the behavior of the system of water allocation of Genale Dawa river basin in the present and future situation.

1.6.Limitation of the Study

The study focuses on the Genale Dawa river basin catchments responses to major stresses of climate change and future development expansion in terms of the water availability at the Wereda scale. Aiming at the objective, this study did not take into account the problem of flooding, sediment which may be happened under future scenarios troubles.

1.7.Study Approach

The study approach or framework is presented in figure below:-

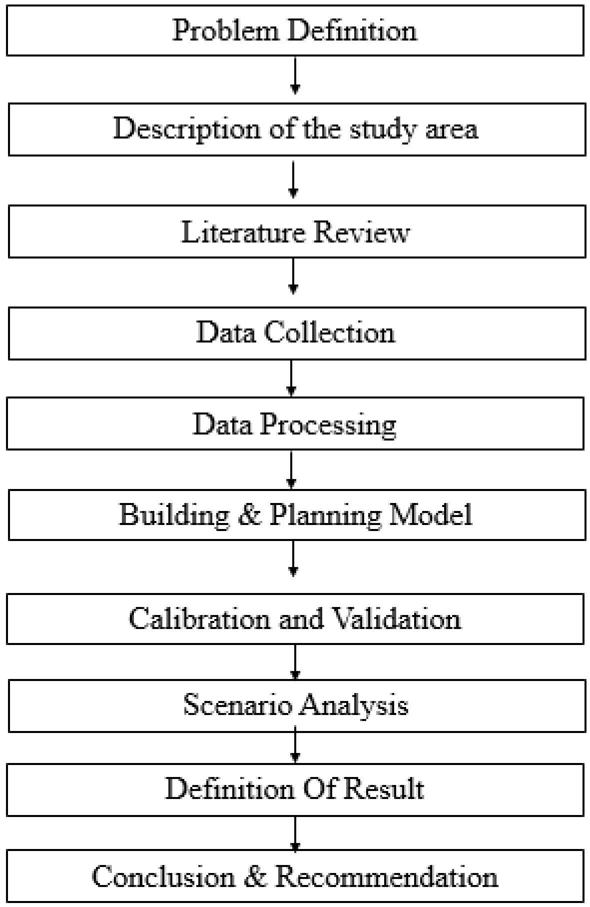


Figure 1.7-1 study approach or framework

1.8.Thesis Outline

The thesis will contain six chapters and organized as follows: Chapter one is an introduction to the study. Chapter two reports on a literature review about the subject matter. Chapter three describes the study area and the methodology applied. Chapter four is about data processing in this research and the WEAP model setup. In chapter five the results will be shown and discussed. At the end in Chapter six conclusions and recommendations will be presented based on findings.

2. LITERATURE REVIEW

2.1.Climate and Climate Change

Weather is the atmospheric state its temperature, humidity, wind, rainfall, etc. over hours to weeks. And when it is influenced by the oceans, land surfaces and ice sheets that form what is called the 'climate system' together with the atmosphere. In its widest sense, climate is a statistical description of the state of the climate system (Jacobson M, et al., 2000) (Steffen, W. et al., 2004). Though based on IPCC (WGAR5, 2013), Climate is the average weather or statistical description of relevant variables in terms of mean and variability for over a period of time. And the conventional period of years for the variables to be averaged is taken 30 years (WMO, 1989).

Over the past century the climate on Earth has changed, the atmosphere and the oceans warmed, the sea levels rose, and glaciers and ice sheets decreased. And latest researches available shows that the key cause is the greenhouse gas emitted from human activities. Continuous increases in greenhouse gases emission will surely results in further warming and other changes in the physical, environment and ecosystems on Earth. (Pierrehumbert R, .2010)

2.2.Climate Change in Ethiopia

Ethiopia is highly vulnerable to climate change (MoA 2015; MoWE 2015) and a significant climate-induced recurrent droughts and flooding have occurred in recent decades as a result of the change. The country's vulnerability to climate change is further enhanced by high poverty rate, rapid population growth and dependence on rain-fed farming. (Simane et al., 2017).

Mean annual temperature in Ethiopia has been rising every ten years by 0.37 °C for the past four decades. (Emerta, 2013). According to Emerta, the major percentage of increase in temperature was recorded in the second half of the 1990s, and temperature rise is more prominent in the country's dry and hot areas, located in the country's northern, northeastern, and eastern regions. Main findings of the IPCC 2007 report shows that the mean monthly temperature changes expected to rise 0.92 °C by 2030s and 1.01 °C by the 2050s under a moderate-emissions. (RCP4.5) and a rise of 1.4°C by 2030s and 1.8 °C by the 2050s under high-emission scenario (RCP 8.5).

Even though there is high level of uncertainty in the future projection due to the variability of the inter annual precipitation trends, the precipitation level forecast indicates a long-term rise in rainfall in given occurrence of regular dry spells with severe rainfall rates over the short and medium term. The average rainfall change is projected to range from 1.4 to 4.5 per cent, from 3.1 to 8.4 per cent, and from 5.1 to 13.8% over 20, 30 and 50 years, respectively, compared to the normal 1961 to 1990. (C. McSweeney et al, 2006).

Launched in 2011, the Climate Resilient Green Economy (CRGE) strategy Sets that By 2025 Ethiopia will Be a middle income country, Resilient to Climate change Impacts and with no net increase in greenhouse gas emissions From 2010 levels. This resilience strategy for agriculture and forestry has been developed as part of the CRGE strategy. It shows that economic growth must be protected against the impacts of current and future climate change. The agriculture and forestry Sectors are Key to Both national Income and Household livelihoods. Combined, the Sectors make up over two---fifths of the National economy (43% of our Gross Domestic Product (GDP)) and employ the vast Majority (around 80%) of the country's population. Due to reliance on rain---fed techniques, agriculture is highly vulnerable to weather and thus to future impacts of climate change. Also, Future climate change is expected to pose significant impacts on the productivity of our forests.

The CREG mainly focuses on Challenge: agriculture and the livelihoods that depend on it are vulnerable, and future climate change poses an even greater threat (for example, with increased incidences of droughts, the negative impacts on GDP could be 10% or more by 2050). However, interventions that can reduce this vulnerability have also been identified. Indeed the analysis shows that a lot of work is already being undertaken to reduce the vulnerability in the agriculture and forestry sectors, yet more needs to be done to ensure the future resilience of our economy and our people, and more financing is required.(NMA,2011)

Within Ethiopia extreme weather events are common, especially droughts and floods. Alongside the evidence of a changing climate, there is a Suggestion that the incidence of droughts and floods may have increased in the last 10 years relative to the decade before. Soil erosion is a key hazard for agriculture with up to 6% of the country at risk. (NMA, 2011)

2.3.Expected Future Climate Projection of Ethiopia

Temperature

Earlier studies reported that Ethiopia's annual average temperature would continue to rise in the future, although the range of possible futures is large. The National Meteorological Agency (NMA) reported a central projection of approximately 1°C increase by 2020s, 2°C by the 2050s and 3°C by the 2080s over Ethiopia (for a medium high emission scenarios, relative to the baseline period of 1961--- 1990). However, the range around these central projections is large: with warming of 0.5 to 1.5°C by the 2020s and 1.5 to 3°Cs by the 2050s).

The most recent climate projections from the global datasets support the previous conclusion that future temperatures will rise in Ethiopia, within a fairly large range. Projected warming is between 0.5 to 1.5 °C by the 2020s (2011-2040) and 1.5 to3 °C by the 2050s (2041---2070) relative to the period 1961 - 1990.

Rainfall

Rainfall is a more difficult climate parameter to model and Ethiopian climatology is more complex and challenging than for most countries. Historical analysis shows there has been no rainfall trend at the national level (unlike temperature) indeed there is a pronounced annual and decadal variability.

Previous Modelling of the future changes in rainfall in Ethiopia has reported a large range, typically reporting projections of between-20% and +40% by midcentury relative to the baseline. This is similar to the current high levels of variability in Ethiopia's current rainfall.

The most recent climate projections from the global datasets continue to show little consensus on the future rainfall trend. The variations across scenarios and model projections indicate changes of 25% to +30% in annual rainfall by the 2050s, relative to the 1961 - 1990 period. This is similar to the levels of historic variability, making the analysis of trends extremely challenging. (NMA, CREG, 2011)

2.4.Climate Change Impacts on Water Resource and Reservoir

The impacts of climate change have been noticed and has greatly influences in weather patterns, precipitation and the hydrological cycle, impacting the supply of surface water, as well as soil moisture and groundwater recharge (UNESCO, 2006).

Increasing global temperatures would result in an escalation of the hydrological cycle, resulting in a long unusual dry seasons and rainy seasons, increased risks of more severe and frequent flooding and drought with major impacts on availability, quality and quantity of usable water. (Cornea, T & Dima, M & Roca, D. 2011)

2.5.Climate Scenarios

Scenarios are an image or alternatives of future changes (Nakicenovic et al., 2000); According to the (IPCC 2007) Climate scenarios are Plausible and often simplified representation of the future climate, based on an internally consistent set of climate relations built for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models. So that they differ from projection or forecast in fact, they are constructed from the climate projections coupled with observed current climate data.

Climate projections are climate system response to greenhouse gas and aerosol emission scenarios. (Cotton and Pielke 1995) There are too many models to simulate future climate that contain embedded assumptions. The most and recent one which is currently is used the climate model base scenario more specifically the General circulation model (GCM).

GCMs are complex numerical climate models that reflect the climate system's physical processes in the atmosphere, ocean, cry sphere, and surface of the earth. They are the only credible instrument currently available to simulate the global climate system's response due to the increasing of greenhouse gas concentration. (IPCC-TGICA 2007; Cotton, 1995; Goodess, 2000).

In GCM simulations, two sets of emission scenarios were used, on the basis of IPCC's last three assessment reports these are SRES (Special Report on Emission Scenarios: AR3 & AR4) (Nakicenovic et al., 2000) and the RCP (Representative Concentration Pathways; AR5; (Moss et al., 2008).

Special Report on Emissions Scenarios (SRES)

The SRES scenarios address a broad range of future emission driving forces, from demographic to technological and economic developments. Four separate lines of narrative stories were created to accurately explain the relationship between emission driving forces and their evolution, and to provide meaning for the quantification of scenarios, each storyline reflects specific demographic, social, economic, technological and environmental developments. And so called SRES scenario families (i.e. Al, A2, B1, and B2). According to (Nakicenovic et al., 2000), the families are summarized as below:-

The **Al** family characterized by rapid economic growth, a global population that peaks in the midcentury. And they are developed into three groups that describe alternative directions of technological change: (A1FI) fossil intensive, (AIT) non-fossil energy sources, or a balance across all sources (A1B).

The **A2** family characterized by a world of independently operating, self-reliant nations continuously increasing population and regionally oriented economic development Low emissions technological change is slower when compared to other storylines.

The **B1** family characterized by rapid economic growth and Population rising and then declining as in A1 but with rapid changes towards a service and information economy and also Reductions in material intensity and the introduction of clean and resource-efficient technologies, An emphasis on global solutions to economic, social and environmental stability.

The **B2** family characterized by a continuously increasing population, but at a slower rate than in A2. Emphasis on local rather than global solutions to economic, social, and environmental stability. Intermediate levels of economic development less rapid and more fragmented technological change than in A1 and B1. (Nakicenovic et al., 2000).

RCP (Representative Concentration Pathways)

On the fifth IPCC Assessment report (AR5) a new set of scenarios is employed which replaces the (SRES) Special Report on Emissions Scenarios standards employed that are presented in two previous reports. They are so called Representative Concentration Pathways (RCPs). There are four pathways: RCP8.5 a very high greenhouse gas emission, RCP6 and RCP4.5 a stabilization scenarios and RCP2.6 an aggressive mitigation scenario (The numbers at the end refer to radioactive forcing for each RCP based on the forcing of greenhouse gases and other forcing agents of 8.5 W/m^2, 6 and 4.5 W/m^2 and 2.5 W/m^2 respectively by the end of the century) and each of the RCPs covers the 1850–2100 period. (Hibbard et al. 2007, Moss et al. 2008, Wayne, 2013).

Hence, among the four dynamically downscaled regional climate multi-model CORDEX-Africa outputs that were (RCP 2.6, RCP 4.5, RCP 6, and RCP 8.5) the RCP 8.5 is used and selected for this study because the CO2 emission concentrations are higher than the other RCPs. Below is a comparison of the CO2 concentrations obtained from RCP emission scenarios

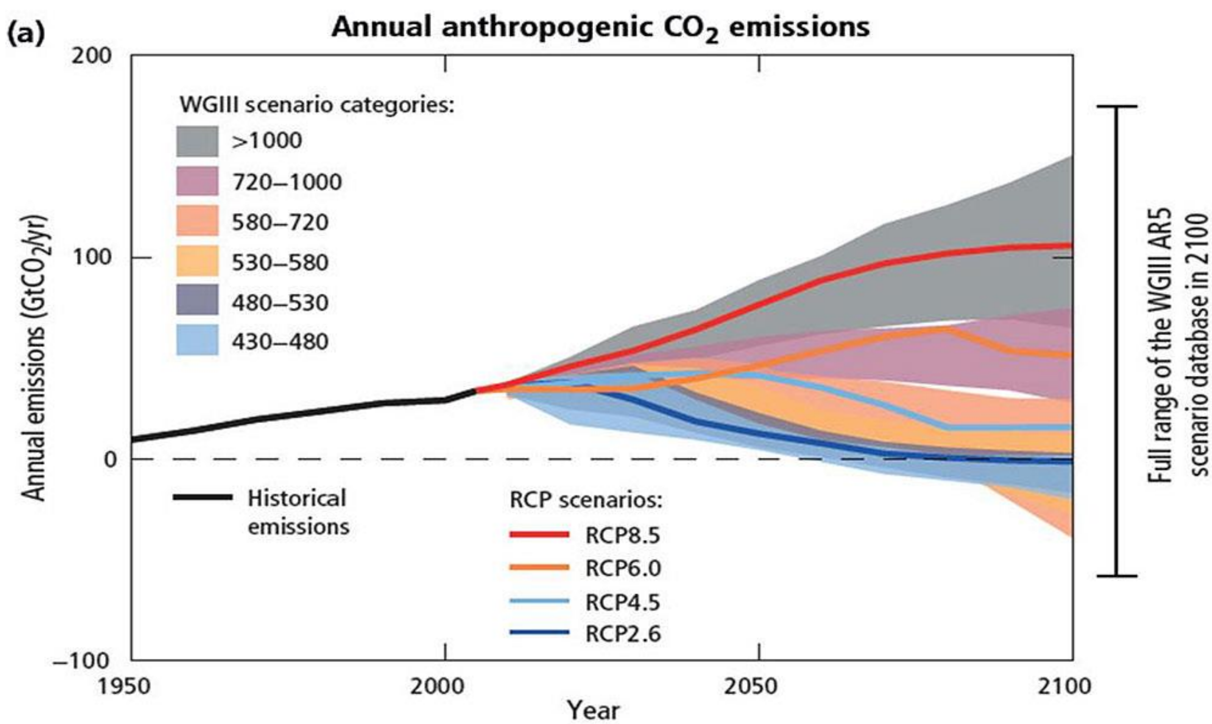


Figure 2.5-1 Annual anthropogenic CO2 emission scenarios (IPCC, 2014)

2.6.Water Allocation

Mullick A. 2011 states 'Water allocation thus indicates distribution of available water resources to its demanding users subject to hydrological balance and preset management principles such as equity, efficiency, sustainability. Owing to the time-varying characteristics of water availability, acute importance spanning from basic human needs to national economy within a complex web of interaction between climate, hydrology, society, and environment, economy and Sustainable development, water allocation is a complicated process'. The ultimate goal of the water allocation is to optimize the benefit of society as a whole from water-related services. Nonetheless, this general purpose implies certain particular objectives to be accomplished, such as social (equity), economic (efficiency) and environmental (soundness) concerns and priorities as indicated by various donor agencies and management bodies necessary when the natural distribution and availability of water fails to meet the needs of all water users in terms of quantity, quality, timing of availability, or reliability. (ABWASP, 2017).

Access to water has traditionally been regulated to meet a wide range of requirements Set of social priorities, including agricultural production; Economic and public health growth, and – more recently protect the environment. Examples of laws on water sharing, and Arrangements date back to the Ancient Civilizations of Babylon, of Rome, of China;

Allocation goals have changed over time, and various approaches to measuring, identifying and controlling water resource have arisen. Ultimately however, the distribution of water supplies remained the method of determining who is entitled to the water available. This, actually, consists of:

I. Determining how much water is available for allocation. This can include assessing different locations, different sources (such as groundwater and surface water), for different times of the year, or under different climatic conditions.

II. Determining how that water should be shared between different regions and competing users: who should be entitled to what? The water allocation process may distinguish between different administrative or geographic regions, different sectors, and (ultimately) individual water abstractors and users.

Water allocation planning has therefore gradually developed from early systems aimed at equitable use of water along irrigation systems, through managing diversions along river reaches, to managing small catchments, and finally to managing larger basins and allocations between administrative regions. More recently water allocation planning has taken on a broader vision of the use of water in the economy, the impacts of variability on different users, and increasingly, making provision for environmental water needs.

2.6.1. Water allocation and climate change

Whilst water managers understand now the impact climate change would have for water Management and distribution remain relevant Identifying how it can really be achieved in equitable way. Taken along with the economic rapidity this means development and changing water demand trends the water allocation preparation needs to be handled rapidly Modifications.

2.7.Principles and Mechanisms of Water Allocation

The key principles of water allocation in sharing scarce water resource are equity, efficiency, and sustainability. The water source should be fairly shared, utilized economically yet and in the coming future period, in a way environment is not harmed when full filling the needs among all water users. (UNESCAP, 2000).Through time various perspective arose in the study of planning water allocation from aiming equitable use of water at small scale catchment to managing of large basins in a way of maximizing the economic, social, and environmental benefits.(R. Speed, et.al. 2013). In our country the water policy of the Federal Democratic Republic of Ethiopia (FDRE 2001) regarding of water allocation suggested that adopting the water allocation should follow the principle that shall not be made on permanent basis, rather it has to vary on an agreed time horizon that fits best with the socioeconomic development plans, especially pertinent to water resources that are subjected to appraisals and revisions in light of new developments.

2.8.Water Demand and Allocation

When water scarcity has risen globally (Rosa et al., 2020), Efficient and productive use of water have become central to exercises in the allocation of river basin water. Fair water distribution requires a dynamic balance between the water demand and supply source. (Yamout and El-Fadel 2005), Planning for the allocation usually involves some calculation of potential water usage; there are a number of methods usually based on current trend predictions or wider national economic growth forecasts. Such forecasts for growth can be used to extrapolate the water demand patterns.

Water allocation of regional development planning requires the incorporation of economic objectives with many factors, including historical, technological, and natural and resource constraints and potentials. (Jin et.al, 2007).

2.8.1. Allocating water to high priority purposes

New approaches to water management are gradually understanding that different users will be given various levels of priority. Priority water needs should be defined and resolved in a cycle of allocation of the basin before the remaining water is shared among the basin regions.
Priority use of water may be defined at the various stages of the water allocation process, not just at the national or basin level. During regional allocation preparation, a regional
Government can determine its own priorities. Water also needs to be controlled at basin level for environmental flows, however, considering the entire system processes associated with the flow scheme.

2.9.Models for Water Allocation

Thompson, Madison (2019) states 'water allocation software is a tool that can be used to plan for the future in the construction of fair and impartial water sharing agreements and operational rules.' Various software tools for the planning and allocation of water resources, the operation and management of catchments have been developed. The flexibility of water allocation modeling is vast and the needs for each basin and analysis have the potential to be met with a variety of available models (Dinar et al. 2007).

The two main type of water allocation models are the optimization models which provide the best solution for a specific problem such as linear and nonlinear programing models and the simulation models which use water balance concepts to allocate water resources. WEAP (Yates et al., 2005), Mike Basin (DHI, 2001), MODSIM-DSS (Fredericks et al., 1998) are among the common ones.

Not only does the use of any of the above models produce better results, but during the analysis of a given area under water allocation, a more reliable and detailed collection of data is needed to match and achieve better results for specific objectives.

2.9.1. Applications of the Water Evaluation and Planning (WEAP) Model

WEAP is a software tool created in 1988 by the Stockholm Environmental Institute (SEI) with the aim of being a flexible, integrated and transparent planning tool for assessing the sustainability of current water demand and supply patterns and exploring alternative long-range scenarios.

WEAP was first used in the study of Areal Sea. Raskin et al. (1992) after adjusting the major limitation of the tool the SEI-US introduce the more modern tool which has friendly graphical user interface that can easily adjusted with a robust solution algorithm to sole the water allocation problem. (Rosenzweiga et al., 2004).

WEAP model has two primary functions (Sieber et al. 2004): Simulation of natural hydrological processes for determining the availability of water to catchments (e.g. evapotranspiration, runoff, and infiltration) and Simulation of anthropogenic activities overlays on the natural system to influence water resources and their allocation to make an impact assessment of the use of human water. Typically, i.e., consumptive and non-consumptive water demands.

Using the underlying concept of a water balance WEAP has been used throughout the world from a single watercourse to a diverse trans-boundary river basin mainly to model water allocation priorities for multiple demand analysis for, hydropower generation and reservoir operations (Yates et al 2013) (Flores-Lopez et al2013), and climate change and water conservation. (Bonelli et al, 2014), (Mohamed Abbas, 2014.)

WEAP operates in many capacities as it can be a Water balance database providing a system for maintaining water demand and supply information, as a Scenario generation tool which simulates water demand, supply, runoff, streamflow, storage, pollution generation, treatment and discharge and in stream water quality and also as Policy analysis tool by evaluating a full range of water development and management options, and takes account of multiple and competing uses of water systems. (Sieber & Purkey 2015, SEI 2019).

WEAP works on the basic concept of water balance, which can be applied to municipal which agricultural systems, single watercourses or complex trans-boundary river basin systems. In addition, Models can simulate a broad range of natural and engineered components of these systems, including precipitation runoff, base flow, and groundwater recharge; sectorial demand analysis; water conservation; water rights and allocation priorities; reservoir operations; hydropower generation; pollution monitoring and water quality; vulnerability assessments; and ecosystem requirements; A module for financial analysis also helps the consumer to study cost benefit analyses for projects. (Sieber & Purkey 2015, SEI 2019).

WEAP Features

An intuitive graphical interface based on GIS offers a simple but powerful means to build, display, and change the configuration. The user designs a system schematic for attaching elements to the device using the mouse to "drag and drop" objects. On a map compiled from ArcGIS and other regular GIS and graphic files, these elements can be overlaid.

Data can be modified directly for any part by clicking on the symbol we want in the schematics. From anywhere in WEAP the user can consult the context-sensitive help feature. Wizards, prompts, and error messages give advice all over the program. (Sieber & Purkey 2015, SEI 2019).

With WEAP's highly flexible and comprehensive reporting system, the user may customize reports as graphical, tabular or map-based output and select from a number of formatting options (e.g., metric or English units, years, absolute levels, percent shares, or growth rates). Specific report configurations can be saved as "favorites," which can be combined into "overviews," or summaries, of key system indicators; these overviews can then be retrieved quickly for review. (Sieber & Purkey 2015, SEI 2019).

With WEAP’s highly flexible and comprehensive reporting system, users can customize reports as graphical, tabular or map-based production and choose from a variety of formatting options (e.g., metric or English units, years etc.). Users can save different report configurations as "favorites," which can be compiled into "overviews" or summaries of key device indicators; these overviews can then be easily retrieved for analysis. (Sieber & Purkey 2015, SEI 2019).

2.10. Bias correction Methods

The main reason behind the bias correction is that direct data from the Climate Data Store may not be used such outputs are often not useful for impact studies due, for example, to severe biases: Temperature can be still too high or low and also high or too low a precipitation Model does a wrong monsoon simulation, the rains start too early or too late Climate models tend to overestimate the number of rain days and understate extreme precipitation. *(*Florian D. 2019)

These biases are due to the incorrect estimation of climate variables and their temporal variations, or the incorrect detection of rainfall events. One indicator of the latter is the simulation of too many days of low rainfall intensity, an appearance assumed as the drizzle effect or drizzling. Biases can rely highly on elevation, aspect, latitude, climate, and rain-showing mechanisms thus it is important to perform location-specific and in some cases season-specific bias corrections. Numerous bias correction methods, starting from simple scaling techniques to the more sophisticated distribution mapping techniques, are developed to correct biased satellite rainfall outputs (Min Luo, et al., 2018)

Linear scaling, local intensity scaling, power transformation, distribution mapping and quintile mapping are among the bias correction methods applied for many studies yet. For temperature correction methods including linear scaling, variance scaling and distribution mapping are used for many studies.

2.11. Overview of previous studies in the basin

In the past a great deal of research has not been conducted in the water management trends and options within the Genale Dawa river basin, both in the thesis and numerous institutional research levels. The limited and spotty occurrence of stream gauges in the basin is still the source of vague in the outputs of most researches conclusions. Among the studies I tried to refer to in search of the best understanding of the basin, this document I found most comprehensive and data will be used as sources for this thesis.

I. National Master Plan Study

WAPCOS, 1990

In the National Master Plan Study (WAPCOS, 1990), yield estimates were made considering annual rainfall and appropriate runoff factors for different zones and sub-basins. Runoff factors of 25 to 30% were computed for the western tributaries in the highland regions, which reduce to around 18% in the middle reaches of Genale and Weyib and about 7% in the central parts of Dawa. The resulting total was then compared with a mean flow of 5.88 Bm3 measured on the Juba river downstream in Somalia and the figure 5.88 Bm3 appears to be the final figure adopted by the study. According to National Master Plan Study (GDMP – Main Report, 2005), through utilization and interpretation of all historic/measured data and by combining the results of GIS procedures applied to determine catchment physical parameters and the mean annual rainfall, revised estimates of the annual rainfall (input) and surface water yield (output) of the sub-basins and the whole river basin can be made.

For each of the sub-basins, the most downstream station on the main river reach was defined as a control point. From the control point up to the sub-basin terminal point, a runoff was estimated through the application of the runoff curve based on mean elevation for the incremental area. This enabled estimation of incremental flow and total flow, or yield for each respective sub-basin.

As can be appreciated the Genale sub-basin yield can be almost completely defined from the station at Halwey, located in the lowest reach, and which commands some 98% of the total sub-basin area. Estimation in Dawa and Weyib are considerably less certain due to the extensive ungauged areas in the lower reaches. Therefore, The annual water yield estimate by WAPCOS (1990) which is about 5.88 Bm^3 and 6.6. Bm^3 that of GDMP (2005).

1997 MoWR: Genale sites GD-2 / GD-3 / GD-4

Under the Medium Scale Hydropower Plants Study Program (MoWR, 1997) MoWR conducted a reconnaissance study this research focussed on the Genale river's immediately most promising sites: GD-2, GD-3 and GD-4 located in the Genale main river in the upper-central region. Both the GD-2 and GD-3 require building a large dam to provide sufficient storage and control where a shaft / tunnel conduit connects to the powerhouse located a short downstream distance. The installed capacity resulted in 138 MW and 180 MW respectively, despite the design net heads of

103 m and 93 m. For GD-4, a slightly different configuration was defined which consisted of a lower dam and a smaller storage reservoir with a 25 km long power channel to gain a net head of 150 m. Capacity installed was 300 MW.

The schemes was found to be equally advantageous through the implementation of a costing and economic assessment method commensurate with the study level. GD-4's specific cost and benefit ratio of generation resulted to be slightly lower than GD-2 and GD-3's. To conclude, a stage development, possibly involving all three projects, was deemed feasible in what construction of the GD-2 or GD-3 alone would eliminate the need to create a dam solely for the development of downstream irrigation potential.

1999 Norplan: Genale sites GD-2 / GD-3

The Genale hydropower idea was taken one step further in this pre-feasibility study, in which more detailed work focused on the development of GD-2 and GD-3 sites (Norplan, 1999). In the GD-3 scenario, several alternatives were evaluated from which the alternative denoted "middle-long" was chosen. The architecture of this scheme was fully re-configured compared to the previous report, whereby a 1,460 m long headrace tunnel leads the water to a Powerhouse cavern, from where a 6,500 m long tailrace joins with the river Genale. The net head is 180 m tall.

The optimized installed capacity resulted in 164 MW with an 80 percent plant factor.

It should be noted that GD-2 has been included as a project to be implemented in the "all-hydro scenario" system expansion plan, with modified cost parameters (ACRES, 2003).

The Sectoral Study Report Section J: Energy provides a brief evaluation of the Genale hydropower projects and possible beneficial implications for future implementation under the ICS.

GDMP (2003)

Proposed Cascade Hydropower Project on Genale Main River

Between 2004 and 2007 a study carried out by a joint venture between Lahmeyer International Consulting Engineers of Germany and Yeshi-Ber Consulting of Ethiopia. The overall goals of the master plan are specified in the Water Resource Management Policy of Ethiopia (WRMP), the policy seeks to strengthen and encourage all national efforts to ensure that the country's available water resources are used effectively, reasonably and optimally for significant socio-economic growth on a sustainable basis.

The Hydropower Sector Study's objective was to screen hydropower options in the basin to find projects that could generate power at a cost below the thermal plants. Such projects are candidate projects for the expansion of the ICS power system, and likely also for exports to earn foreign exchange, in line with the sector's national policies. More than 40 hydropower options, identified in previous studies, were first pre-screened, removing all projects that are not likely to be economical the remaining 22 projects were then optimized by changing dam heights and positions at the powerhouse. Eventually, it was found that nine projects had generation costs below those of comparable thermal power plants and the economic hydropower potential is about 1,200 MW capacity with a corresponding energy generation of 5,500 GWh (not accounting for the Weyb-Wabi project). From the nine GD 3, GD 5, and GD 6 are the country's most promising potential hydroelectric developments selected in the Genale dawa river basin. In addition, the feasibility study of the GD-3 Multipurpose Hydropower Project by Lahmeyer International and Yeshi-Ber Consult, 2007, and the Feasibility Study Genale GD-6 Hydropower Project undertaken by Norplan and Norconsult in conjunction with Shebelle Consult, 2009 are also used primarily for this study.

II. Thesis Study on the Basin

Tandem Reservoir Operation of Cascade Hydropower Plants; Tsegazeab Dejene (2015)

Out of the nine large scale hydropower potential projects in the basin, this study deals with the optimal operation of the cascade hydropower plants namely, GD-3, GD-5 and GD-6 that are located on the main river channel of Genale River. HEC-ResSim (Version 3.1) used to simulate the multi-reservoir system network. The physical and operational data are obtained from previous studies of these projects and used as input in reservoir network module of ResSim Model. Implicit (default) and Explicit (user defined) system storage balance has been used to get the maximum power and energy and plot the optimal guide curve so as to be used by the operator to attain the optimal overall energy generated from the system. The explicit system storage balance has generated a better power and energy for the reservoir system. The study showed that, when the individual hydropower reservoirs deliver energy and capacity into a common power system, operating the projects as system has produce more average energy or firm energy than the sum of individual projects operating independently. The maximum overall average energy of the system found in this study is 4417.7GWh/yr. Comparing with the feasibility study, the proposed model is capable to produce an extra amount of 487.7 GWh average electrical energy (a 12.4% increment) annually. The optimal guide curve denotes that there is a tendency, in the optimal explicit system storage, to leave more water from GD-3 reservoir and prepare the storage to hold more water during high flood seasons. The water released from this reservoir can generate additional power at the downstream power plants. The reverse is true for the operation of the downstream power plants. The pool level of GD-5 is almost in the flood zone except for the first three months, January to March, where the pool level is in the active live storage zone. InGD-6 the reservoir pool level is in the flood zone throughout the year.

Assessing Surface Water Potential and Water Demand in Genale Dawa River Basin by Tilahun Araya Asmerom (2015)

The study aims to quantify the quantity of surface water potential leaving the whole basin as surface runoff and the water demand considering the large scale projects in the Genale Dawa river basin and the study hydro-meteorological data were used to characterize the hydrology of the study area. SWAT (Soil and Water Assessment Tool) model was used to determine the surface water potential leaving the whole basin as surface runoff on a mean annual basis and WEAP (the water demand assessment Water Evaluation and Planning) model was used.

The water demand assessment was done for only selected large scale irrigation, hydropower, and water supply projects. Two large scale irrigation projects, one large scale hydropower project, and five water supply schemes were selected. The five water supply schemes were intended to serve 143,865 people with in the base year. And According to this study, the estimated annual water yield from the entire basin is found to be 6.37Bm^3.

Modeling the Water Balance, Reservoir Operation and Simulation Analysis for Cascaded Hydropower Plants. (A Case Study of Upper Genale-Dawa River Basin) By Sora Denge Wariyo (2019)

This research is intended to assure the equilibrium between energy production and consumption from hydroelectric energy. Hydroelectric power plant development on Genale-Dawa River basin is, a part of development plan for Ethiopian energy production. Modeling of Water balance and Reservoir Operation is frequently required in Hydraulic engineering for reservoir management and to control fluctuation of water. This study mainly focuses on water balance and reservoir operation analysis for cascaded hydropower plants in the Genale-Dawa river basin by using HEC-ResSim and HEC-HMS model. The stream flow generation were estimated by using HEC-HMS model to enhance the water balance components at Genale cascade reservoirs in the semi-ungauged parts of upper river basins. A Digital Elevation Model (DEM) with 30×30 resolution of the study area was used to extract the physical characteristics of watersheds using Arc-Hydro and the Geospatial Hydrologic Model Extension HEC-GeoHMS. Then the HEC-HMS program was selected for this study, to attain the water balance components of the basin due to its versatility, capability for flow generation, automatic parameter optimization and its connection with GIS through HEC-GeoHMS.

HEC-ResSim (Hydrologic Engineering Center-Reservoir System Simulation) was used to simulate the water allocation and operation of ongoing and planned reservoirs system in Genale-Dawa River basin. The performance of the model has been evaluated through calibration and validation process. The HEC-HMS model was calibrated and validated on a monthly time scale, with reference to Chena-Mansa gauging station to estimate the flow from Genale-Dawa river basin using a time series dataset of 16 years from 1990-2005. Following the configuration, and application of HEC-ResSim model, the position of guide curve was fixed at a minimum operative level for GD-3 and assigned at top of conservation zone for GD-5, and GD-6 along with explicit system storage balance which is used to force the upstream reservoir, GD-3, to fill first, allowing the downstream reservoirs, GD-5, and GD-6 to stay empty as long as possible when operating for flood control. The results of annual average hydropower energy generated by the model from joint operation of the reservoirs system is 4,311.25 GWh/year. The whole cascade power generation increment is 381.25 GWh/year and it is a 9.701% improvement over the current design which is 3,930 GWh/year. Also, combined reservoir system operation model is capable to store 517.13 million cubic meter flood water resources annually which shows 16.75% total reduction of spill release over the current design.

3. MATERIALS AND METHODOLOGY

3.1.Description of the Study Area

3.1.1. Location of the study area

The Genale-Dawa river basin occupies parts of the three Regional States: Oromiya and Somali and a small part of the Southern Nations, Nationalities and Peoples' Region (SNNPR). The geographical coordinates are: 3°30' N to 7°20' N; and 37°05' E to 43°20' E. The total area of the basin is about 172, 889 km^2. (GDMP 2005, WLRC, 2015).

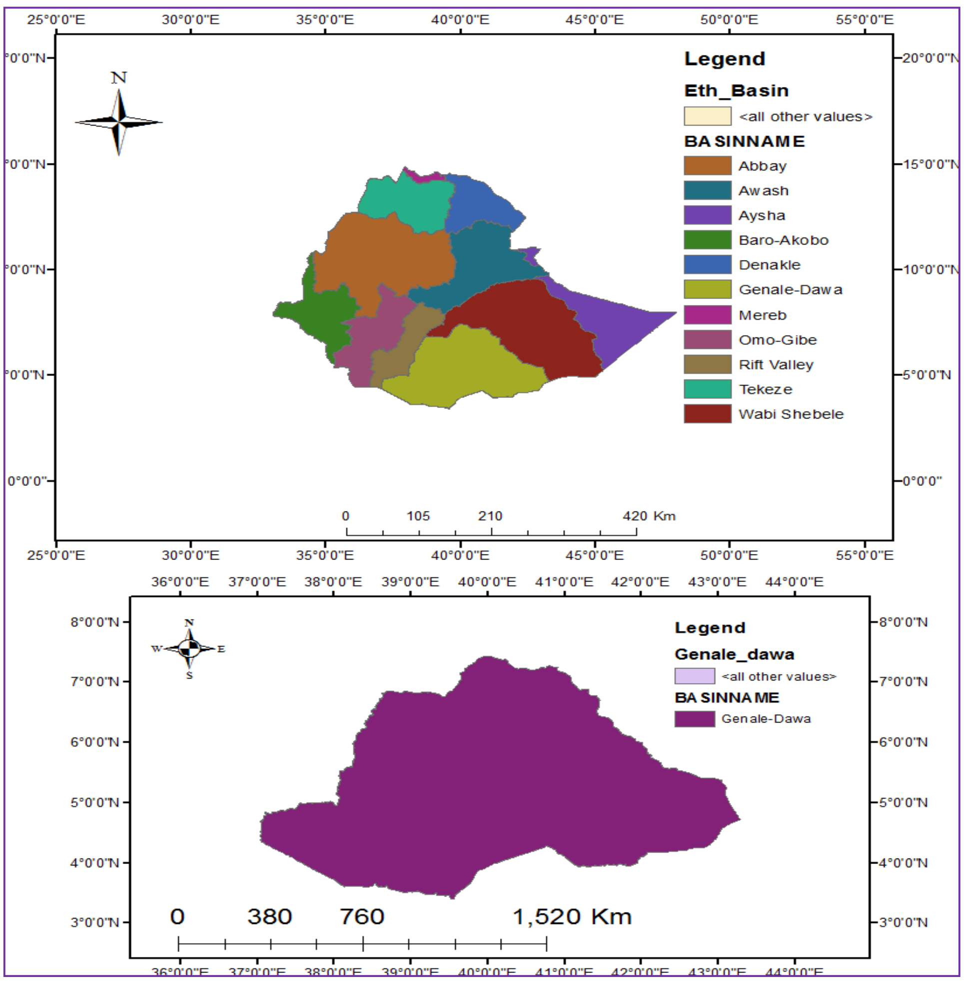


Figure 3.1-1 Location of the study area

3.1.2. Topography

Genale Dawa basin is found within the southernmost a part of Ethiopia characterized by great geographical diversity with high and rugged mountains, flat-topped plateau, deep gorges, and plains. On the northern side of the basin, the highest peak is Mount Tulu Dimtu (4,377m a.m.s.l). The altitude decreases from north to south and west to east to attain an elevation of 176m a.m.s.l. at both Genale and Dawa sub-basins. (GDMP 2005, WLRC, 2015)

The basin can be defined in terms of four major landforms: Highlands and plateau surrounded by a range of volcanoes, Steep sloping escarpments, gently sloping lowlands adjacent to the foot of the escarpments, and Lowlands and flood plain basins. (WLRC, 2015)

3.1.3. Climate and Hydrology

Rainfall

The easterly and southeasterly moist air currents ascend over the highlands in spring, produce the main rainy season in southeastern Ethiopia in general, and in Genale Dawa basin in particular and bring "small rains" of spring (March to May) to most parts of the country. Southeast (Genale-Dawa river basin), therefore, gets its first maximum rainfall during spring and receives the year's secondary maxima rainfall during autumn from the Indian Ocean easterlies. While the basin receives little rainfall in summer compared to spring (March to May) and autumn (September to November) due to the case that the Southerly Indian Ocean air currents lie in the lee side of the highlands in summer and Atlantic westerly's reach the southeastern lowlands (Genale-Dawa) after losing their moisture on the highlands to the west. (GDMP 2005, WLRC, 2015)

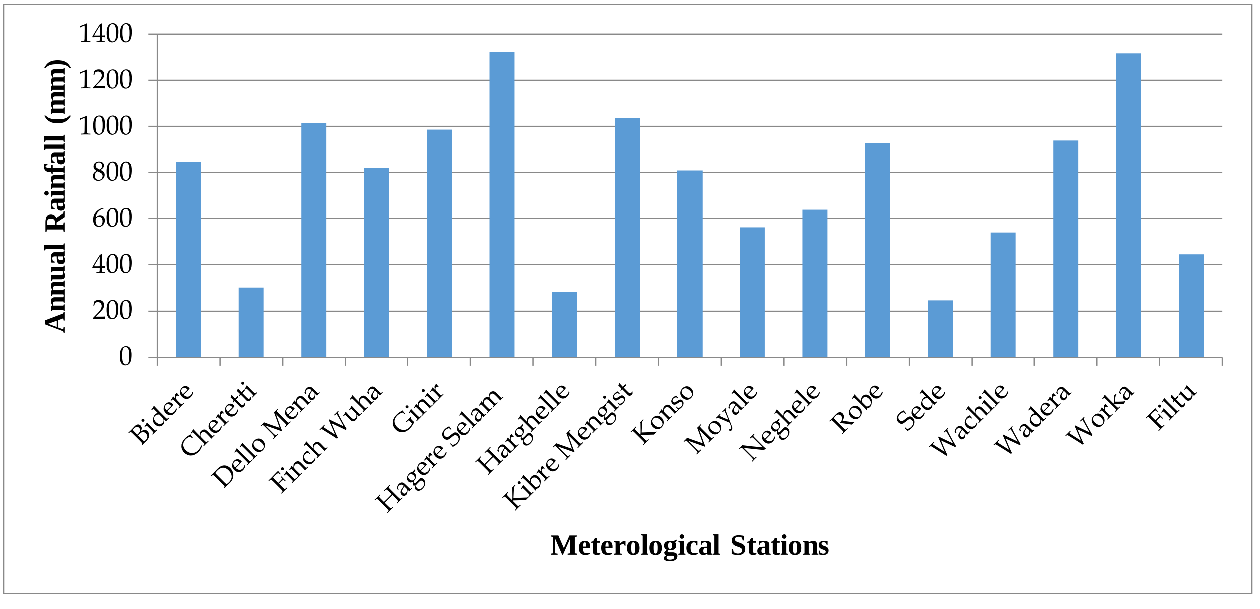


Figure 3.1-2 Annual Rainfall (mm)

Temperature

The temperature varies considerably in the basin within altitude. The mean annual maximum temperature of the study area varies from 22.91c° to 35.08 c°; while the mean annual minimum temperature varies from 6.5 c° to 21.8 c°.

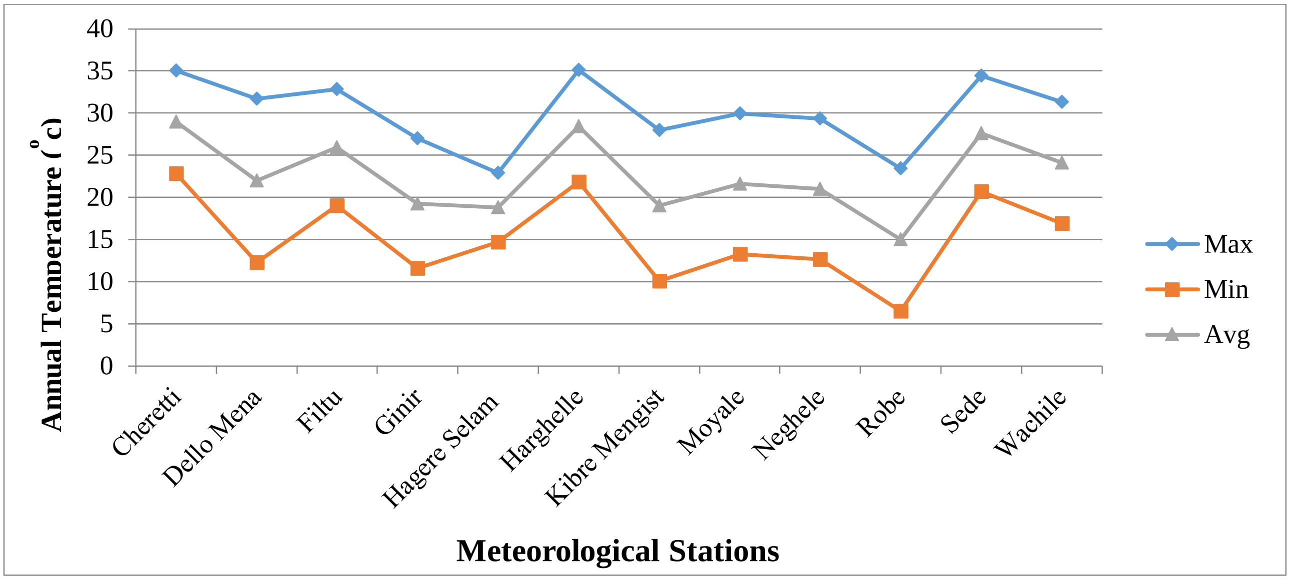


Figure 3.1-3 Annual mean temperature in the basin

3.1.4. Land Use and land cover

The land cover in Genale-Dawa River basins is highly mirrored by cultivated lands and natural vegetation. Each of these cover types is tremendously influenced by the properties of landform, soils, and climate. Below Table 3-1 shows the relative contribution of each land cover type in the basin while Figures 3-1-4 shows the spatial distribution of these land cover types. Generally, the major land-use activities in the basin are:-

Table 3.1-1 Land Use Groups Used in the WEAP Model

No	Class	Area Ha	Area %	No	Class	Area Ha	Area %
1	Forest	8849051.1	7.78%	6	Barrenland	12325513	10.84%
2	Woodland	26768665	23.55%	7	Wetland	363221.1	0.32%
3	Shrub/Bush	28081235	24.70%	8	Water Body	850897.6	0.75%
4	Cropland	22620755	19.90%	9	Afroalpine	224985.2	0.20%
5	Grass Land	13372674	11.76%	10	Settlements	224597	0.20%

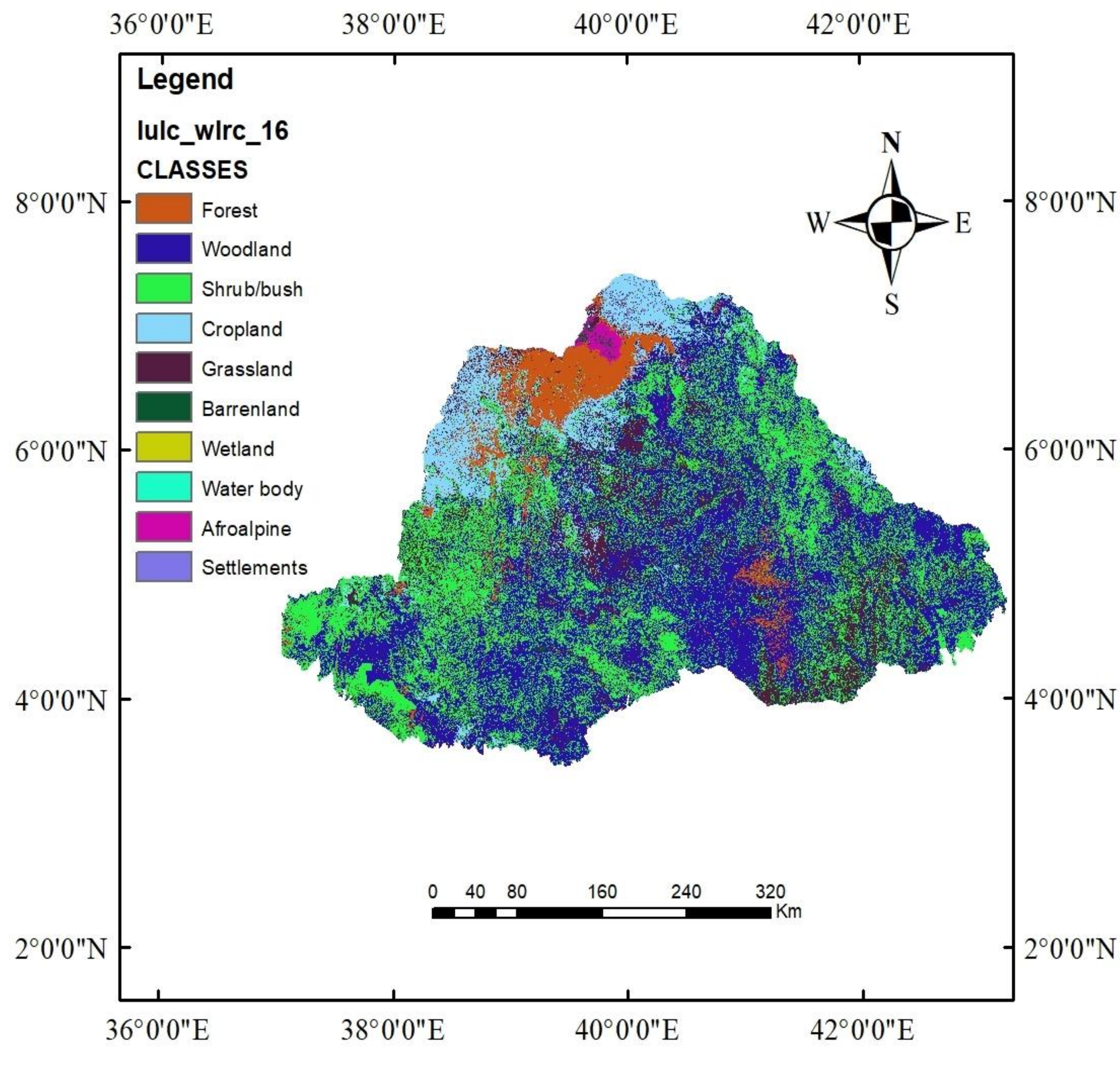


Figure 3.1-4 Land use Land cover of Genale Dawa river basin (WLRC, 2017)

3.1.5. Soil map and soil properties

Soils that have predominantly available in the study area are Cambisols, Leptosols, Luvisols, Calcisols, Nitisols, Arenosols, Vertisols, Fluvisols and Regosols. The detailed soil types and major soil Physico-chemical properties for the Genale Dawa river basin was obtained from Water Land Resource Center, Addis Ababa University (WLRC). Information, and presented below in figure and tables

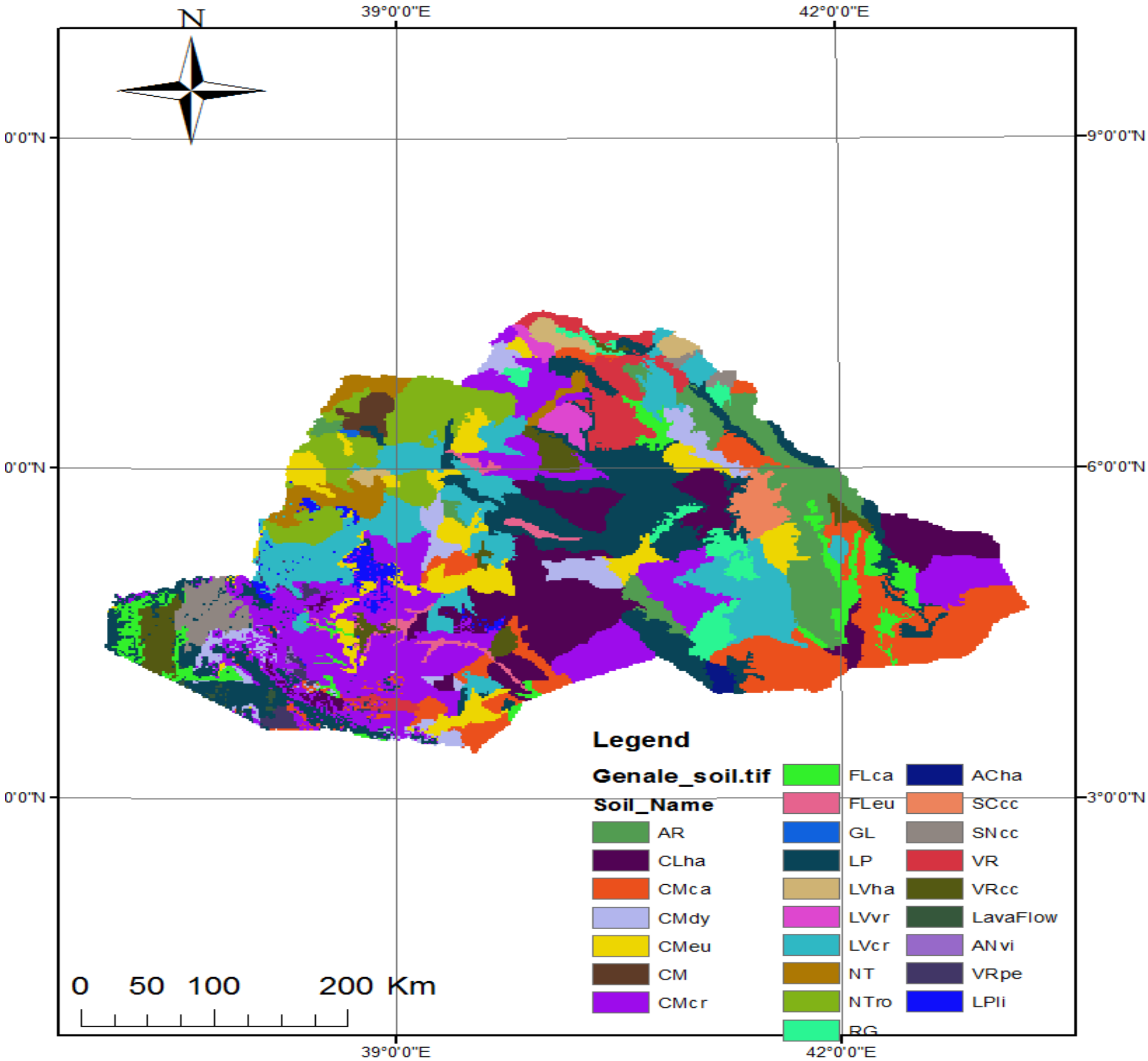


Figure 3.1-5 Soil distribution map of Genale Dawa River basin (Soil geo-database of Ethiopia prepared by (Belete B. 2013)

Table 3.1-2 Major Soil distribution within Genale Dawa riveTable 3.1-3r basin

Code	SOIL TYPE	AREA(KM2)	Area %	SNAM	SOIL TYPE	AREA (KM2)	Area %
ACha	Haplicacrisols	281.4	0.2	LVcr	Chromic Luvisols	17643.1	10.2
AR	Arenosols	9824.4	5.7	NT	Nitisols	3603.7	2.1
CLha	Hapliccalcisols	17498.0	10.1	NTro	Rhodicnitisols	8938.0	5.2
Cmca	Calcariccambisols	16401.0	9.5	RG	Regosols	3581.0	2.1
Cmdy	Dystriccambisols	5693.4	3.3	SCha	Haplicsolonchaks	504.6	0.3
Cmeu	Eutriccambisols	9588.2	5.5	SCcc	Chromic Solonchaks	1902.1	1.1
CM	Cambisols	1109.6	0.6	SNcc	Solonetz	2833.8	1.6
CMcr	Chromic Cambisols	27801.0	16.1	VR	Vertisols	4933.2	2.9
FLca	Calcaricfluvisols	6178.6	3.6	VRcc	Calcaricvertisols	4380.0	2.5
FLeu	Eutricfluvisols	1488.1	0.9	LavaFlow	Lavaflow	207.0	0.1
GL	Gleysols	84.1	0.1	ANvi	Verticandosols	71.2	0.0
LP	Liptosols	22554.0	13.0	VRpe	Petrivvertisols	928.4	0.5
LVha	Haplicluvisols	1591.6	0.9	LPli	Lithic Liptosols	1772.7	1.0
LVvr	Verticluvisols	1497.8	0.9	**Total**		**172889.0**	**100.0**

3.2.Existing Situation of Genale Dawa River Basin

3.2.1. Existing Irrigation Situation

In the Ganale Dawa river basin an area under irrigation and supposed to include under irrigation all together account for 37,951 ha to be utilized by about 156,727 households. The irrigation schemes for which design and study underway and completed together with those under construction all together account for 31,010 ha. A total of 36 modern schemes were constructed in the basin among which 10 are currently fully functional, 17 are semi-functional and 9 are non-functional. Functional and semi-functional together covering about 2627 ha of irrigated land (table 3-2) and the detail schemes functional, semi-functional, non-functional, study and design completed and those under construction are attached on annex table at the end of this study document The non-functionality of modern schemes in most cases is due to scarcity of irrigation water during the peak period, structural damage and siltation problems. There are about 35 traditional and 2 state & private schemes irrigating 2255 ha of land utilized by 150,479 household beneficiaries. (OIDA, 2017).

Crops such as maize, potato, onion, tomato, cabbage, garlic, beetroot, and some fruits are predominantly produced with both traditional and modern irrigation schemes. Pump irrigation is common, borrowing or renting from each other, by small scale producers in the basin where a large volume of vegetable and maize crops are produced and supplied to local markets. (OIDA, 2017)

Table 3.2-1 Existing Irrigation Situation (Source OIDA, 2017)

Category	Number	No of Woreda	Planed (ha)	developed (Ha)	Beneficiary (HHS)
Functional	10	5	1445	1331	
semi-functional	17	4	2225	1242	
non functional	9	8	1244		6,248
under study	28	17	13840		
study & design completed	34	21	15920		
under construction	15	11	1250		
Total	113	66	35924	**2573**	6248
traditional scheme > = 25 ha	36	9		2027	150,479
State & private Irrig, devel.	2			228	
Total				**2255**	
Grand total	**150**	**75**	**37951**	**4,882**	**156,727**

3.2.2. Potential for Expansion

The development potential is a function of the agro-climate, soil, water availability, crop water demand, and land capability in the basin. An initial assessment was carry out in GDMP to clearly understand and identify the available potential irrigable land of about 500,000 ha in the basin. According to GDMP and various studies undertaken the current potential of the area that can be considered as an opportunity for further expansion is possible as potential big rivers and available groundwater potential are the main indicators for further development. Under the present study, the main selected potential irrigation projects which have been studied detail are selected for this analysis and also have been prepared in table below

Table 3.2-2 Potential for Expansion

No.	**Scheme Name**	**Area (ha)**	**Remark**
1	Bale Gadula Irrigation	5000	Detail design
2	Welmel Irrigation	11,040	Detail design
3	Yadot Irrigation	5400	Detail design
4	Lower Genale Irrigation	14460	Feasibility Design

3.3.Methodology

3.3.1. Watershed delineation

Before data collection the boundary of the study area was delineated. The Digital Elevation Model (DEM) following drainage boundaries with Rift valley reservoir basin coverage was shown blow.

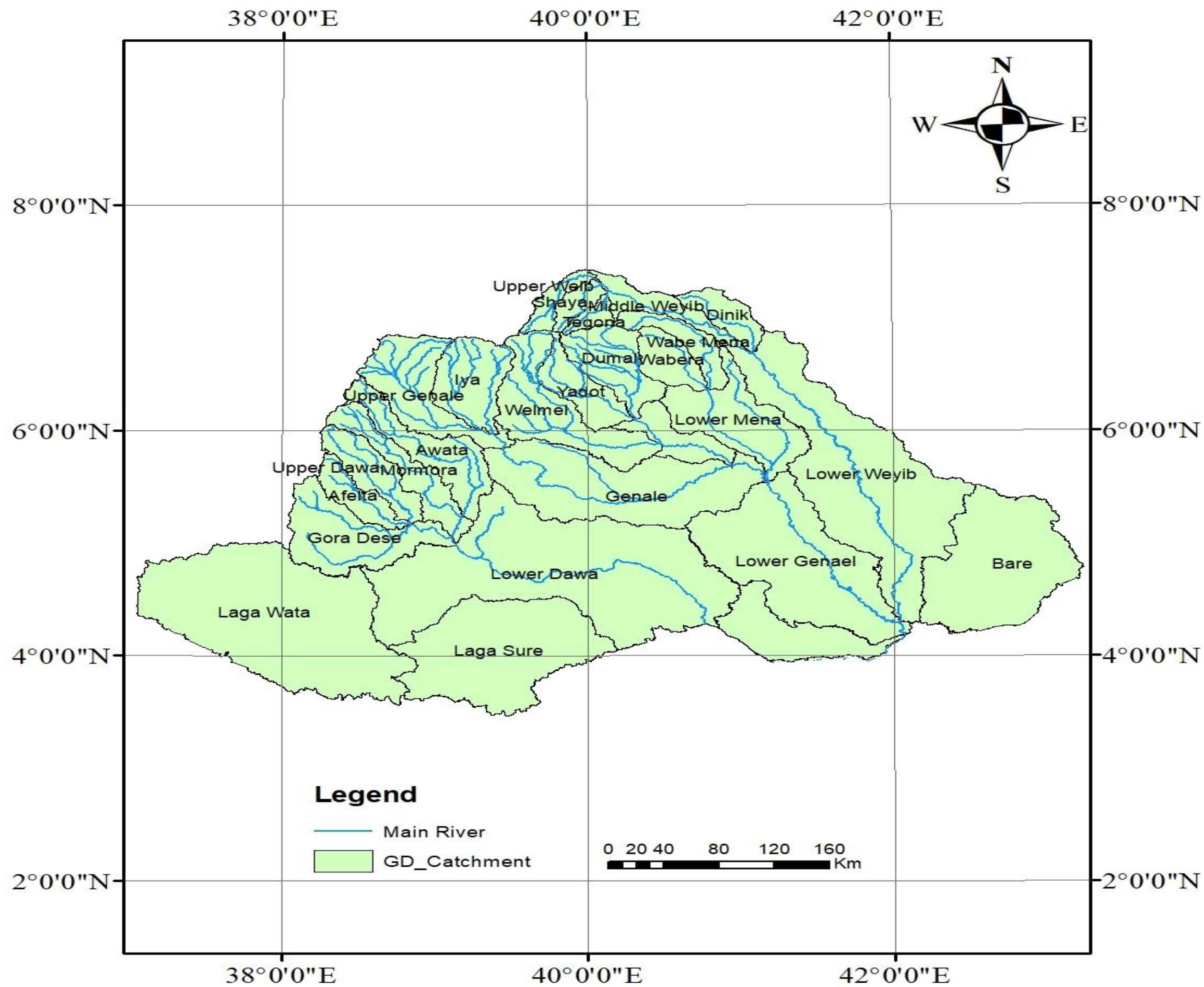


Figure 3.3-1 Genale Dawa River Basin Watershed delineation

3.3.2. Data collection

Before using and processing of any research, the primary task of the study was getting/collecting relevant information or data of the study area. This section identifies and discusses the types and sources of data required for the study.

3.3.3. Materials Used

The materials used for this research depending on the objective were Arc view GIS tool to obtain hydrological and physical parameters and spatial information of the study area, DEM data used as an input data for ARC-GIS software for catchment delineation and estimation of catchment characteristic, Hydrological and meteorological data, WEAP model for basin simulation, CMhyd tool is used for bias Correction of climate projections and Microsoft EXCEL to analyze WEAP outputs.

3.3.4. Hydrological data

Hydrological gauging stations in the Genale Dawa River basin are mainly maintained by the Hydrology Department of the Ministry of water and energy (MoWIE) which processes and files data. In the Genale Dawa River basin, there are about 21 hydrological gauging stations that record the flow in the River, figure 3-2-2 below shows the basic spatial distribution of streamflow gauging stations in the basin.

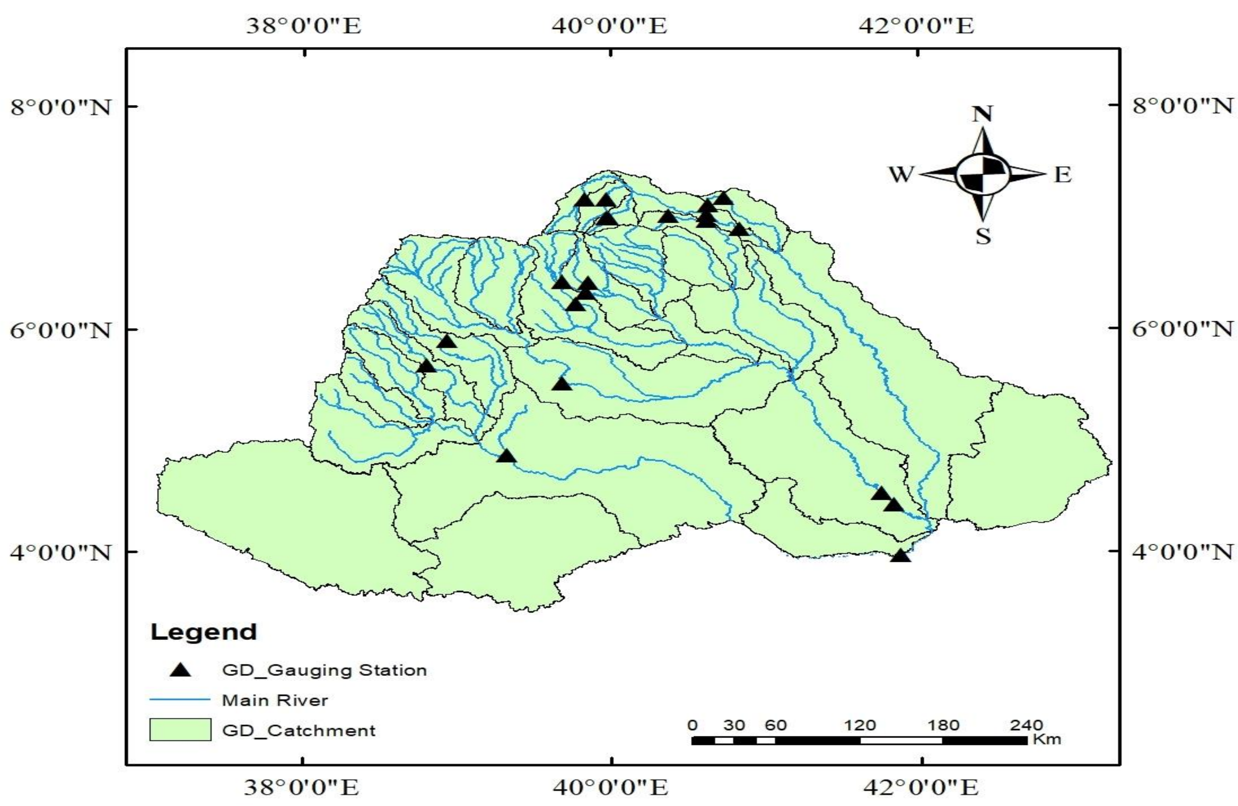


Figure 3.3-2 Stream flow gauging stations in Genale Dawa Basin (MOWIE, 2018)

The streamflow data (available throughout the entire year) was used for calibration and validation of the results obtained from model simulation. The stream flow data (1990 - 2008) were collected from the Ministry of Water, Irrigation, and Energy of Ethiopia hydrology department specifically for the Genale Dawa river basin.

Table 3.3-1 Selected hydrological gauging station for the study in the baisn

No.	Gauge Location River	Gauge Station Name	Calibration Period	Validation period
1	Dawa	Melka Guba	1990 - 2000	2001 - 2008
2	U/s Genale	Chenemesa Gauge	1990 - 2000	2001 - 2008
3	D/s Genale	Halowey Gauge	1990 - 2000	2001 - 2008
4	Upper Weyib	Nr.Bore Dimtu Gauge	1990 - 2000	2001 - 2008

3.3.5. Meteorology data

At present there are several meteorological stations, which were installed by the National Meteorological Agency (NMA) of Ethiopia. Even though sufficient numbers of meteorological stations have been established throughout the project area, information regarding the detailed climatic conditions of the area is very limited because of malfunctioning of gauging stations, recorder not timely measuring the data, etc.

The quality of the studies is dependent on the quality of required elements and quantity or long term records of data. The most commonly observed problems were related to insufficient and incomplete basic data. In this study, there was a problem of insufficiency of complete data for areas in the basin. Meteorological data of this study was mainly based on rainfall data obtained from the National Meteorological Service Agency of Ethiopia (NMAE) and the summary of the selected stations presented in the table below.

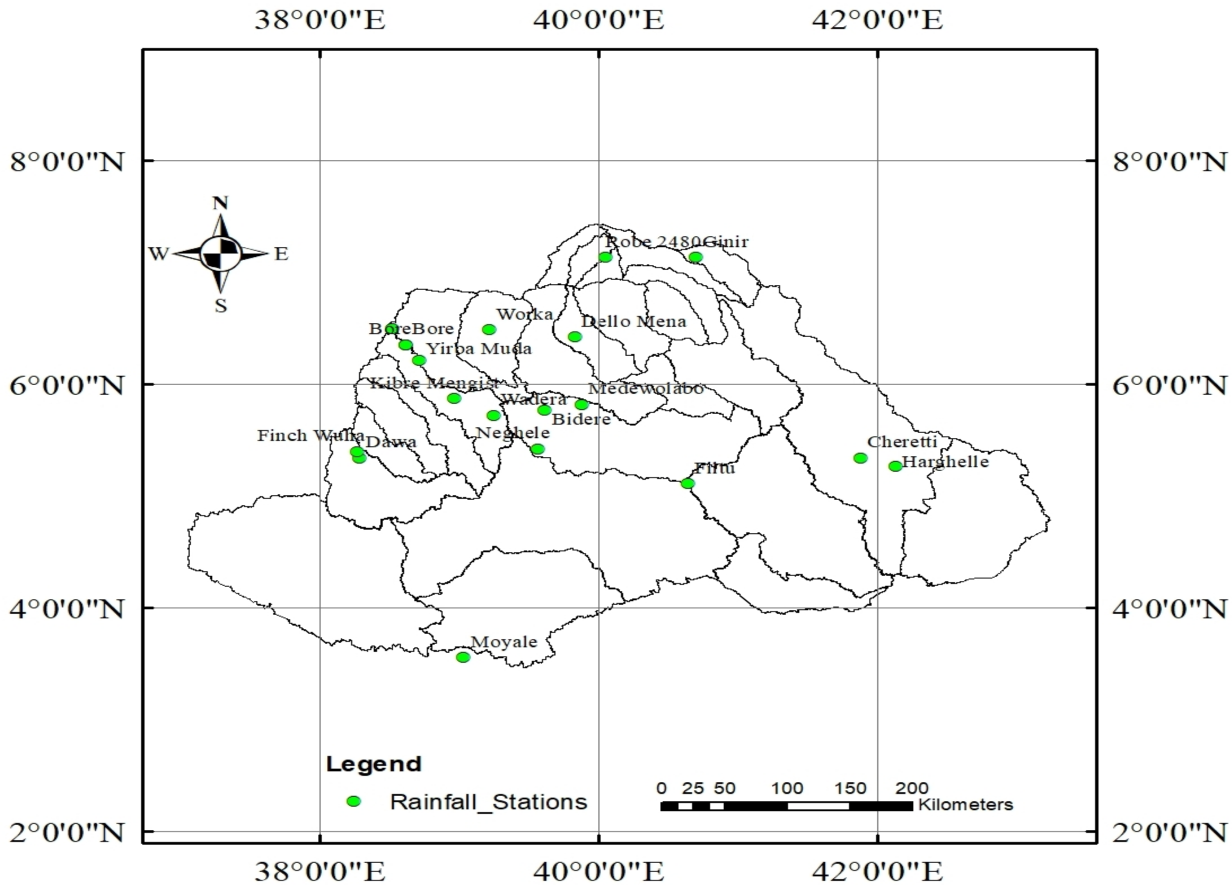


Figure 3.3-3 Meteorological station in Genale dawa Basin (NMA, 2018)

Table 3.3-2 Summary of selected rainfall stations within the study area

Station	Long	Lati	Years of Data Used	(%) Missed	Station	Long	Lati	Years of Data Used	(%) Missed
Konso	37.4	5.3	1987 - 2018	2.1	Worka	39.2	6.5	1987 - 2018	33.3
Robe	40.1	7.1	1987 - 2018	8.9	Finch Wuha	38.3	5.4	1987 - 2018	35.9
Kibre Mengist	39	5.9	1987 - 2018	13.5	Sede	41.3	4	1987 - 2018	38
Dello Mena	39.8	6.4	1987 - 2018	14.3	Wadera	39.3	5.7	1987 - 2018	40.1
Hagere Selam	38.5	6.5	1987 - 2018	14.3	Bidere	39.6	5.8	1987 - 2018	40.9
Neghele	39.6	5.4	1987 - 2018	14.8	Cheretti	41.9	5.3	1987 - 2018	42.6
Ginir	40.7	7.1	1987 - 2018	19.5	Harghelle	42.1	5.3	1987 - 2018	44.4
Moyale	39	3.6	1987 - 2018	32	Wachile	39.1	4.6	1987 - 2018	46

3.3.6. Filling missing rainfall data

The consistency and completeness of these time series is important in that's why Preprocessing of raw data sets by filling data gaps is the became the necessary procedure. (Gao, Y. et al 2018)

However, it is well known that various hydrological research databases contain missing values (Elshorbagy et al. 2002).

For gauges requiring periodic measurement, failure or absence of the observer to make the required visit to the gauge, destruction of the recording gauges and failure of the instrument due to mechanical or electrical malfunctions which result in missing data. (Fufa T. 2015). For any such cause of instrument failure reduces the length and information content of the precipitation record. The multi-regression filling method was therefore used to compute missing data for the analysis of rainfall data.

After selecting which station better matches the station records in a query using less percentage of the missing data process, multi-regression between them indicates the equation in which the given value should be determined in order to obtain the approximate missing data records for the corresponding time. In most cases, missing data should be filled using multiple stations, as the missing data may not be found as a whole only in one station, in which case either the unfilled rest will be filled using the monthly mean already available (if there is a short period of time) or another regression will be made with another station that has a record in those months and years.

$$Y1 = m_1x_1 + b \quad (3.1)$$

The first regression is done to fill the first station using one station X and slope m1 and intercept

$$Y2 = m_1x_1 + m_2x_2 + c \quad (3.2)$$

The second regression using two filled stations the third station is being filled and the third and so on will continue using n-1 station to fill the nth regression station.

$$Y3 = m_1x_1 + m_2x_2 + m_3x_3 + d \quad (3.3)$$

$$Yn = m_{n-(n-1)}x_{n-(n-1)} + m_{n-(n-2)}x_{n-(n-2)} \ldots + m_nx_n + \text{Constant} \quad (3.4)$$

3.3.6.1.Consistency test

Rainfall data can be made consistent by adopting double mass curve technique. It is a technique that a plot of two cumulative quantities that are measured for the same period should be a straight line and their proportionality unchanged, which is represented by slop. The stations to be checked should be meteorologically similar in the given area of study and the double mass curve technique was used to adjust precipitation records to take account of non-representative factors such as a change in location or exposure of rain gauge. The accumulated totals of the gauge in question are compared with the corresponding totals for a representative group of the nearby gauge. (Ponce V.M, 1989) If significant change in the system of the curve is observed, it should be corrected by:

$$P'_X = P_X * \frac{M'}{M} \quad \text{……………………………………………………………………………} (3.5)$$

Where: - P'_X = Corrected precipitation at station x

P_x = Original recorded precipitation at station x

M' = Corrected slope of the double mass curve

M = Original slope of the double mass curve

3.3.6.2. Areal rainfall determination

Rain gauge stations are uniformly distributed into the sub-system in a given drainage basin. The rain of one station in the basin may be different from that of the second station in the same catchment area. And since a single point precipitation measurement is also not indicative of the volume of precipitation occurring over the catchment area the average precipitation value for the entire basin is worked out in order to achieve sufficient rainfall such that the catchment limits are carefully defined. Rainfall over a region of concern must also be determined from such point measurements.

There are usually three ways of determining the areal precipitation over a catchment from rain gauge measurement. These methods are the Arithmetic means, the Thiessen polygon, and the Isohyetal method. However, the Thiessen polygon was used for this study for its sound theoretical basis and availability of computational tools. But the method is dependent on a good network of representative rain gauges and does not allow the hydrologist to consider factors, such as topography (Daniel, 2008).

To determine the mean areal rainfall, the rainfall amount of each station was multiplied by the area of its polygon and the sum of these products was divided by the total area of the catchment. If P_1, P_2, P_3…… P_n is the rainfall magnitudes recorded by the gauging stations 1, 2…….n, respectively, and if the areas of Thiessen Polygon A1, A2, and A3...… An, are formed as representative of the respective stations then the average rainfall over the catchment is given by:

$$P_{avg} = \frac{P_1A_1 + P_2A_2 + P_3A_3 + P_nA_n}{A} \quad (3.6)$$

Where: -

P_{avg} = areal precipitation over the sub-basin (mm); P1, 2…n = precipitation depth in each station (mm);

A1, 2 …n = area of each polygon (km2);

A = total watershed area of sub-basin (km2).

3.4.RCM data correction procedure

The added benefit of the RCMs is linked to their ability to provide additional climate change signals that are not solved in the GCMs coarser resolution. (Di Luca, A. et al 2011). The main improved features of RCM over GCM are a better representation geographical features with higher spatial resolution (12.5-50km) and that of description of physical process by means of sub grid scale parameterization and more detailed surface schemes. (Wei Young et al 2010).

Biases are a long term average deviations between simulations and observations (Mendez M. et al, 2020) and the removing of this deviation is known as bias correction.

Boundary errors transferred from GCMs to RCMs, Insufficiently resolved surface properties related to spatial resolution, Numerical resolution and internal model parameterization are among the main cause of RCM biases. Therefore this errors and biases should be corrected. There are several methods of bias correction methods which have been developed to adjust meteorological variables ranging from simple scaling approaches to sophisticated distribution mapping from the RCM. (Fowler, H.J et al, 2009) and for this study the Distribution mapping bias removal approach is selected which is a method that has been extensively discussed and applied in similar studies based on climate model predictions (Fufa T. 2016). And from representative gauges daily precipitation data is prepared from a period of 01/01/1987 up to 31/12/2017 and also climate Model data (CORDEX-AFRICA RCP 8.5) is extracted and prepared from a period of 01/01/1987 up to 31/12/2050 for CMhyd (Climate Model data for hydrologic modeling) to identify the biases the tool used the overlapping period (1987-2017) and formulate a parameterize bias correction algorithm to correct the Climate Model data and parameterization the current climate conditions are assumed to be valid for future conditions.

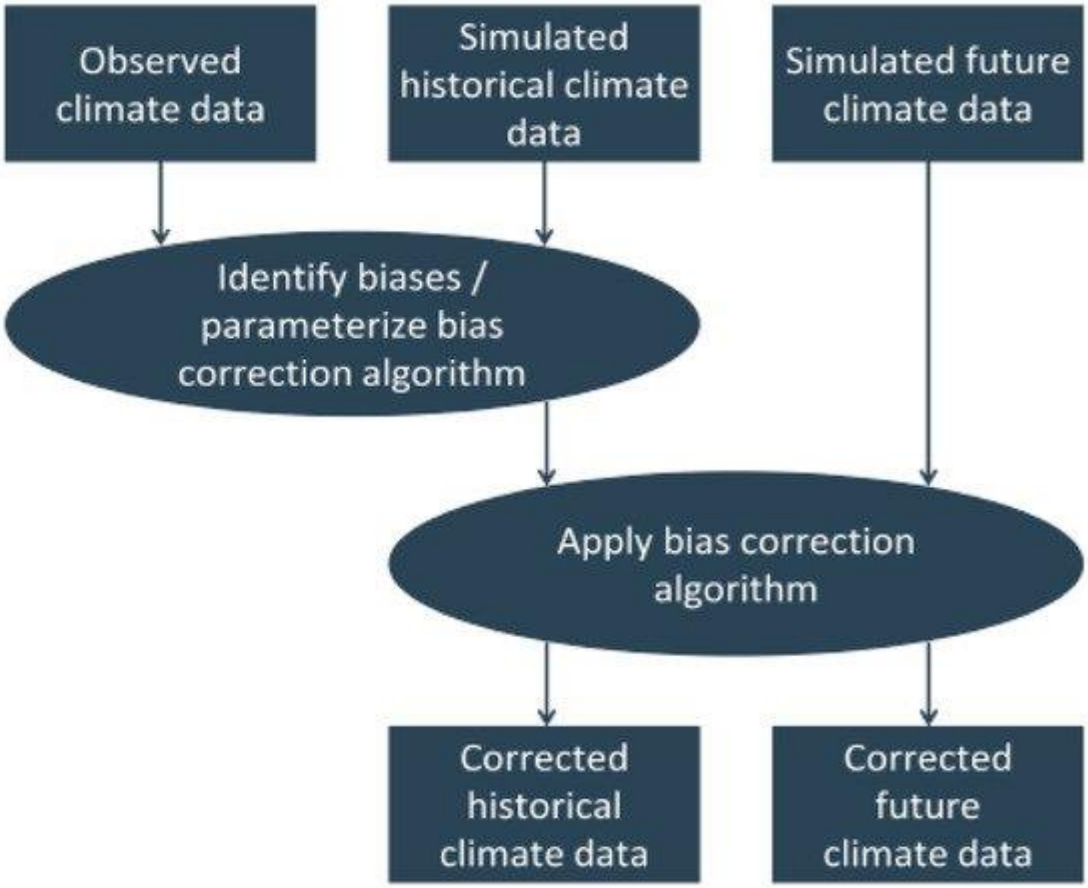


Figure 3.4-1 RCM data correction procedure

CMhyd was designed to work with the CORDEX data archive, which provides downscaled regional climate model data. The data can be downloaded for specific domains.

The bias-corrected was based on the Distribution mapping; a method that has been extensively discussed and applied in similar studies based on climate model predictions (Tadesse Fufa, 2016). The Distribution mapping bias removal approach is to match the distribution function of raw RCM data to that of observation data.

It was used to adjust mean, SD, and quintiles. The distribution mapping (DM) method considers computing parameters, the Gamma distribution with shape parameter (α), and scale parameter (β) often used for precipitation distribution the two parameters were obtained from easy fit software by inputting monthly local intensity scaling corrected and monthly observed data. The DM method thus assumes that future model biases will be the same as those in present-day simulations.

The performance evaluation of these RCM data corrected datasets were tested with time series performances against observed precipitation data. The time series based metrics include the Nash–Sutcliffe measure of efficiency (NSE) and the correlation coefficient (R2) has been applied NSE indicates how well the simulation matches the observation, and it ranges between – ∞ and 1.0, with NSE = 1 indicating a perfect fit. The higher this value, the more reliable is the model. The above indication defined as follow:

$$R^2 = \frac{\sum_{i=1}^{n}(P^i obs - \bar{P}^i obs)^2 - \sum_{i=1}^{n}(P^i sim - \bar{P}^i sim)^2}{\sum_{i=1}^{n}(P^i obs - \bar{P}^i obs)^2} \quad (3.7)$$

$$NSE = 1 - \frac{\sum_{i=1}^{n}(P^i obs - P^i cor)^2}{\sum_{i=1}^{n}(P^i obs - P^{mean} obs)^2} \quad (3.8)$$

Where: P^i obs andP^i cor is the ith observed and simulated variables, $P^{mean}$is the mean of observed variables, and n is the total number of observations.

3.5. Model Calibration

Calibration is an iterative exercise used to establish the most suitable parameter in modeling studies. It is very important because reliable values for some parameters can only be found by calibration (Reuben, 2007). It involves the user is capable or adjust the default values of the input parameter that define the underlying mechanics to represent the real conditions that have been observed in models. Model parameters changed during calibration were classified into physical and process parameters. It is important to calibrate the model against real-world data, in order to have faith in the results of a distribution system model. This process includes comparing model results with data obtained from the field, finding places where the model and field differ, assessing the reasons for any inconsistencies, and making the necessary changes to calibrate the model. (Walski, T. 1983). And after calibration the results can be checked by using the Nash-Sutcliffe Efficiency (NSE), and coefficient of correlation (R2)

Table 3.5-1 Calibration parameters in possible ranges

No.	Variable / Parameter	Range	Unit
1	Soil Water Capacity	> = 0	Mm
2	Deep Water Capacity	> = 0	Mm
3	Runoff Resistance Factor	> = 1000	---
4	Root Zone Conductivity	20	mm/month
5	Deep Conductivity	> = 0.1	mm/month
6	Preferred Flow Direction	> = 1	---
7	Initial Z1	0 - 100	%
8	Initial Z2	0- 100	%

3.6.Model Validation

Model Validation is the process of representing that a given site-specific model is capable of making accurate predictions. This was done by applying the calibrated model using a different data set out of the range of calibration without changing the parameter values. The model is said to be validated if its accuracy and predictive capability in the validation period have been proven to lie within acceptable limits (Reuben, 2007). Observed and simulated hydrograph values were again compared as in the previous calibration procedure. If the resultant fit is acceptable then the model's prediction as valid.

3.7.Catchment Simulation Methods

Depend on the level of complexity desired for representing the catchment processes and data availability, WEAP offers five different methods for simulating the catchment water. Which are Rainfall-Runoff (Simplified Coefficient Method), Irrigation Demand Only (Simplified Coefficient Method), Rainfall-Runoff (Soil Moisture Method), and MABIA (FAO56) and Plant Growth method (SEI 2019).

In this analysis the method of soil moisture was chosen to simulate the relationship of rainfall runoff in the region of study. This method divided soil into two layers (See figure 3-7-1). The upper layer of soil, or Bucket 1, is used to simulate runoff, shallow interflow, evapotranspiration, and soil moisture while the lower layer of soil, or Bucket 2, is used to simulate percolation and base flow that can be transmitted to the aquifer or routed to a river (Sieber & Purkey 2015, SEI 2019).

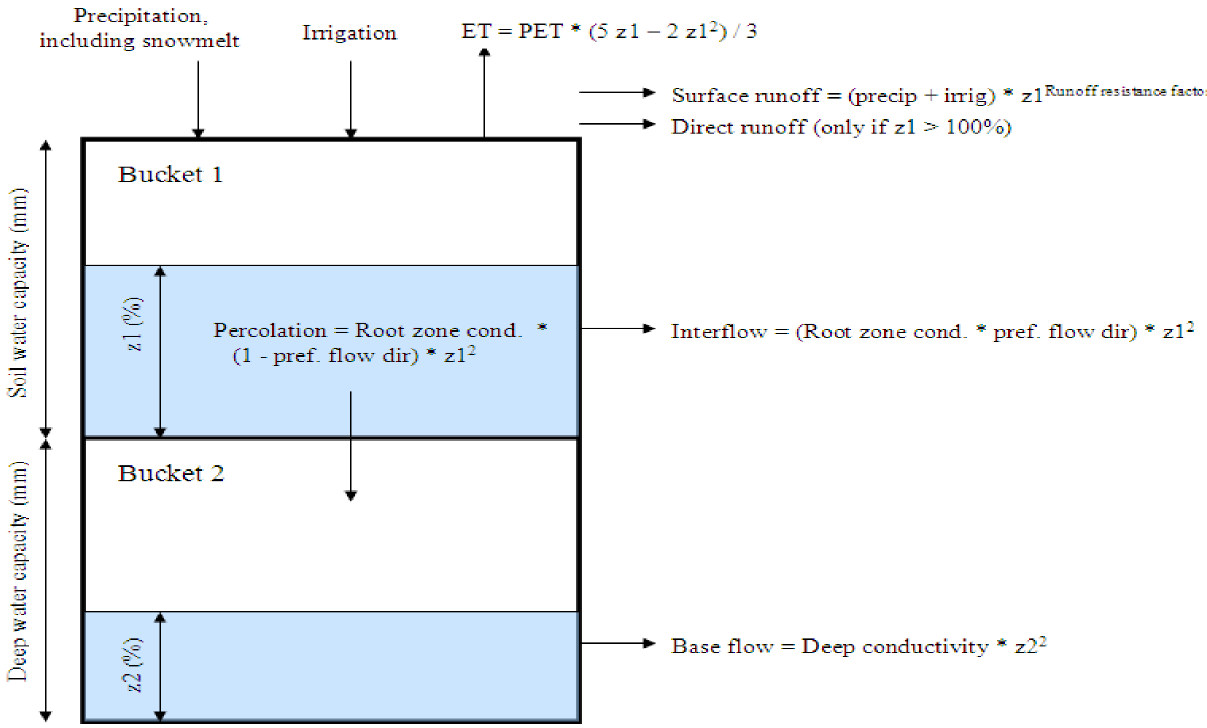


Figure 3.7-1 Concept of soil moisture and equations (source: WEAP User Manual)

Each watershed unit was representing different land use, and a water balance was computed for each fractional area, j of N. Climate is assumed uniform over each sub-catchment, and the water balance of the sub-catchment was given as,

$$Rd_j \frac{dz_{1j}}{dt} = p_e(t) - PET(t)K_{cj}(t)\left(\frac{5z_{1,j} - 2z_{1,j}^2}{3}\right) - P_e(t)Z_{1,j}RRF_{j1} - (1 - f_j)k_{s,j}Z_{1,j}^2 - f_jk_{s,j}Z_{1,j}Z_{1,j}^2 \quad (3.9)$$

Here $Z_{1,j}$= [1, 0] is the relative storage given as a fraction of the total effective storage of the root zone, Rd_j (mm) for land cover fraction, j. P_e is the effective precipitation. PET is the Penman-Montieth reference crop potential evapotranspiration where $K_{c\,j}$is the crop/plant coefficient for each fractional land cover. The third term (Pe (t) z1, j RRFj) represents surface runoff, where $RRF_{j1}$is the Runoff Resistance Factor of the land cover. The higher values of RRFj lead to less surface runoff. The third and fourth terms are the interflow and deep percolation terms, respectively, where the parameter ks,j is an estimate of the root zone saturated conductivity (mm/time) and fj is a partitioning coefficient related to soil, land cover type, and topography that fractionally partitions water both horizontally and vertically. The total runoff (RT) from each sub-catchment at time t is,

$$RT\ (t) = \sum_{j=1}^{N} A_j \left(p_e\ (t) Z_{1,j} + RRF_{\ j} + f_j\ k_{s,j}\ Z_{1,j}{}^{2}\right) \ldots\ldots (3.10)$$

Baseflow emanating from the second bucket is computed as:

$$S_{max}\ \frac{dz_{\ 2}}{dt} = \left(\sum_{j=1}^{N} \left(1 - f_j\right) k_{s,j}\ Z_{1,j}{}^{2}\right) - k_2 Z_{\ 2}{}^{2} \ldots\ldots (3.11)$$

Where the inflow to this storage, Smax is the deep percolation from the upper storage and Ks2 is the saturated conductivity of the lower storage (mm/time), which was given as a single value for the catchment.

3.7.1. Water demand calculation and Allocation Priorities

As described in the WEAP User Guide, the calculation process is based on a mass water balance for each node, and the link is subject to demand priorities and supply preferences. The estimate begins from the current account year's first month until the last month of the last scenario. For non-storage nodes like points on a river, calculation of the current month is independent of calculation of the previous month. For storage nodes like reservoirs, soil moisture, or aquifer storage, storage for the current month depends on the value of the preceding month. Whatever water enters the system in the course of a month, it will either be deposited in a reservoir, aquifer, or catchment soil, or exit the system through consumption or evapotranspiration from demand site. In the schematics configuration, the identified sites were included in the model as individual demands rather than group demands, but it could reduce the flexibility in modeling how each irrigation site can make demands on the surface water network according to its particular cropping pattern.

WEAP will determine the allocation order to be followed when assigning water demand Using demand priorities and supply preferences the Allocation Algorithm processes demand sites with higher priorities first and the rest in numerical order assigned. These assigned priorities are useful in the representation of a system of water rights and are also important during water shortages (SEI, 2015). Supply Preferences indicate the preferred supply source where there is more than one source at the demand site. Table 3.4.1 show assigned priority levels of different demand.

Table 3.7-1 Assigned priority levels for Genale Dawa River Basin Catchments

Demand type	Priority level
Water Supply and Livestock	1
Irrigation	2
Reservoir	3

Demand for water was calculated as the sum of the demands for all the demand site bottom level branches (Br). A bottom-level branch is one that has no branches below it. Annual water demand was then calculated as follows:-

$$\text{Annual Demand} = \sum_{Br}(\text{Total Activity Level}_{Br} * \text{Water use rate}_{Br}) \ldots\ldots\ldots\ldots \quad (3.12)$$

The total activity level for a bottom-level branch is the product of the activity levels in all branches from the bottom branch back up to the demand site branch (where Br is the bottom level branch, Br' is the parent of Br, Br'' is the grandparent of Br). The Total Activity Level was given as:

$$\text{Total Activity level}_{Br} = \text{Activity level}_{Br} * \text{Activity level}_{Br} * \text{Activity level}_{Br} * \ldots\ldots \quad (3.13)$$

The activity levels for each branch and the water use rates for all the bottom level branches were inputs into the model. Monthly demands were calculated based on each month's fraction specified as data under Demand\Monthly Variation of the adjusted annual demand as follows:-

$$\text{Monthly Demand}_{DS,m} = \text{Monthly varia fraction}_{DS,m} * \text{Adjusted Annual Demand}_{Ds} \ldots\ldots\ldots \quad (3.14)$$

3.7.1.1. Water supply Demand Calculation for the Genale Dawa river basin

1. Average Daily Demand (ADD)

The average daily demand is taken to be the combined total of the domestic, commercial, institutional, and industrial demands and the system losses.

Average Daily Demand = Demands for Domestic + Commercial & Institutional + Industrial+ Losses.

2. Maximum Daily Demand (MDD)

The daily water consumption in a town varies depending on the time of day, season, and climatic conditions. Therefore, the Maximum Daily Demand (MDD) has been taken as 1.15 times the Average Daily Demand (ADD) for all towns in the basin.

MDD = 1.15 ADD …………………………………………………………………..…. (3.15)

The Maximum Daily Demand sets the requirements from the sources. Thus, the water demands of urban centers are calculated according to the above methodology.

Annual Water Use Rate

The WEAP model needs an annual water use rate as basic input. Based on the specific guidelines given by Ministry of Water, Irrigation and Energy for the Genale Dawa river basin the annual water use rate per person in the basin is calculated below:

Domestic Water Demand (DWD) = 100 lpcd = 0.1 $m^3/c/d$

CIWD = 5% DWD = 0.05 x 0.1 = 0.006 $m^3/c/d$ ………………………………………...… (3.16)

IWD = 10% DWD = 0.10 x 0.1 = 0.012 $m^3/c/d$ ……………………………………………… (3.17)

System Losses = 20% (DWD + CIWD + IWD) …………………………………………… (3.18)

20% (0.1 + 0.006 + 0.012)

= 0.2 x 0.138 = 0.0276 m^3/d

The Average Daily Demand (ADD) = 0.120 + 0.0060 + 0.012 + 0.03 + 0.0276

= 0.195 $m^3/c/d$

Maximum Daily Demand (MDD) = 1.15 ADD

= 1.15 x 0.1956$m^3/c/d$

= 0.2242 $m^3/c/d$

Maximum Demand per person per year = 0.225 x 365 days m^3 = 82.1 m^3/ year

Therefore, take annual water use rate per person is 82m^3 which is the input for WEAP model.

Where: - DWD: Domestic Water Demand, CIWD: Commercial and Institutional Water Demand, IWD: Industrial Water Demand, LWD: Livestock Water Demand and SL: System losses.

The water demand for livestock has been based on FAO livestock standard water demand for East-Africa countries mainly Ethiopia is applied 20litres, 5litres and 37litres per head of cattle, sheet/goat and camel per day respectively. But in the GDMP the average water requirement of the livestock per capital per day is from 10 – 15 lpcd. (GMP, 2005, Tilahun, 2015).

For the agricultural water demand, annual water use is entered based on the (CWR) crop water requirement of each specific schemes in their feasibility or detail design reports.

3.7.2. Scenario Analysis

In Scenario Analysis first the user has to create current water system account then a "reference" or "business-as - usual" scenario projection, referred to as the Reference Scenario, is then established on the basis of a variety of economic, demographic, hydrological and technological trends final a set of one or more policy scenarios with alternative assumptions about future developments can be formulated in scenario development features.

A Scenarios can address a wide range of "what if" questions, such as: what if population growth and patterns of economic development change? What if the operating rules of the reservoir are changed? What happens if the groundwater is more fully exploited? What happens if water management is introduced? What if the criteria of the environment are tightened? What happens if new sources of water pollution are added? What happens if a water recycling program is implemented? What if a more efficient irrigation technique is put in place? What happens if the composition of agricultural crops changes? What happens if climate change changes hydrology? These scenarios can be viewed simultaneously in the WEAP results for easy comparison of their effects on the water system. (SEI, 2019).

In this study a set of three scenario is developed each of the three scenario will have been analyzed in two terms of period a short term which is **2019 – 2030** and a long term from **2031 – 2050** years.

Scenario One "Future Development scenario" a scenario that address what if the future development in the river basin is changed.

Scenario Two "Climate Change Scenario" a scenario that address What if climate change changes of the basin is changed and

Scenario Three "Combination Scenario" a scenario that address both what if the future development and climate changes of the river basin is changed.

4. DATA PROCESSING AND WEAP MODEL SETUP

4.1.Data Analysis

The continuity of recorded data may be broken with missing data due to many reasons such as damage or fault in the gauging station during a measuring period. So, before starting any model simulation, it is important to check whether the data were homogenous, consistent, sufficient, and complete with no missing data. The existing missing data estimated using the data filling methods. Because incorrect data leads to inconsistency and ambiguous results that may contradict the actual value.

4.2.Consistency test

From the double mass curves analysis, all the stations used in the study were consistent. For illustration the double mass curves for some selected stations are presented below and for the others it was attached in Annex 2.

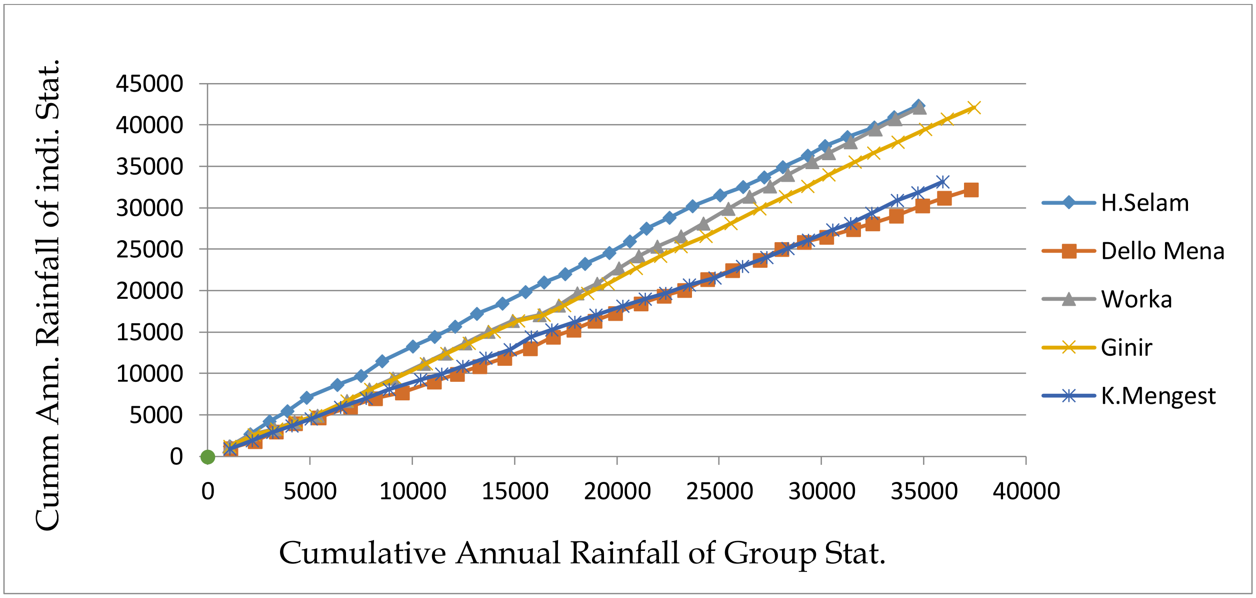


Figure 4.2-1 Consistency Test for selected stations

4.3.Outlier Test

Outliers are data points that depart significantly from the trend of the remaining data. The retention or deletion of these outliers can significantly affect the magnitude of statistical parameters computed from the data, especially for small samples. Procedures for treating outliers require judgment involving both mathematical and hydrologic considerations.

The following frequency equation can be used to detect the outliers from the gathered and filled data using the regression:

$$Y_H = \bar{y} + K_n S_y \text{ ……………………………………………………………………….. (4.1)}$$

$$Y_L = \bar{y} - K_n S_y \text{ ……………………………………………………………...…… (4.2)}$$

Where

Y_H Is the higher outlier threshold in log unit and Y_L is the log of low outlier limit,

K_n The critical deviate taken from Table for sample n

S_y Is the standard deviation of the logs of the sample flows, and $\bar{y}$ is the mean of the log of the sample flows,

After the regression all the station are taste for outlier and hence No outlier set of recorded data is found in all stations. Figure below presented Dello Mena station outlier graph and for the other stations attached in Annex 2

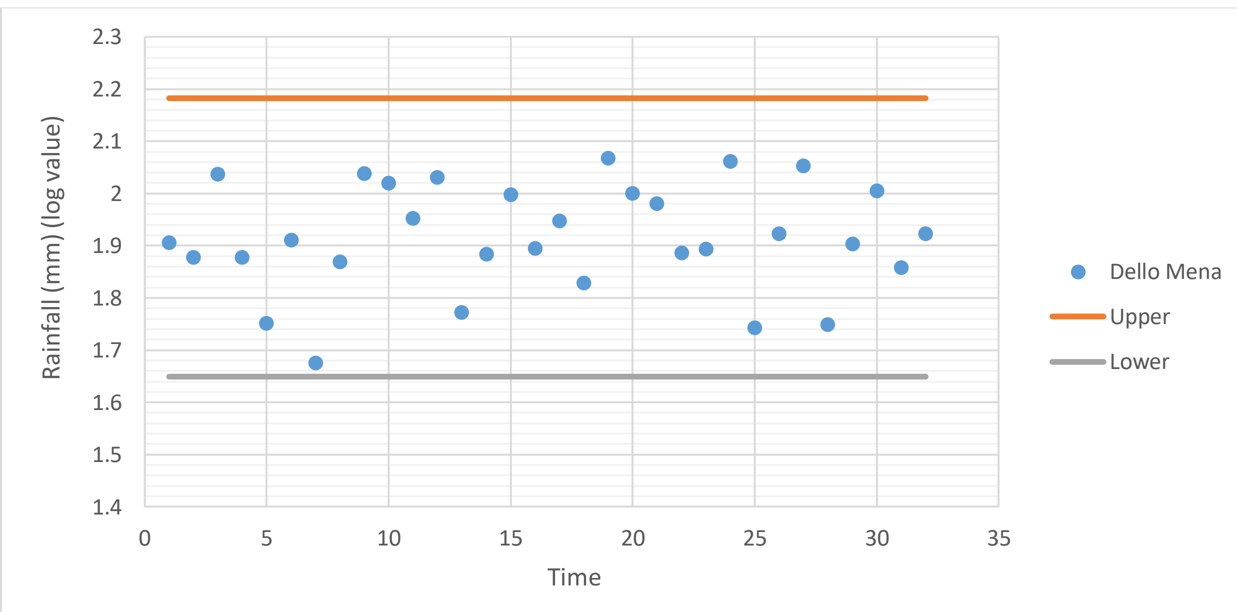


Figure 4.3-1 Outlier Test for selected stations

4.4.Areal rainfall determination

In a given drainage basin rain gauge stations are evenly distributed into sub-basin. The rain of one station in a basin may be different from that of the second station in the same catchment. From this idea the average precipitation value on the entire basin is worked out, to get average rain catchments to have the limits of the catchment carefully defined. Therefore, rainfall over an area of interest has to be estimated from these point measurements.

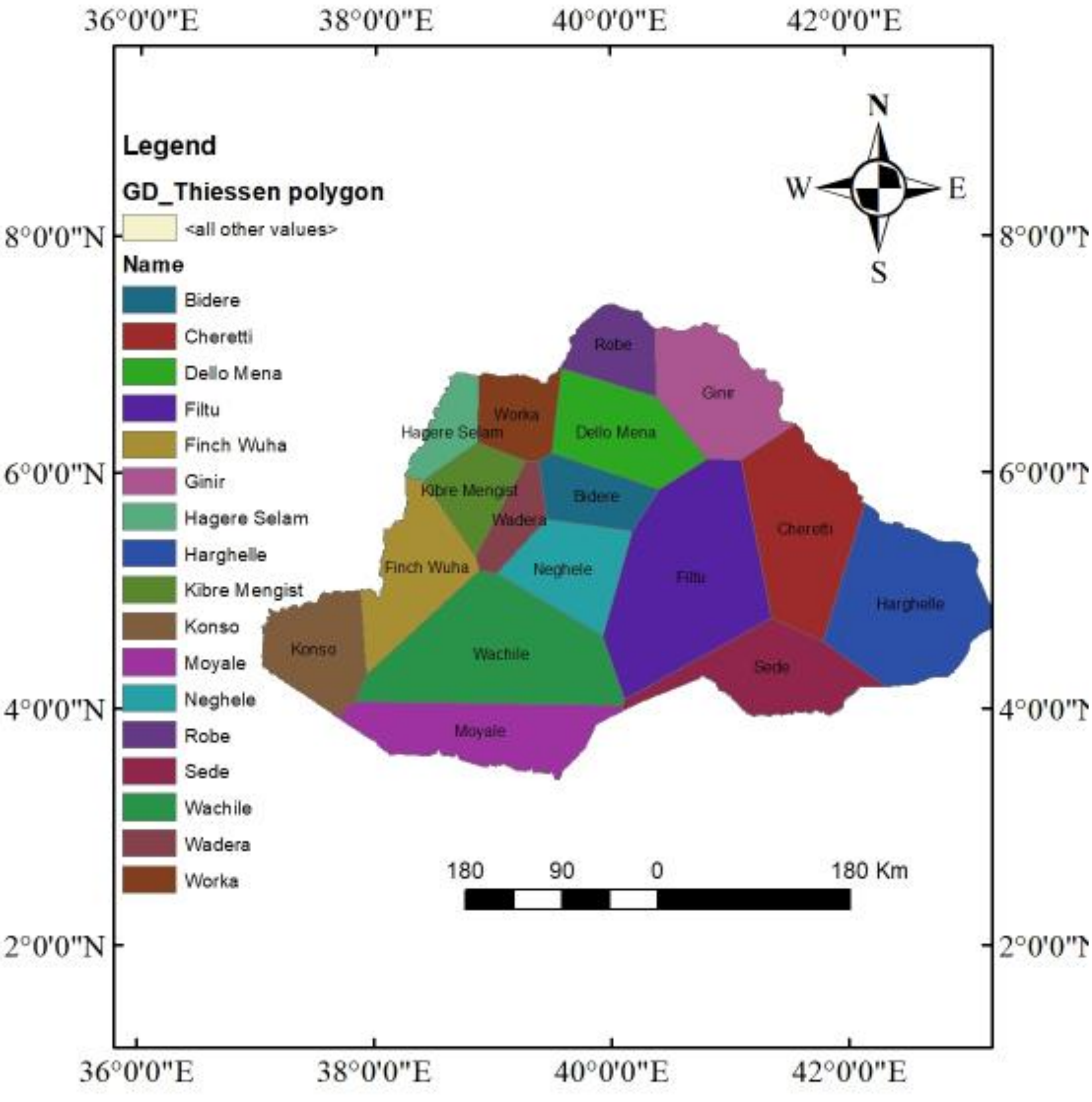


Figure 4.4-1 Areal rainfall determination

4.5.Sub-basin and seasonal rainfall variation profile

The mean monthly rainfall profile illustrates local seasonal rainfall variation as well as spatial differences within the basin. The corresponding profiles are graphically illustrated in figure 4-4-1 above and relevant Statistics of the selected key stations base series rainfall values within this region are given in table 4.1 below. The monthly profile indicates the occurrence and relative strength of the dry, wet, and intermediate season of monthly rainfall in the different locations of the catchments area. The rainfall patterns of the study area reflect the Bi-Modal regime with wetland dry seasons.

Table 4.5-1 Mean Monthly Rainfall of the sub-basin (mm)

Catchment	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Awata	29	37	105	258	236	61	52	59	106	218	101	30	1292
Afelta	25	19	64	196	141	39	17	30	54	124	81	21	811
Bare	0	0	12	111	44	0	0	0	0	71	40	2	280
Dinik	27	35	76	201	149	41	24	50	94	182	80	32	991
Dumal	20	28	80	178	157	48	61	79	86	153	71	20	981
Genale	7	12	55	161	102	9	5	6	30	112	59	14	572
Iya	34	44	82	179	185	115	116	129	140	175	73	35	1307
Laga Sure	16	15	58	154	81	10	10	7	19	96	60	21	547
Laga Wata	27	24	68	161	102	25	16	22	38	99	66	27	675
Lower Dawa	7	11	50	151	83	5	6	4	20	95	54	15	501
Lower Genale	1	3	26	112	52	1	1	0	8	69	52	8	333
Lower Mena	12	17	52	161	106	19	11	20	47	125	67	17	654
Mormora	23	29	78	192	176	51	43	52	83	163	74	23	987
Shaya	23	31	64	102	93	74	151	186	99	60	25	18	926
Tegona	23	31	64	102	93	74	151	186	99	60	25	18	926
Upper Dawa	24	24	73	201	164	44	30	38	67	143	79	22	909
Upper Genale	32	38	80	182	181	90	81	103	115	163	70	27	1162
Weyb Upper	23	31	64	102	93	74	151	186	99	60	25	18	926
Wabe Mena	27	34	74	183	139	47	46	73	95	160	71	29	978
Wabera	26	33	76	196	150	42	31	55	92	176	78	29	984
Welmel	19	24	80	201	165	37	25	34	71	171	79	21	927
Weyib	4	6	24	127	63	7	4	8	15	84	51	8	401
Weyib Middle	24	31	67	149	118	54	78	107	92	121	53	25	919
Yadot	19	26	88	213	187	37	20	30	80	195	93	20	1008
Gora Dese	22	17	62	186	125	31	15	24	44	115	73	20	734

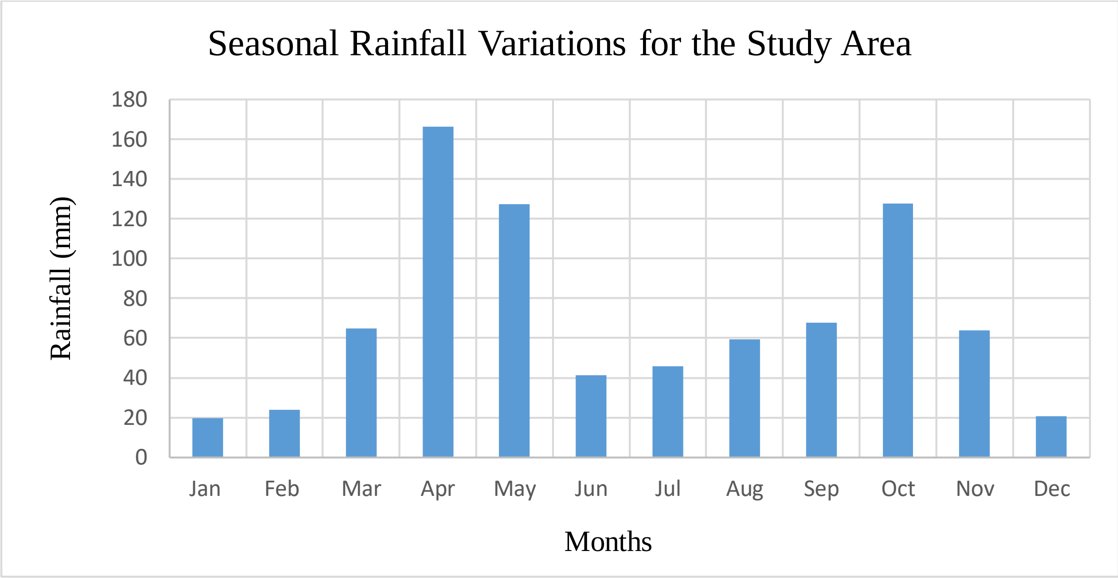
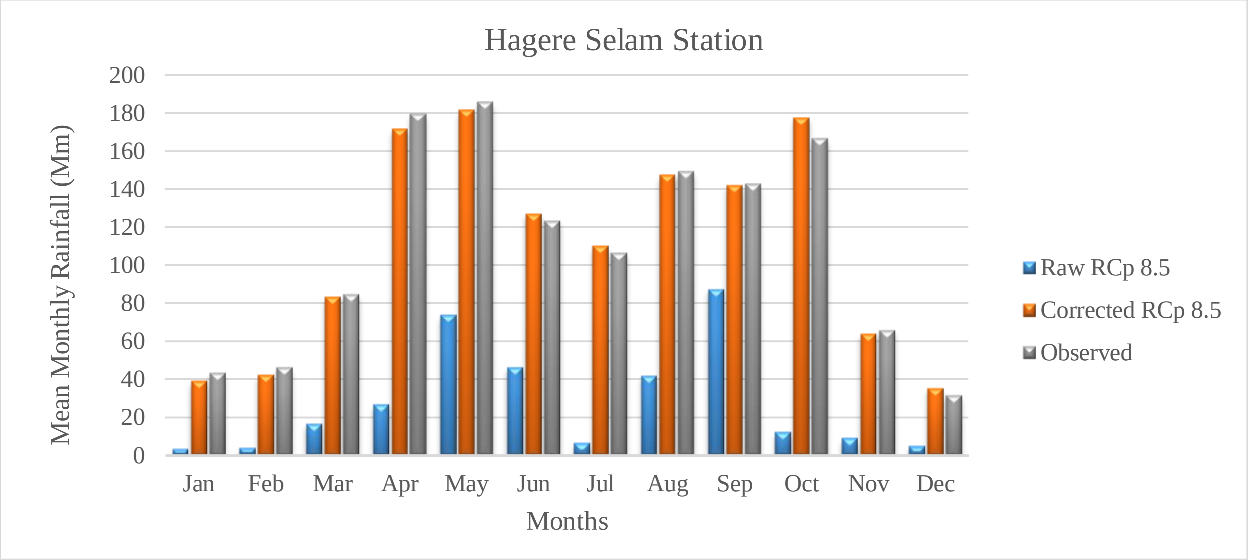


Figure 4.5-1 Seasonal Rainfall Variations for the Study Area

4.6.RCM performance evaluation

The performance evaluation of RCM data assessment was done as per the statistical measure with the corrected RCM precipitation data time series against observed precipitation data using the software tool CMhyd. CMhyd was designed to provide simulated climate data that can be considered representative of the location of the gauges used in a watershed model setup. Therefore, climate model data should be extracted and bias-corrected for each of the gauge locations. Figure 4-6-1 and Table 4.2 below show the summary of the evaluation. (See others at annex 2.4)



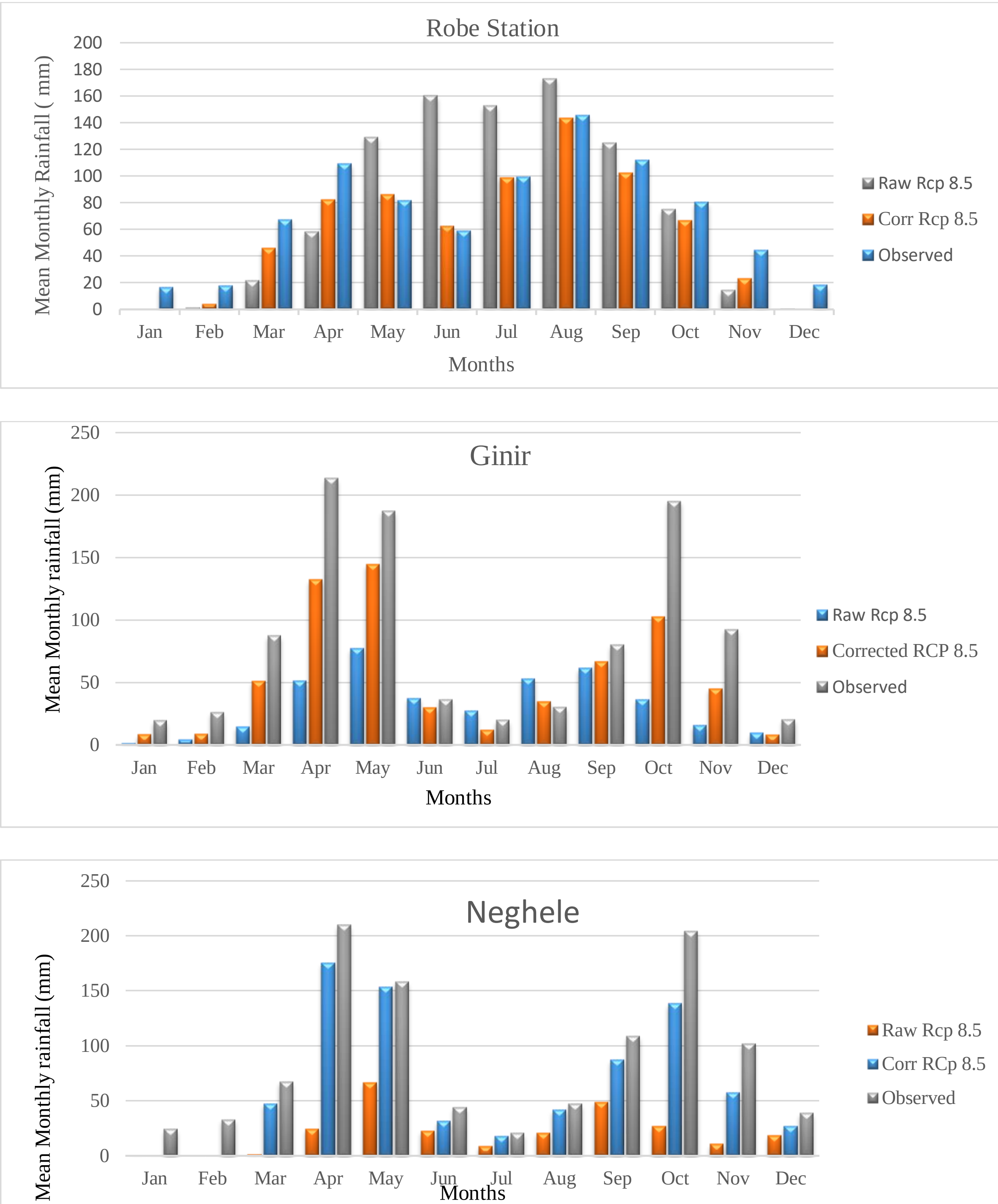


Figure 4.6-1 Stations and grid-based comparison of mean monthly rainfall datasets

Table 4.6-1 Statistical measures of mean monthly corrected RCM PPt. data sets.

No.	Station Name	Long	Lat.	NSE	R2
1	Moyale	39.0333	3.550	0.744	0.941
2	Neghele	39.5667	5.41667	0.522	0.740
3	Hagere Selam	38.52	6.49	0.992	0.996
4	Finch Wuha	38.2697	5.39317	0.638	0.950
5	Robe	40.05	7.13333	0.850	0.976
6	Ginir	40.7	7.13333	0.801	0.960
7	Dello Mena	39.8333	6.41667	0.648	0.960
8	Kibre Mengist	38.9667	5.86667	0.732	0.930
9	Konso	37.4333	5.33333	0.641	0.760
10	Bidere	39.6167	5.76667	0.482	0.540
11	Worka	39.2167	6.48333	0.580	0.540
12	Wadera	39.25	5.71667	0.424	0.643
13	Cheretti	41.8789	5.33792	0.411	0.566
14	Wachile	39.05	4.5500	0.418	0.540
15	Filtu	40.643	5.1063	0.484	0.590

4.7.WEAP model set up

WEAP consists of five main views: Schematic, Data, Results, Overviews, and Notes. The schematic view is GIS-based tools for easy arrangement of the system including objects like demand nodes, rivers, and reservoirs. The data view allows creating variables and relationships, entering assumptions and projections mathematical expressions, and dynamically link to Excel. The resulting view allows a detailed and flexible display of all model outputs, in charts and tables, and on the Schematic. On the other hand the overview highlights key indicators of the system for quick viewing. Finally the note view provides a place to document your data and assumptions.

A typical stepwise approach followed to develop WEAP for an area:

- Create a geographic representation of the area,
- Enter the data for the different supply and demand sites,
- Compare results with observations and simulated model data,
- Define scenarios and
- Compare and present the results of different scenarios.

The Priority assignment recommendation for each demand is between1 to 99. Level 1 is the highest demand priority for water in the system. This means that WEAP tried to satisfy all the demands at this level before any other level of priority demand. The model uses these priority levels when allocating water for the demand sites. The model delivers water to all the level one priority sites at the same time and, if there is any water remaining in the system, it will then deliver water to the remaining priority levels. (SEI, 2012).

4.7.1. Configuration of the WEAP model

In the schematic part of WEAP the boundary of watershed delineated, rivers, demand sites, and reservoirs is specified. GIS maps of rivers and reservoirs are used to determine the exact location of the streams in WEAP. Importantly, these features act as storage within the model and also as local sites of evaporation losses. Demand areas from the surface water in the study area were integrated into thirteen groups for setting up of the WEAP model. The irrigation areas were taken together based on the water abstraction sources, the demand sites which included in the schematics are:-

1. Irr_Adola which abstract water from Logita River
2. Irr_Agarfa which abstract water from Weyib Upper River
3. Irr_Berber which abstract water from Dumal River
4. Irr_Dello Mena which abstract water from Deyu River
5. Irr_Dinsho which abstract water from Weyib Upper River
6. Irr_Ginir which abstract water from Dinik River
7. Irr_Goba which abstract water from tegona river
8. Irr_Harena which abstract water from Iya River
9. Irr_Medawelabo which abstract water from Welmel River
10. Irr_wadera which abstract water from Awata River
11. Welmel Irrigation Project which abstract water from Welmel River
12. Yadot Irrigation Project which abstract water from Yadot River
13. Bale Gadula Irrigation Project which abstract water from Weyib River
14. Lower Irrigation Project which abstract water from Genale River

The livestock demand was taken together based on the water abstraction sources, the demand sites of the livestock in the basin which included in the model are:-

1. Liv Bale which abstract water from Dumal River
2. Liv Bare which abstract water from Weyib River
3. Liv Bdolo which abstract water from Genale River
4. Liv Chereti which abstract water from Weyib River
5. Liv Dire which abstract water from Teltel River
6. Liv Guji which abstract water from Awata River
7. Liv Moyale which abstract water from Lege Sure
8. Liv Sidama which abstract water from Logita River
9. Liv Yab which abstract water from Gora Dese River
10. Liv_Areo which abstract water from Lower Dawa River
11. Liv_Liben which abstract water from Genale River

The model is configured at wereda level there are around 38 weredas in the basin which is considered each wereda and their population census is feed to the model with their corresponding growth rate at a particular year which is a recent projection from CSA 2017 (See wereda detail data at Annex 1) and the model consider the return flows from each irrigation sites. However return flow from domestic water supply and livestock abstractions were not included since the quantity is insignificant it is preferred to overlook. Figure 4-7-1 below shows the schematic configuration of the WEAP model of the study area for the existing condition.

Reservoirs and Hydropower Schemes

Three reservoirs are created on Genale Main River these are GD 3, GD 5, and GD 6 reservoir.

The GD-3 reservoir created by a dam at the GD-3 will have a total storage capacity of 2,570 Mm3 at full supply level (1120 m asl) and will cover an area of 98 km2. The minimum operating level will be 1080masl and storage at MOL will be 260 Mm3 and this will cover 23 km2. The active storage is some 2310 Mm3. A dam created for multipurpose water resource development project designed to harness potential hydropower, flood control and irrigation benefits with other proposed downstream projects and hydropower generation as its main purpose. (GDMP, 2005)

Expected Energy Generation: Considering a total installed capacity of 254 MW, a plant discharge of about 116 m^3/sec (equal to 1.25 times the mean flow) and a rated head of 254.5 m, the GD-3 scheme would show the following energy production features:

Average energy Production = 1640 GWh/yr

Firm energy Generated = 1600 GWh/yr

Mean Power production = 254 MW with Plant factor of 72% (GDMP Volume II, August, 2007)

The GD -5 the reservoir created by a dam at the GD-5 will have a total storage capacity of 132Mm3 at full supply level (690 masl) and will cover an area of 6.5 km2. The minimum operating level will be 672masl and storage at MOL will be 75Mm3 and this will cover 3.5km2. The active storage is some 57Mm3. This project combined with hydropower projects GD-3 and GD-6, is a good candidate for power export to Kenya. (GDMP, 2005)

Considering a total installed capacity of 106 MW, a plant discharge of about 120m³/sec and a rated head of 83 m, the GD-3 scheme would show the following energy production features:

Average energy Production = 712 GWh/yr.

Mean Power production = 107 MW with Plant factor of 56%

Percentage of firm energy = 71% (GDMP Volume II, August, 2007)

The GD 6 reservoir created by a dam at the GD-6 will have a total storage capacity of 183.6Mm3 at full supply level (585masl) and will cover an area of 8.15km2. The minimum operating level will be 580masl and storage at MOL will be 143.6Mm3 and this will cover 7.2km2. The active storage is some 40Mm3. At full supply level 585 masl the headwater of the reservoir extends more than 12 km upstream with a width of the reservoir of some 600 m near the dam site. 650 m will be the average width of the reservoir.(GDMP, 2005).

Considering a total installed capacity of 246 MW, a plant discharge of about 120 m³/sec and a rated head of 182 m, the GD-6 scheme would show the following energy production features:

Average energy Production = 1575 GWh/yr.

Firm energy Production = 1540 GWh/yr.

Mean Power Production = 246 MW with Plant factor of 73% (GDMP Volume II, August, 2007)

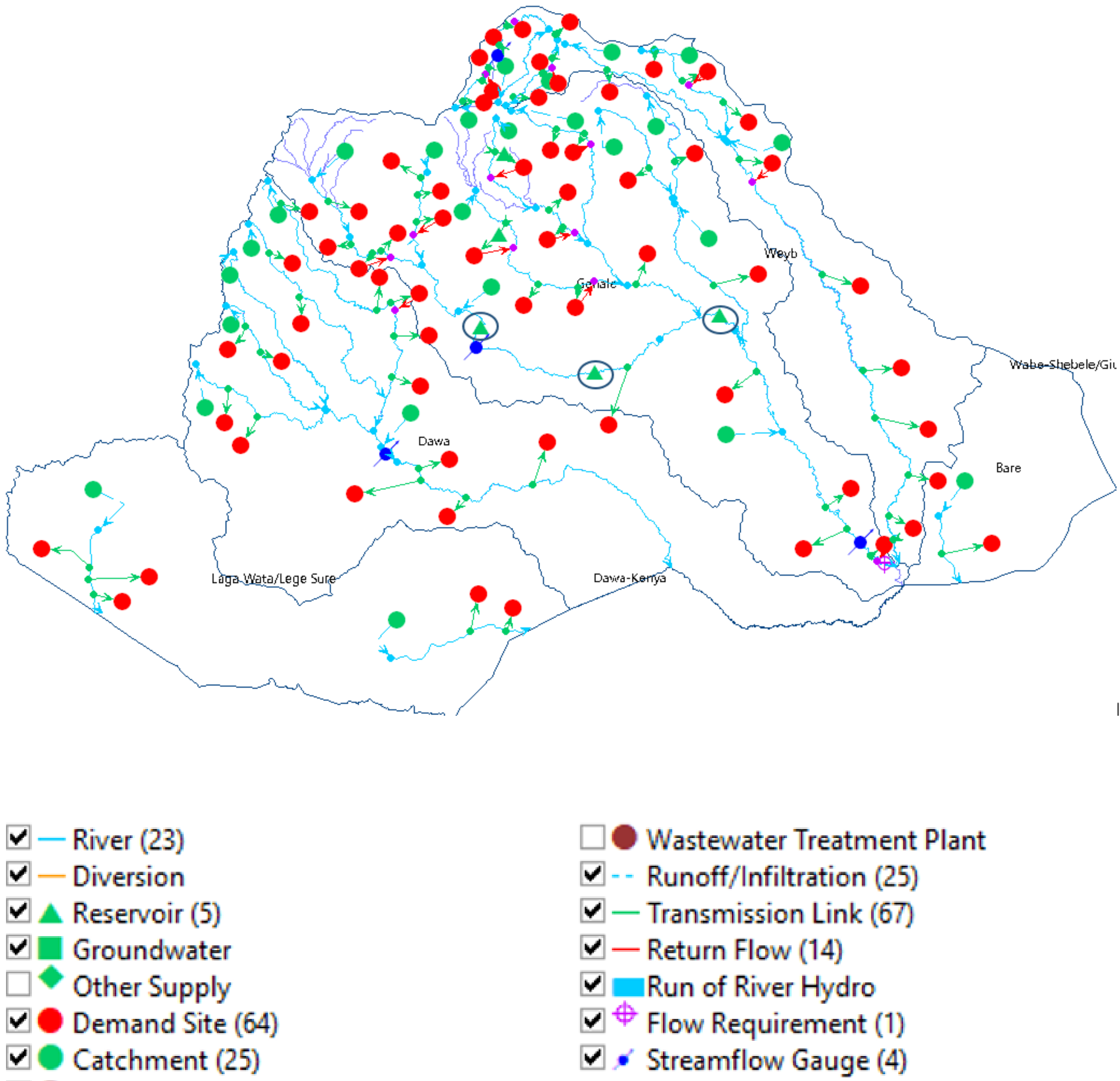


Figure 4.7-1 Schematic part of the WEAP model for Genale Dawa River Basin

4.7.2. Input data to WEAP

The WEAP input data refers to the data that was included and used for the "WEAP" model. The model was based on long term average conditions using monthly mean values of river flow, climate data like (rainfall, and temperature), and water demands for existing users (domestic water demand, livestock demand, and Irrigation schemes, etc.) also these land use data from WLRC and average Kc value were used which is obtained from FAO paper 56 (see Annex 1).

5. RESULT AND DISCUSSIONS

5.1.Evaluation of the WEAP Model

Before starting with the actual calibration and validation procedure it should be necessary an understanding of the influence potential of calibration and validation parameters on model performance. Therefore the parameters were adjusted in variable possible ranges to overlap the mean monthly observed stream flow with the model simulated data and the model response was evaluated.

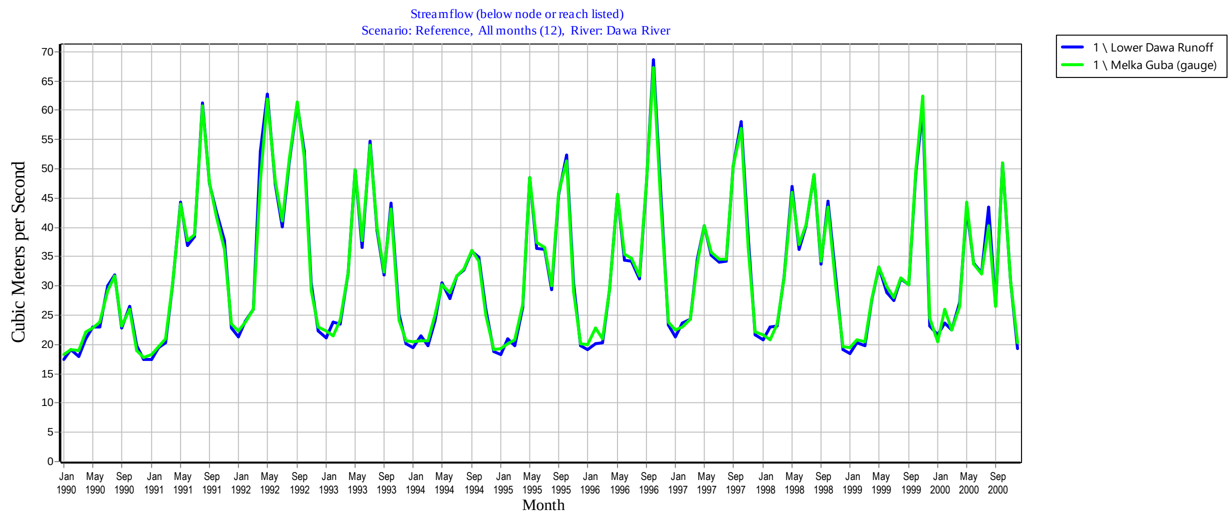
5.2.Calibration and validation results

In this section, simulated model results were compared with the observed flows for each control station. These comparisons are carried out taking account of the statistical parameters mentioned in previous sections. For this research, observed stream flows from five (5) stations located along the river basin were compared with the simulated outputs of the model and the two data's result should be overlapped monthly, this shows that the model simulates the output from the catchment land use and land cover should be matched with the recorded stream flow data. In general, the results indicated that the model able to relate the hydrological dynamic of the basin with the measured data as it was shown in the calibration and validation processes result. Figures 5-2-1 shows calibration results of different stations and 5-2-2 show the validation results of different stations in different data ranges and with the calibration parameters the stream flow results were also validated between different periods of the data range.

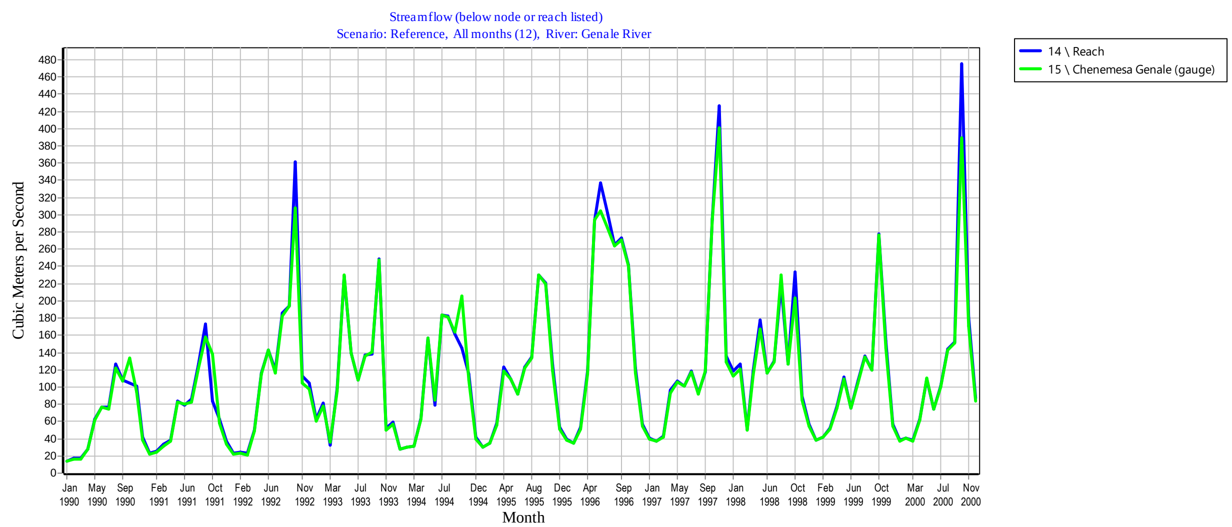
5.2.1. Calibration

Calibration is the subsequent step of adjusting the most parameters of the watershed to the model consider the basin reality while simulating the result. The WEAP Model performances of downstream gauges are depending on the performance of upstream gauges. Thus the head flow gauge should be calibrated first, to have a stable upper boundary condition for the downstream gauges. Therefore the WEAP model was calibrated and validated before analyzing the scenarios.

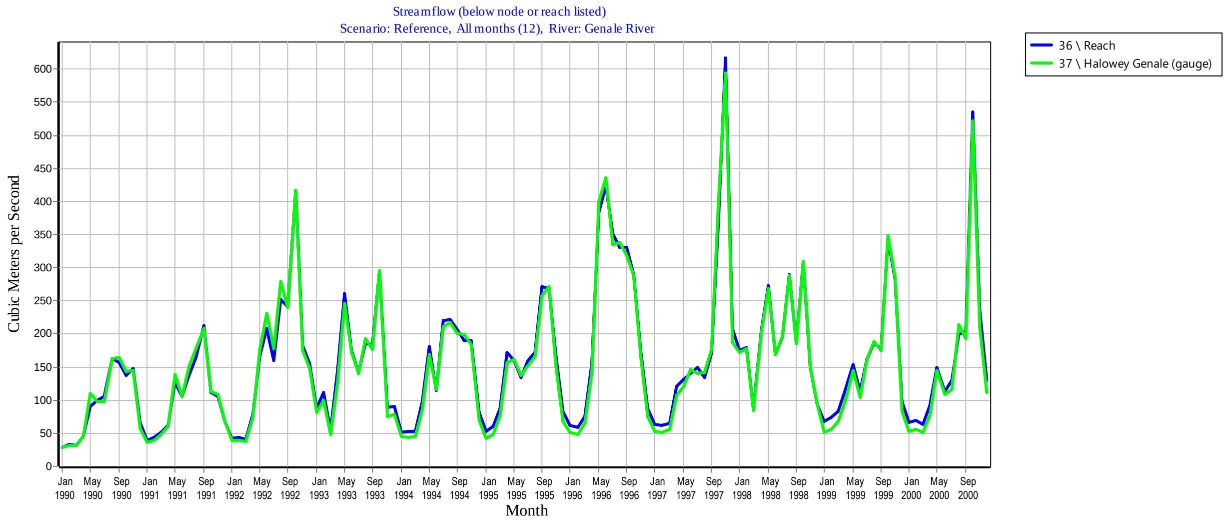
The monthly model-simulated and observed stream flows for the calibration of the different periods can be seen in figures 5-2-1a-d for the major control stream flow gauging stations Chenemesa Gauge, Halowey Gauge, Nr. Bore Dimtu Gauge and Melka Guba Gauge Stations depending on data availability without missed. Calibration was performed by comparing observed stream flows and a simulated result of the model in the watershed.



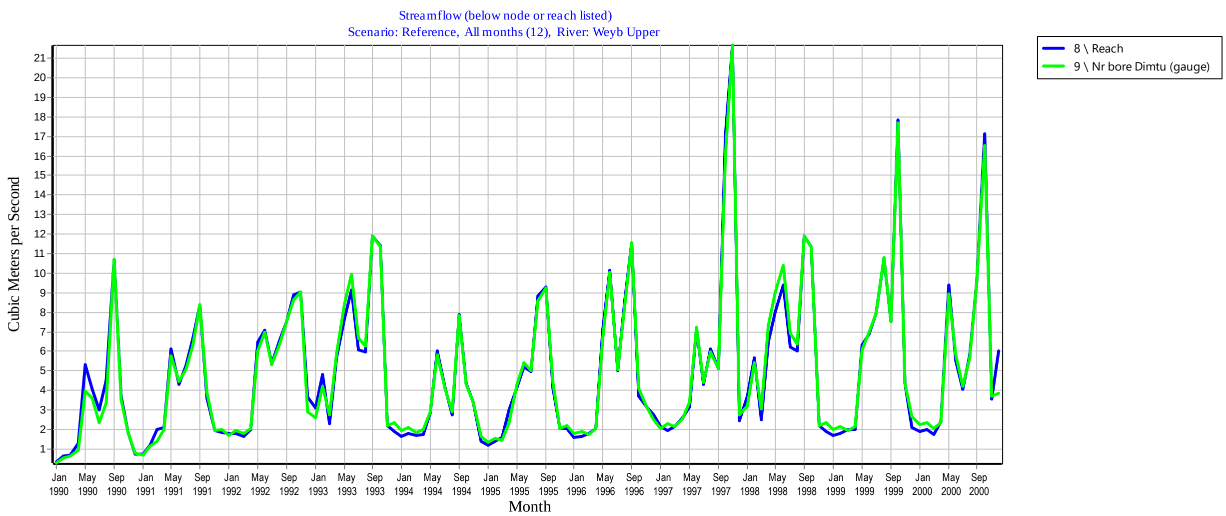
A. Dawa River (@ Melka Guba Gauge Station)



B. U/s Genale River (@Chenemesa Gauge Station)



C. D/s Genale River (@Halowey Gauge Station)



D. Upper Weyib River (@Nr.Bore Dimtu Gauge Station)

Figure 5.2-1 Monthly observed and simulated stream flows of selected stations.

Table 5.2 shows the statistical summary of the comparison between simulated and observed streamflow values for the calibration period. Likewise, as it was mentioned above, the correlation coefficient (R2), and Nash-Sutcliffe Coefficient (NSE) were used to measure the variation between the model outputs and the observed flows.

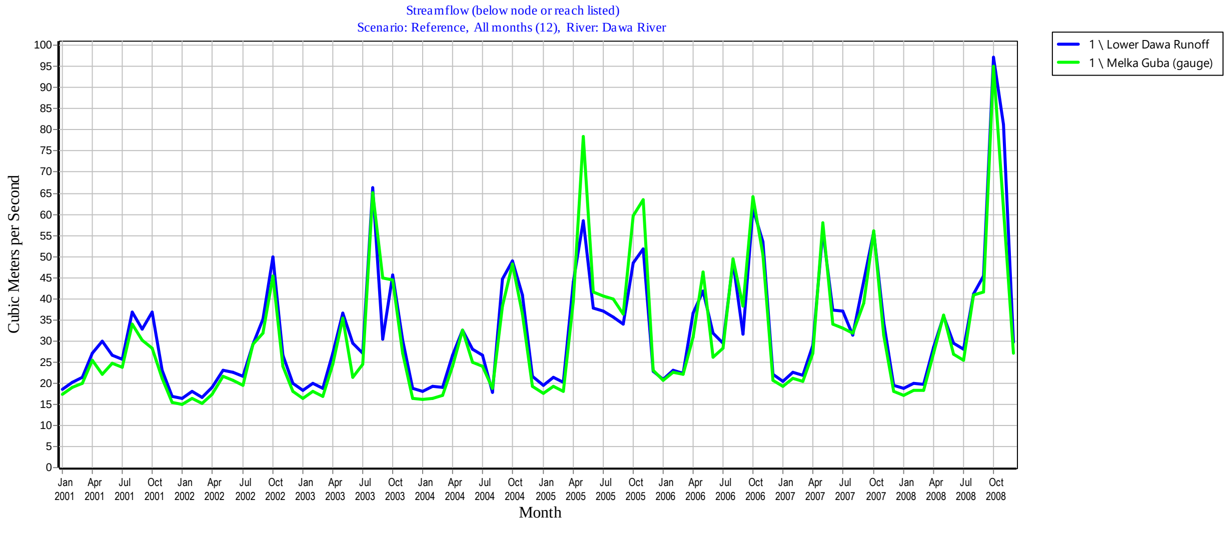
Table 5.2-1 statistical summaries of the comparison between simulated and observed stream

No.	Gauge Location River	Gauge Station Name	Period	NSE	R2
1	Dawa	Melka Guba	1990 - 2000	0.90	0.98
2	U/s Genale	Chenemesa Gauge	1990 - 2000	0.94	0.97
3	D/s Genale	Halowey Gauge	1990 - 2000	0.90	0.98
4	Upper Weyib	Nr.Bore Dimtu Gauge	1990 - 2000	0.94	0.96

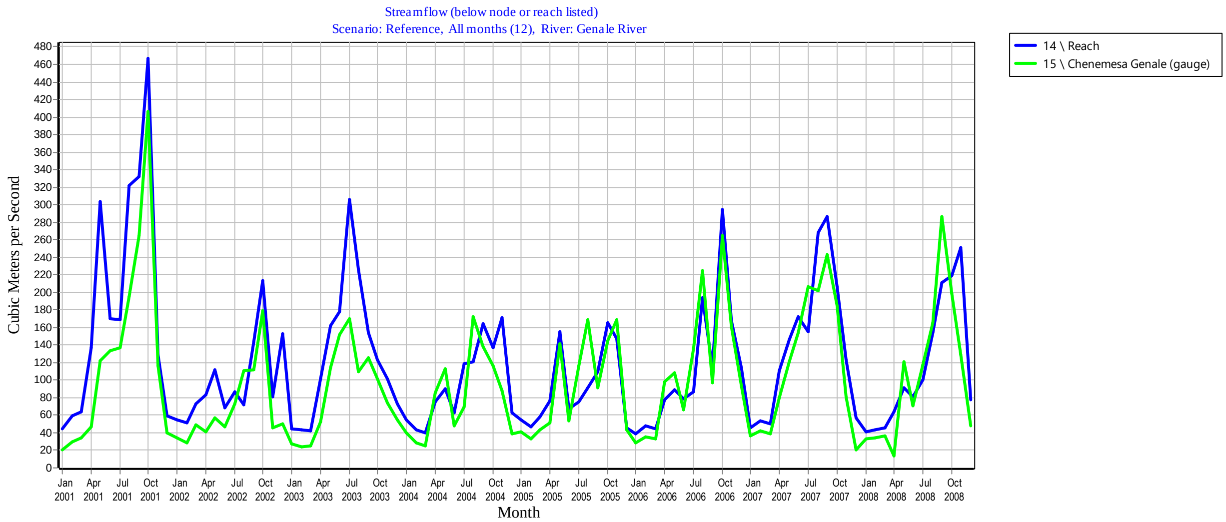
The statistical summary for the calibration period, the Nash-Sutcliffe Coefficient (NSE) ranges from 0.90 to 0.94 indicating a Very good agreement between modeled and observed flows. On the other hand, the Correlation Coefficient ranges from 0.96 to 0.98 for the calibration period this shows there are good agreement results between the modeled and observed station flow data.

5.2.2. Validation

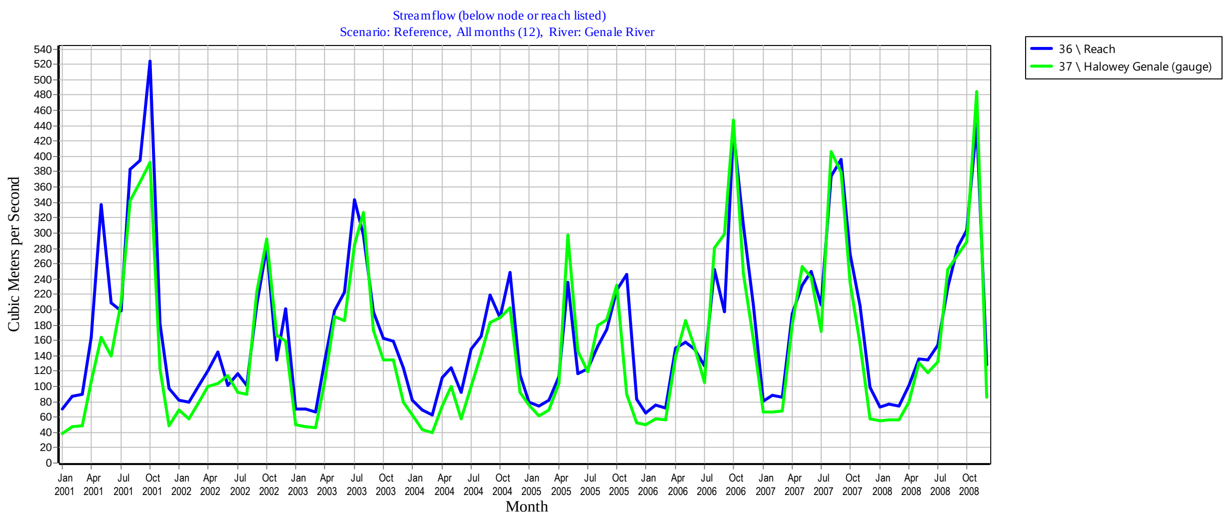
To validate the hydrological model, it was necessary to run the model out of the calibrated time range of data this is because more represent the catchments characteristic than calibration to make sure the output results are valuable. The results of the model validation were presented in Figures 5-2-2. For all the selected stations, simulated monthly flows were closed to the naturalized or observed flows. On the other hand the relationship between these flow data indicates a very good correlation for the selected stations. Now the model statistically validated result shows very good performance in reproducing all its outputs needed for analyzing the scenarios result.



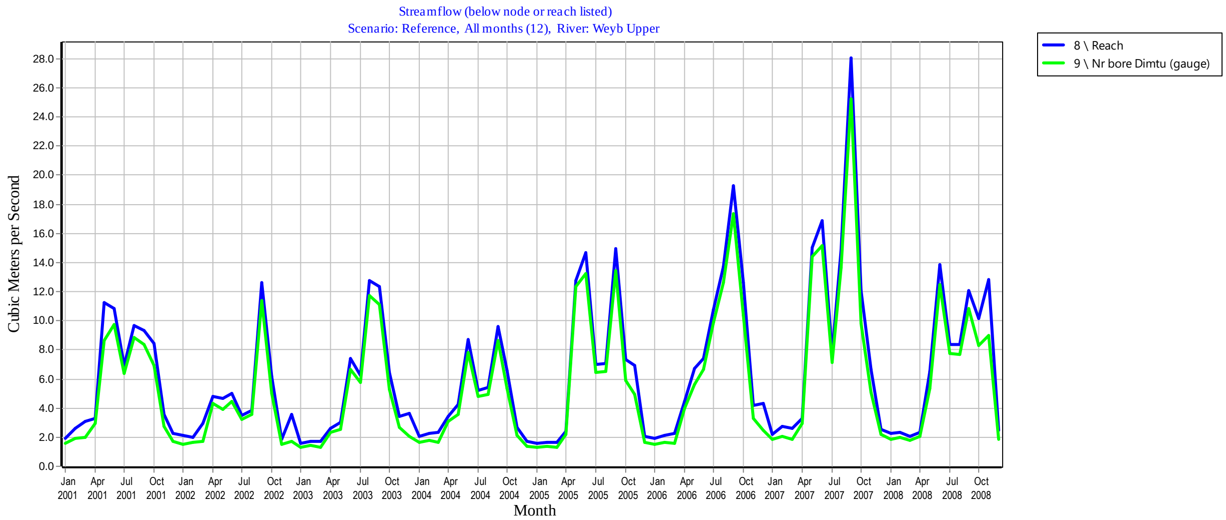
A. Dawa River (@Melka Guba Gauge Station)



B. U/s Genale River (@Chenemesa Gauge Station)



C. D/s Genale River (@Halowey Gauge Station)



D. Upper Weyib River (@Nr.Bore Dimtu Gauge Station)

Figure 5.2-2 Monthly observed and simulated stream flows of selected stations.

Table 5.3 shows the statistical summary of the comparison between simulated and observed streamflow values for the validation period and again the correlation coefficient (R2), and Nash-Sutcliffe Coefficient (NSE) were used to measure the variation between the model outputs and the observed flows.

Table 5.2-2 Statistical summaries of the comparison between simulated and observed stream

No.	River Location	Gauge Station Name	Validation Period	NSE	R2
1	Dawa	@Melka Guba Gauge	2001 - 2008	0.81	0.95
2	U/s Genale	@Chenemesa Gauge	2001 - 2008	0.69	0.87
3	D/s Genale	@Halowey Gauge	2001 - 2008	0.88	0.94
4	Upper Weyib	@Nr.Bore Dimtu Gauge	2001 - 2008	0.90	0.92

The statistical summary for the calibration period, the Nash-Sutcliffe Coefficient (NSE) ranges from 0.69 to 0.9 indicating a Very good agreement between modeled and observed flows. On the other hand, the Correlation Coefficient ranges from 0.87 to 0.95 for the Validation period this shows there is good agreement result between the modeled and observed station flow data.

5.3.Demand Analysis for Study periods

In this section the water demand of the three sectors of the basin in different periods found in the basin is being presented. The domestic water demand of all wereda's in the Genale Dawa river basin from current (2018) and future terms years 2030 and 2050. Projection of populations based on the data from CSA last projection report at the year 2017. And using WEAP expression build the model project the population growth to each year up to 2050

Table 5.3-1 Domestic Demand Analysis at different Time Schedule

Period	Total Population (Million)	Water Requirements (Mm^3/Year)
Current (2018)	5.11	420.14
Short Term Plan (2030)	6.85	562.79
Long Term Plan (2050)	11.20	919.83

The recent irrigation coverage is about 4,270.75 ha while the potential irrigation expansion area is 15,310 ha and 36,900.75 ha for the short term plan and future long term plan respectively. Their water requiremnet is get from their agronmony report in the (CWR)cropwat requiremnts.

Table 5.3-2 Irrigation Demand Analysis at different Time Schedule

Period	Irrigation area (Ha)	Water Requirements (Mm^3/Year)
Current (2018)	4,270.75	85.18
Short Term Plan (2030)	15,310.75	294.1
Long Term Plan (2050)	36,900.75	414.4

Table 5.3-3 Livestock Demand Analysis at different Time Schedule

Period	Total Population (Million)	Water Requirements (Mm^3/Year)
Current (2018)	5.6	56.1
Short Term Plan (2030)	6.3	63.3
Long Term Plan (2050)	7.8	77.7

5.4.Scenarios and results of WEAP Model Analysis

5.4.1. Basin rainfall

The rainfall over the catchment shown in figure 5-4-1 below which looks like a fluctuating pattern but a little variation in the baseline year (1980-2014) after then a great variation for the future period.

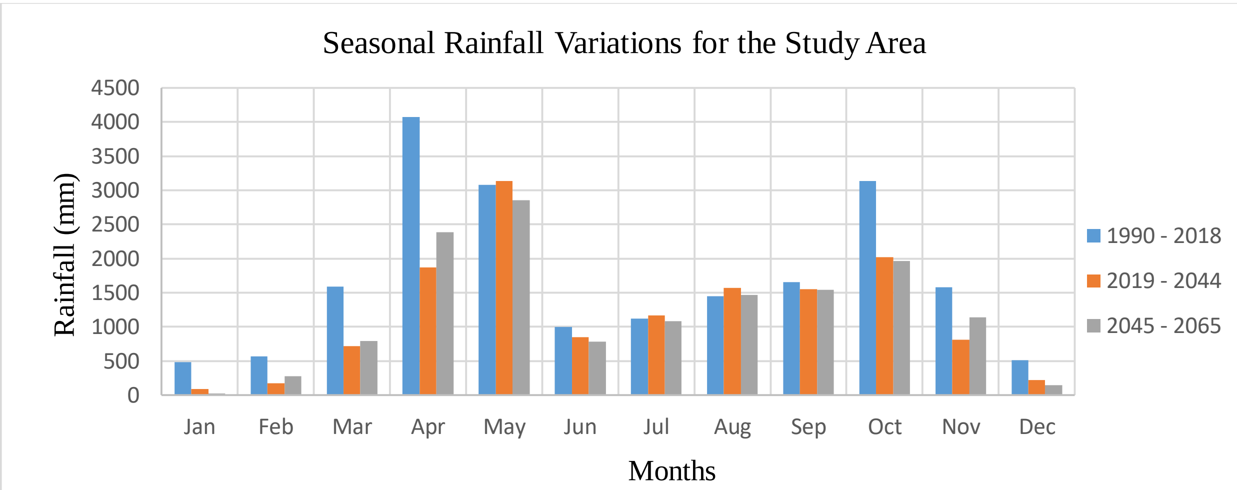


Figure 5.4-1 Basin Monthly rainfall variables in a deferent period

5.4.2. Basin Temperature

The changes in climate also affect temperatures, as shown in Figure 5-2-4 overall, it can be seen that there is an increase in the long-term average surface temperature of the catchment in the future scenarios in comparison to the baseline long-term average temperature. The average watershed temperature increases from 21.63ºC (baseline value) to 24.66ºC in 2019 – 2044 and 25.32ºC from 2045 – 2069.

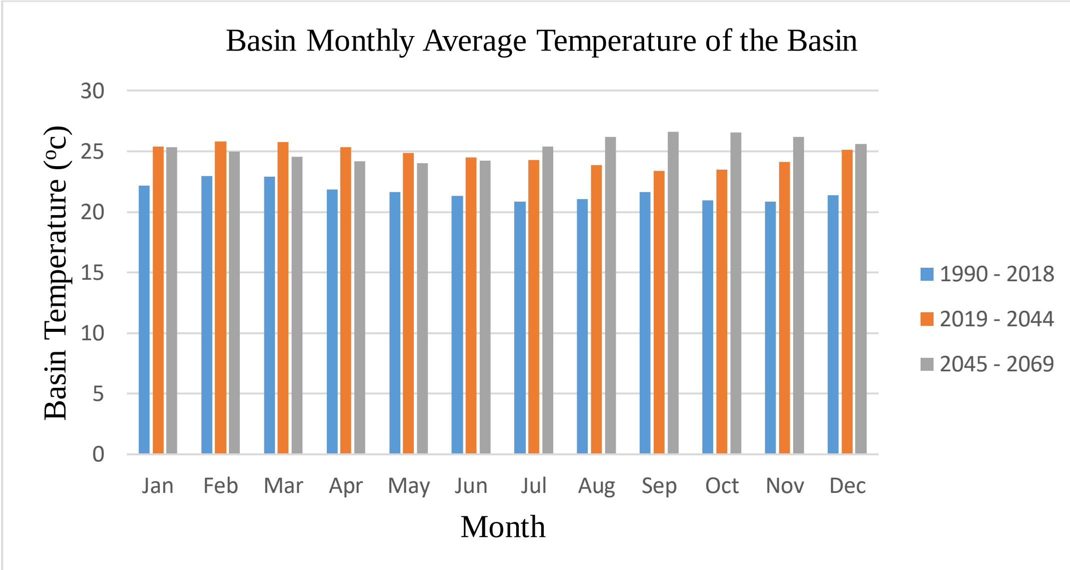


Figure 5.4-2 Basin Monthly Average temperature in the deferent period

5.5.Reference Scenario

Based on a variety of economic, demographic, hydrological, and technological trends, a "reference" scenario projection is established called a reference scenario. The reference scenario is developed from the current account to simulate the likely evolution of the system without intervention. This scenario serves as a reference to all other scenarios created to show different trends. Hence, every scenario developed to show its trend on the model result is compared to the reference scenario as there are interventions in the reference scenario other than projecting the current account year to the future year. In my study area, I have created the reference scenario from 1990 to 2018 and population projections were done accordingly.

5.5.1. Water Demand

The model result gives the monthly average water demand and annual summation demand for all sites both individually and also the summation of these all demands. And The Water demand for domestic, Irrigation, and livestock is analyzed in the reference (current account) year for all demand is about 506.49Mm^3. And also the total water demand for current and future period is presented in figure below

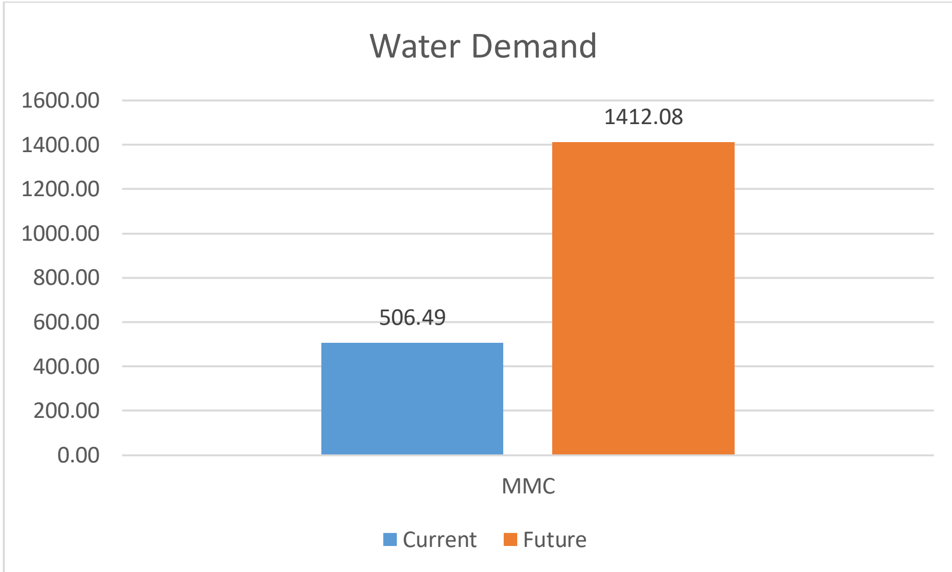


Figure 5.5-1 water demand

Figure 5.5-2 Total Water Current demands (without including losses) in current and future

5.5.2. Supply delivered

The total net amount of water delivered to the Demand sites from the water required to meet the demands of all the sites from 1980 to 2018 was 657.27Mm^3 and no Demand is Unmet in the analysis.

5.6.Development Scenario (Scenario One)

Key scenarios describing possible future Development Basin have been defined. The starting point for the scenarios is an assumption that in line with the new Water Resources Management Strategy, the overriding policy is to prioritize the development of irrigation areas to their full potential, an increase in the human and livestock population towards the periods. Working from this assumption two-term scenarios are developed short term plan which is the future development is considered those are planned and will start operation till the year 2030 and Long term plan which is the far future development is considered those are planned and will start operation till the year 2050.

5.6.1. Short Term Scenario I (2019 – 2030)

In this scenario the future development planned to the year 2030 is considered and analyzed. Based on the simulation results the domestic irrigation and livestock demand are presented.

5.6.1.1. Water Demand

The domestic water demand of all wereda's in the Genale Dawa river basin in the future years is 562.79Mm^3 for the 6.85 Million Population in the year of 2030. The irrigation water demand of all schemes in the Genale Dawa river basin in the future years is 294.1 Mm^3 for the 15,310.75ha of irrigable land in the year of 2030. The monthly water required of these schemes is presented in the table below.

Table 5.6-1 Domestic water demand for each site in Short Term Scenario I (Mm3).

Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: SHORT TERM SCENARIO I, All months (12), Annual Total							
Weredas	Demand MMC	Weredas	Demand MMC	Weredas	Demand MMC	Weredas	Demand MMC
Adaba	20.9	Goba	6.0	Dawe	4.6	Moyale	4.6
Adola	16.2	Gololcha	12.8	Dinsho	5.9	Rayitu	5.0
Afder	18.4	Goro Baqaqsa	7.4	Dire	9.5	Shakiso	31.2
Agarfa	15.6	Goro Dola	11.7	Dolo Odo	16.3	Sinana	17.5
Arero	6.1	Goro	12.6	Dugda Dawa	21.9	Teltele	10.6
Aroresa	23.4	Gura Damole	2.9	Elkere	11.4	Uraga	26.3
Bare	13.4	Harena	12.2	Filtu	18.8	Wadera	7.6
Bdolo Bay	10.7	Hudet	6.4	Gasera	11.7	Yabelo	15.8
Berbere	13.6	Liben	20.0	Ginir	21.4	Medawelabo	14.3
Bore	24.8	Bule Hora	39.7	Mena	13.6	**SUM (MMC)**	**562.7**

Table 5.6-2 Monthly irrigation water demand for each site in Short Term Scenario I (Mm3).

DEMAND	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
Irr_Adola	1.4	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.0	4.0
Irr_Agarfa	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	1.4
Irr_Berber	6.3	7.4	5.8	0.5	2.9	4.2	4.9	5.3	5.6	2.4	3.3	3.9	52.6
Irr_D.Mena	6.0	7.1	5.6	0.4	2.8	4.0	4.6	5.1	5.4	2.3	3.1	3.7	50.2
Irr_Dinsho	2.6	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.2	7.8
Irr_Ginir	6.6	3.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.6	19.9
Irr_Goba	3.9	4.6	3.6	0.3	1.8	2.6	3.0	3.3	3.5	1.5	2.0	2.4	32.8
Irr_Harena	0.4	0.5	0.4	0.0	0.2	0.3	0.3	0.4	0.4	0.2	0.2	0.3	3.7
Irr_Medawelabo	1.3	1.6	1.2	0.1	0.6	0.9	1.0	1.1	1.2	0.5	0.7	0.8	11.2
Irr_wadera	1.9	1.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.5	5.7
Irr_Welmel	4.6	2.8	5.2	0.0	12.0	18.2	4.6	2.3	6.6	0.0	27.3	21.3	104.8
TOTAL	35.6	30.8	24.7	1.3	20.3	30.3	18.5	17.5	22.7	6.9	42.4	43.0	**294.1**

And the Livestock water demand in the Genale Dawa river basin in the future years is 63.3Mm^3 for the 6.3 Million Livestock Population in the year of 2030.

5.6.1.2. Supply Delivered

In this scenario the supply water delivered for the future development planned to the year 2030 is considered and analyzed. Based on the simulation results the domestic irrigation and livestock demand are presented.

The total average amount of water delivered from the basin to the water required to meet the demands of all the sites in the short term scenario I for Domestic Water demand is 504.92 Mm^3 and for Livestock 61.01Mm^3.

Table 5.6-3 Monthly Livestock water Supply delivered for Short Term Scenario I (Mm3).

Livestock	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
Liv Bale	0.15	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	1.80
Liv Bare	0.41	0.38	0.41	0.40	0.41	0.40	0.41	0.41	0.40	0.41	0.40	0.41	4.88
Liv Bdolo	0.37	0.34	0.37	0.36	0.37	0.36	0.37	0.37	0.36	0.37	0.36	0.37	4.41
Liv Chereti	0.40	0.36	0.40	0.38	0.40	0.38	0.40	0.40	0.38	0.40	0.38	0.40	4.68
Liv Dire	0.16	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	1.90
Liv Guji	1.30	1.18	1.30	1.26	1.30	1.26	1.30	1.30	1.26	1.30	1.26	1.30	15.31
Liv Moyale	0.20	0.18	0.20	0.19	0.20	0.19	0.20	0.20	0.19	0.20	0.19	0.20	2.36
Liv Sidama	0.53	0.49	0.53	0.51	0.53	0.51	0.52	0.52	0.51	0.52	0.51	0.52	6.21
LIV Yab	0.23	0.21	0.23	0.22	0.23	0.22	0.23	0.23	0.22	0.23	0.22	0.23	2.70
Liv_Areo	0.12	0.11	0.12	0.11	0.12	0.11	0.12	0.12	0.11	0.12	0.11	0.12	1.37
Liv_Liben	1.31	1.20	1.31	1.27	1.31	1.27	1.31	1.31	1.27	1.31	1.27	1.31	15.49
Sum	5.19	4.74	5.19	5.02	5.19	5.02	5.18	5.18	5.02	5.18	5.02	5.18	61.10

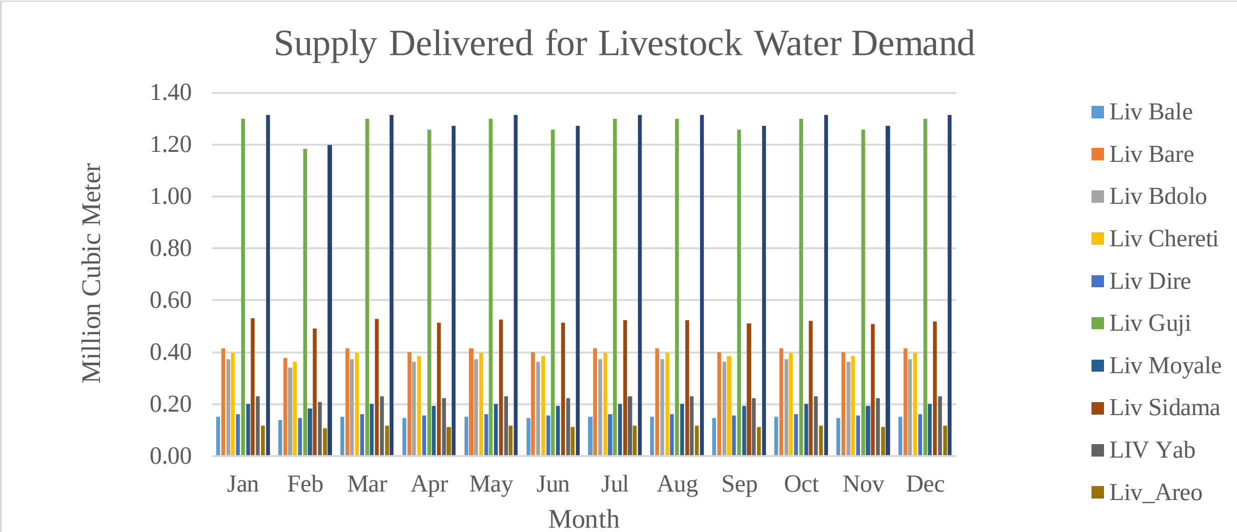


Figure 5.6-1 Supply Delivered for livestock water demand in Short term Scenario I

The total net amount of water delivered to the irrigation site from the water required to meet the irrigation demands of all the sites in short term scenario one 294.1Mm^3 is under furrow irrigation which is the efficiency of the system is kept 45 % became 286.9 Mm^3 and by increase the overall efficiency by 5% and became 50% and the water demand for the irrigation demand is 264.7Mm^3 the water delivered is 260 Mm^3 and by increase the efficiency by 10% making the irrigation efficiency 60% and for the water demand will be 220.6Mm^{3}and the supply delivered for the demand is 218.7Mm^3. (See Annex 3).

5.6.1.3.Unmet Demand

Unmet demand is the supply requirement that is not met. In other words unmet demand is the difference between supplies require and supply delivered at a particular demand site and in the time duration. In this analysis, the important quantity of unmet demand in the current and future was observed in some demand sites of irrigation water supplies.

The unmet demand for domestic water demand of all wereda's in the Genale Dawa river basin from the future Demand of 562.79Mm^3 for the 6.85 Million Population at the year of 2030 is became 10.12% of the total domestic demand is unmet and for that of Livestock, the unmet Demand is about 2.29 Mm^3 which is 3.6% of the total demand in the Short Term Scenario one.

The unmet demand for irrigation Demand varies depending on the efficiency of the irrigation for the Furrow irrigation the unmet demand when the overall irrigation efficiency kept 45% is

7.2Mm^3(2.45%) and at 50% overall efficiency It became 4.7 Mm^3 (1.78%) and finally when the overall efficiency of the system is increased by tenth which is 60% the total unmet demand will be 1.8 Mm^3 (0.83%) from the total demand.

Table 5.6-4 Unmet Irrigation Demand in Short term Scenario I

Irrigation efficiency	Supply Delivered	Water Demand	Unmet	UNMET (%)
ɳ=45%	286.9MMC	294.1MMC	7.2MMC	2.45%
ɳ=50%	260.0MMC	264.7MMC	4.7MMC	1.78%
ɳ=60%	218.7MMC	220.6MMC	1.8MMC	0.83%

Hydropower analysis in short term scenario I

The short term hydropower expansion includes the completion and operation of one of the three proposed dame which is GD 3 the water demand and supply delivered and unmet is presented below

GD 3Hydropower Demand Gigawatt-Hourper year (GWH/yr)												
Scenario: SHORT TERM SCENARIO I, All months (12), Monthly Average												
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
HP Demand (GWH)	133	133	133	133	133	133	133	133	133	133	133	133	1600
HP Unmet Demand (GWH)	8	8	8	7	6	5	1	0	0	0	0	0	44
HP Unmet Demand (%)	6	6	6	5	5	4	1	0	0	0	0	0	3
HP Coverage	94	94	94	95	95	96	99	100	100	100	100	100	#

As we can see form the result the GD 3 hydropower reservoir has an annual average firm power demand of 1600GWH/yr from total demand 3% of the demand is unmet in the short term scenario one and an average demand coverage more than 90%. And for the long term scenario one the analysis is explained in the net section.

5.6.2. Long Term Scenario I (2030 – 2050)

In this scenario the future development planned to the year 2050 is considered and analyzed. Based on the simulation results the domestic irrigation and livestock demand are presented.

5.6.2.1. Water Demand

The domestic water demand of all wereda's in the Genale Dawa river basin in the future years is 919.8Mm3 for the 11.20 Million Population and 77.67Mm^3 of water demand for livestock.

Table 5.6-5 Domestic water demand for each site in long Term Scenario I (Mm3).

Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: LONG TERM SCENARIO I, All months (12), Annual Total							
Weredas	Demand MMC	Weredas	Demand MMC	Weredas	Demand MMC	Weredas	Demand MMC
Adaba	35.6	Gasera	19.9	Medawelabo	23.6	Dawe	7.8
Adola	27.6	Ginir	36.3	Mena	23.2	Dinsho	10.0
Afder	25.8	Goba	10.2	Moyale	7.8	Dire	14.9
Agarfa	26.5	Gololcha	16.9	Rayitu	8.5	Dolo Odo	26.2
Arero	8.1	Goro Baqaqsa	11.9	Shakiso	51.8	Dugda Dawa	37.3
Aroresa	38.8	Goro Dola	19.8	Sinana	29.7	Elkere	18.3
Bare	21.6	Goro	21.4	Teltele	18.0	Filtu	30.2
Bdolo Bay	17.1	Gura Damole	4.6	Uraga	44.7	Bule Hora	65.9
Berbere	23.1	Harena	20.8	Wadera	13.0	Liben	32.7
Bore	32.8	Hudet	10.6	Yabelo	26.8	**Sum**	**919.8**

The irrigation water demand of all schemes in the Genale Dawa river basin in the future years is 414.4Mm3 for the 25,710.75ha of irrigable land in the year of 2030. The monthly water required of these schemes is presented in the table below.

Table 5.6-6 Monthly irrigation water demand in the Long Term Scenario I (Mm3).

DEMAND	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
Irr_Adola	1.4	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.0	4.0
Irr_Agarfa	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	1.4
Irr_Berber	6.3	7.4	5.8	0.5	2.9	4.2	4.9	5.3	5.6	2.4	3.3	3.9	52.6
Irr_D.Mena	6.0	7.1	5.6	0.4	2.8	4.0	4.6	5.1	5.4	2.3	3.1	3.7	50.2
Irr_Dinsho	2.6	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.2	7.8
Irr_Ginir	6.6	3.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.6	19.9
Irr_Goba	3.9	4.6	3.6	0.3	1.8	2.6	3.0	3.3	3.5	1.5	2.0	2.4	32.8
Irr_Harena	0.4	0.5	0.4	0.0	0.2	0.3	0.3	0.4	0.4	0.2	0.2	0.3	3.7
Irr_Medawelabo	1.3	1.6	1.2	0.1	0.6	0.9	1.0	1.1	1.2	0.5	0.7	0.8	11.2
Irr_wadera	1.9	1.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.5	5.7
Irr_Welmel	4.6	2.8	5.2	0.0	12.0	18.2	4.6	2.3	6.6	0.0	27.3	21.3	104.8
Irr_Yadot	4.5	1.9	9.6	0.0	10.6	7.8	5.3	3.6	2.9	0.0	13.0	13.1	72.1
Irr_Bale Gadula	0.9	0.3	3.9	2.7	6.0	7.0	1.6	4.0	4.9	0.6	8.7	7.6	48.2
TOTAL	40.9	33.0	38.2	4.0	36.9	45.0	25.4	25.1	30.5	7.6	64.1	63.6	**414.4**

5.6.2.2.Supply Delivered

In scenario II long term the supply water delivered for the future development planned to the year 2050 is considered and analysed. Based on the simulation results the domestic irrigation and livestock demand are presented. The total average amount of water delivered from the basin to the water required to meet the demands of all the sites in the short term scenario I for Domestic Water demand is 729.62Mm^3 and for Livestock 70.61Mm^3.

And the total net amount of water delivered to the irrigation site from the water required to meet the irrigation demands of all the sites in long term scenario one 414.1Mm^3 is under furrow irrigation which is the efficiency of the system is kept 45 % became 388.5Mm^3 and by increase the overall efficiency by 5% and became 50% and the water demand for the irrigation demand is 373.3Mm^3 the water delivered is 352.3Mm^3 and by increase the efficiency by 10% making the irrigation efficiency 60% and for the water demand will be 310.8Mm^{3}and the supply delivered for the demand is 296.4Mm^3.

5.6.2.3.Unmet Demand (Long Term Scenario I)

In this analysis the important quantity of unmet demand in the current and future was observed in some demand sites. The unmet demand for domestic water demand of all wereda's in the Genale Dawa river basin from the future Demand of 919.8Mm3 at the year of 2050 is became 20.67% of the total domestic demand is unmet and for that of Livestock the unmet Demand is about 2.29 Mm3 which is 9.08% of the total demand in the Long Term Scenario one. The unmet demand for irrigation Demand varies depending on the efficiency of the irrigation for the Furrow irrigation the unmet demand when the overall irrigation efficiency kept 45% is 28.8Mm3(6.24%) and at 50% overall efficiency It became 20.7Mm3 (5.5%) and finally when the overall efficiency of the system is increased by tenth which is 60% the total unmet demand will be 14.4Mm3 (4.62%) from the total demand.

Table 5.6-7 Unmet Irrigation Demand in Long Term Scenario I

Irrigation efficiency	Supply Delivered	Water Demand	Unmet	UNMET (%)
ɳ=45%	388.5MMC	414.1MMC	28.8MMC	6.24%
ɳ=50%	352.3MMC	373.3MMC	20.7MC	5.5%
ɳ=60%	296.4MMC	310.8MMC	14.4MMC	4.62%

Hydropower analysis in Long term scenario I

The Long term hydropower expansion includes the completion and operation of the three proposed dame which is GD 3,GD 5, and GD 6 the water demand and supply delivered and unmet is presented below in terms of the coverage demand.

Hydropower Demand Gegawatt-hour (GWH/yr)													
Scenario: LONG TERM SCENARIO ONE, All months (12), Monthly Average													
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
GD 3 HP	133	133	133	133	133	133	133	133	133	133	133	133	1600
GD 6 HP	131	131	131	131	131	131	131	131	131	131	131	131	1575
GD5 HP	59	59	59	59	59	59	59	59	59	59	59	59	712
Total	324	324	324	324	324	324	324	324	324	324	324	324	3887

Hydropower Coverage (Percent)												
Scenario: LONG TERM SCENARIO ONE, All months (12), Monthly Average												
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
GD 3 HP	93	91	93	97	98	100	100	100	100	100	100	100
GD 6 HP	79	75	77	80	88	79	88	95	97	98	96	89
GD5 HP	55	49	51	51	58.1	52	59	64	64	66	64	61

As it is seen the GD 3 and GD 6 average monthly hydropower demand is being met more than 75% and for GD 5 about 50 % of the total average demand is met.

5.7.Climate Change Scenario (Scenario Two)

A climate scenario is a plausible representation of future climate that has been constructed for explicit use in investigating the potential impacts of anthropogenic climate change. Climate scenarios often make use of climate projections (descriptions of the modelled response of the climate system to scenarios of greenhouse gas,), by manipulating model outputs and combining them with observed climate data. In this scenario by changing the climate data specifically the precipitation and temperature and I will simulate the model for the current water demand.

5.7.1. Water Demand

Here in climate change scenario all the demand is kept constant throughout the time and the climate is changed and foreseen in the two terms therefore, the domestic water demand of all wereda's in the Genale Dawa river basin is 410.07Mm^3.

Table 5.7-1 Monthly Domestic water Demand for climate change scenario II (Mm3).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SUM
TOTAL Demand	34.8	31.7	34.8	33.6	34.8	33.6	34.8	34.8	33.6	34.8	33.6	34.8	410.0

And the irrigation water demand of all schemes in the Genale Dawa river basin in the coming years is 294.1Mm3 for the 15,310.75ha of irrigable land and also the Livestock water demand in the Genale Dawa river basin in the future years is 55.50Mm3.

5.7.2. Short Term Scenario II (2019 – 2030)

In this scenario the future climate change effect to the year 2030 on the sectional demand is considered and analysed.

5.7.2.1.Supply Delivered

In this scenario, the supply water delivered for the future development planned to the year 2030 is considered and analysed

Table 5.7-2 Monthly Domestic water Supply delivered for Short Term Scenario I (Mm3).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**SUM**
Total Water Supplied	33.6	31.0	33.5	33.0	34.7	33.3	34.0	34.1	33.3	34.7	33.0	33.6	**401.7**

The total net amount of water delivered to the Domestic water demand in all weredas in short term scenario two is 401.7Mm^3.

Table 5.7-3 Monthly livestock water Supply delivered for Short Term Scenario I (Mm3).

SUPPLY.D	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
Liv Bale	0.14	0.13	0.14	0.13	0.14	0.13	0.14	0.14	0.13	0.14	0.13	0.14	1.63
Liv Bare	0.37	0.34	0.37	0.36	0.37	0.36	0.37	0.37	0.36	0.37	0.36	0.37	4.42
Liv Bdolo	0.34	0.31	0.34	0.33	0.34	0.33	0.34	0.34	0.33	0.34	0.33	0.34	3.99
Liv Chereti	0.36	0.33	0.36	0.35	0.36	0.35	0.36	0.36	0.35	0.36	0.35	0.36	4.24
Liv Dire	0.15	0.13	0.15	0.14	0.15	0.14	0.15	0.15	0.14	0.15	0.14	0.15	1.72
Liv Guji	1.18	1.07	1.18	1.14	1.18	1.14	1.18	1.18	1.14	1.18	1.14	1.18	13.86
Liv Moyale	0.18	0.17	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	2.14
Liv Sidama	0.50	0.46	0.50	0.49	0.50	0.49	0.50	0.50	0.49	0.50	0.49	0.50	5.91
LIV Yab	0.21	0.19	0.21	0.20	0.21	0.20	0.21	0.21	0.20	0.21	0.20	0.21	2.44
Liv_Areo	0.10	0.09	0.10	0.09	0.10	0.09	0.10	0.10	0.09	0.10	0.09	0.10	1.12
Liv_Liben	1.19	1.08	1.19	1.15	1.19	1.15	1.19	1.19	1.15	1.19	1.15	1.19	14.03
TOTAL	4.71	4.29	4.71	4.56	4.71	4.56	4.71	4.71	4.56	4.71	4.56	4.71	**55.50**

The total net amount of water delivered to the Livestock site from the water required to meet the demands of all the sites in short term scenario two is 55.50Mm^3.

Table 5.7-4 Monthly irrigation water Supply delivered for Short Term Scenario I (Mm3).

SUPPLY.D	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
Irr_Adola	1.4	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.0	4.0
Irr_Agarfa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Irr_Berber	5.2	5.2	5.1	0.5	2.9	4.2	4.9	5.3	5.6	2.4	3.3	3.9	48.5
Irr_D.Mena	3.8	3.9	3.8	0.4	2.6	3.9	4.5	4.8	5.2	2.3	3.1	3.6	41.9
Irr_Dinsho	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.4
Irr_Ginir	6.6	3.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.6	19.9
Irr_Goba	0.2	0.3	0.1	0.2	0.8	0.7	0.7	1.1	2.2	0.4	0.2	0.1	7.1
Irr_Harena	0.4	0.5	0.4	0.0	0.2	0.3	0.3	0.4	0.4	0.2	0.2	0.3	3.7
Irr_Medawelabo	1.3	1.6	1.2	0.1	0.6	0.9	1.0	1.1	1.2	0.5	0.7	0.8	11.2
Irr_wadera	1.9	1.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.5	5.7
Irr_welmel	4.6	2.8	5.2	0.0	11.5	12.6	4.6	2.3	6.6	0.0	14.0	12.4	76.6
TOTAL	25.4	19.8	18.1	1.2	18.7	22.7	15.9	15.0	21.2	5.8	26.1	29.2	**219.0**

The total net amount of water delivered to the irrigation site from the water required to meet the irrigation demands of all the sites in short term scenario one 219.0Mm^3 is under furrow irrigation which is the efficiency of the system is kept 45 %.

5.7.2.2. Unmet Demand Short Term Scenario II

The unmet demand for domestic water demand of all wereda's in the Genale Dawa river basin from the total domestic is 8.35Mm^3 which is 2.03% of the total demand and for that of irrigation, the unmet demand is about 75.07Mm^3 and No unmet demand for the livestock demand in the short term scenario two.

Table 5.7-5 Total Unmet Demand in short term scenario II

DEMAND	Supply Delivered	Water Demand	UNMET	UNMET %
Domestic	401.7 MMC	410.0 MMC	8.35 MMC	2.03%
Livestock	55.50 MMC	55.50 MMC	0.00 MMC	0.00%
Irrigation	219.0 MMC	294.1 MMC	75.0 MMC	25.5%

5.7.3. Long Term Scenario II (20130 – 2050)

In this scenario the future climate change effect to the year 2050 on the sectional demand is considered and analyzed. Based on the simulation results the domestic, irrigation and livestock demand is presented below

5.7.3.1.Supply Delivered

In this scenario the supply water delivered for the year 2050 under climate change is considered and analyzed. Based on the simulation results the domestic irrigation and livestock demand are presented. The total average amount of water delivered from the basin to the domestic water required to meet the demands of all the sites in the in long term scenario II is 401.4Mm^3.

Table 5.7-6 Monthly Domestic water Supply delivered for Long Term Scenario I (Mm3).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
Domestic Demand	33.7	31.0	33.7	32.9	34.4	33.2	33.9	34.1	33.1	34.5	33.1	33.9	401.4

The total net amount of water delivered to the Livestock site from the water required to meet the demands of all the sites in short term scenario two is 55.50Mm^3.

Table 5.7-7 Monthly livestock water Supply delivered for Long Term Scenario I (Mm3).

SUPPLY.D	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
Liv Bale	0.14	0.13	0.14	0.13	0.14	0.13	0.14	0.14	0.13	0.14	0.13	0.14	1.63
Liv Bare	0.37	0.34	0.37	0.36	0.37	0.36	0.37	0.37	0.36	0.37	0.36	0.37	4.42
Liv Bdolo	0.34	0.31	0.34	0.33	0.34	0.33	0.34	0.34	0.33	0.34	0.33	0.34	3.99
Liv Chereti	0.36	0.33	0.36	0.35	0.36	0.35	0.36	0.36	0.35	0.36	0.35	0.36	4.24
Liv Dire	0.15	0.13	0.15	0.14	0.15	0.14	0.15	0.15	0.14	0.15	0.14	0.15	1.72
Liv Guji	1.18	1.07	1.18	1.14	1.18	1.14	1.18	1.18	1.14	1.18	1.14	1.18	13.86
Liv Moyale	0.18	0.17	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	2.14
Liv Sidama	0.50	0.46	0.50	0.49	0.50	0.49	0.50	0.50	0.49	0.50	0.49	0.50	5.91
LIV Yab	0.21	0.19	0.21	0.20	0.21	0.20	0.21	0.21	0.20	0.21	0.20	0.21	2.44
Liv_Areo	0.10	0.09	0.10	0.09	0.10	0.09	0.10	0.10	0.09	0.10	0.09	0.10	1.12
Liv_Liben	1.19	1.08	1.19	1.15	1.19	1.15	1.19	1.19	1.15	1.19	1.15	1.19	14.03
TOTAL	4.71	4.29	4.71	4.56	4.71	4.56	4.71	4.71	4.56	4.71	4.56	4.71	55.50

Table 5.7-8 Monthly irrigation water Supply delivered for Long Term Scenario I (Mm3).

SUPPLY.D	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
Irr_Adola	1.4	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.0	4.0
Irr_Agarfa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2
Irr_Berber	5.6	5.8	5.4	0.5	2.9	4.2	4.9	5.3	5.6	2.4	3.3	3.9	49.9
Irr_D.Mena	4.6	4.6	4.6	0.4	2.6	3.8	4.6	5.1	5.2	2.3	3.1	3.6	44.6
Irr_Dinsho	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.1	1.0
Irr_Ginir	6.6	3.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.6	19.9
Irr_Goba	0.2	0.3	0.1	0.2	1.3	1.0	1.2	2.3	2.6	0.9	0.6	0.3	10.9
Irr_Harena	0.4	0.5	0.4	0.0	0.2	0.3	0.3	0.4	0.4	0.2	0.2	0.3	3.7
Irr_Medawelabo	0.6	0.7	0.5	0.0	0.3	0.4	0.4	0.5	0.5	0.2	0.3	0.4	4.8
Irr_wadera	1.9	1.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.5	5.7
Irr_Welmel	4.6	2.8	5.2	0.0	11.1	12.2	4.6	2.3	6.6	0.0	15.2	11.1	75.6
TOTAL	26.0	20.3	18.5	1.2	18.4	21.9	16.0	15.9	21.0	6.0	27.7	27.6	**220.5**

The total net amount of water delivered to the irrigation site from the water required to meet the irrigation demands of all the sites in short term scenario one 220.5Mm^3 is under furrow irrigation which is the efficiency of the system is kept 45 %.

5.7.3.2.Unmet Demand Long Term Scenario II

The unmet demand for domestic water demand of all wereda's in the Genale Dawa river basin from the total domestic is 4.81Mm^3 which is 1.17% of the total demand and for that of irrigation, the unmet demand is about 67.21Mm^3 and No unmet demand for the livestock demand in the long term scenario two.

Table 5.7-9 Total Unmet Demand for Long term Scenario II

DEMAND	Supply Delivered	Water Demand	UNMET	UNMET %
Domestic	401.4 MMC	410.0 MMC	4.81 MMC	1.17 %
Livestock	55.50 MMC	55.50 MMC	0.00 MMC	0.00 %
Irrigation	220.5 MMC	294.1 MMC	67.21.MMC	22.8 %

5.8.Combination Scenario (Scenario Three)

The combined effects of climate change and future development scenarios together are seen below. In the current scenario the exiting domestic demand, livestock, and irrigation schemes are satisfied under the present climate condition. But not in the future due to climate change effects and future developments. In the future under the combination of the scenarios it will be unmet demand this indicates the unmet demand is not the case of climate change it is due to future development.

5.8.1. Short Term Scenario III (2019 – 2030)

In this scenario both the future development and climate change effect to the year 2030 on the sectional demand is considered and analyzed. Based on the simulation results from total demand of 916.13Mm^3 of water at 2030 the unmet demands on the domestic, irrigation, and livestock demand is 100.5Mm^3 (10.97%) and presented below from all demand sites 8 Weredas and 6 Irrigation schemes are unmet.

Table 5.8-1 Monthly Unmet water demand for Short Term Scenario III (Mm3).

Unmet Demand (Cubic Meter)													
Scenario: SHORT TERM SCENARIO THREE, All months (12), Monthly Average													
UNMET	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
Adaba Wereda	0.6	0.4	0.6	0.4	0.1	0.0	0.3	0.2	0.0	0.0	0.4	0.5	3.5
Agarfa Wereda	0.4	0.3	0.4	0.3	0.0	0.0	0.2	0.2	0.0	0.0	0.3	0.4	2.6
Bule H. Wereda	0.9	0.6	0.9	0.5	0.1	0.6	0.8	0.8	0.6	0.0	0.6	0.8	7.3
Dinsho Wereda	0.2	0.1	0.2	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.2	1.0
Dugda.D Wereda	0.5	0.4	0.5	0.3	0.1	0.3	0.5	0.4	0.3	0.0	0.3	0.5	4.0
Ginir Wereda	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	2.1
Goba Wereda	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.1	0.7
Irr_Agarfa	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	1.4
Irr_Berber	1.4	2.5	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8
Irr_D.Mena	2.1	3.0	1.7	0.0	0.0	0.0	0.2	0.3	0.1	0.0	0.0	0.1	7.5
Irr_Dinsho	2.6	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.2	7.5
Irr_Goba	3.9	4.5	3.6	0.2	1.1	2.2	2.5	2.6	1.5	1.3	2.0	2.4	27.8
Sinana Wereda	0.3	0.2	0.3	0.1	0.1	0.1	0.2	0.0	0.0	0.2	0.2	0.3	2.0
Irr_Welmel	0.0	0.0	0.0	0.0	0.5	5.7	0.0	0.0	0.0	0.0	13.2	8.9	28.4
Sum	13.5	13.6	9.9	2.2	2.3	9.4	5.1	4.8	2.8	1.8	18.4	16.9	**100.5**

5.8.2. Long Term Scenario III (2030 – 2050)

In this scenario both the future development and climate change effect to the year 2050 on the sectional demand is considered and analyzed. Based on the simulation results unmet the domestic, irrigation, and livestock demand is presented below from all demand sites 10 Weredas and 7 Irrigation schemes are unmet and from the total demand of the 1412 Mm^3 project the total unmet demand is 179.8Mm^3 (12.73%) of the total demand.

Table 5.8-2 Monthly Unmet water demand for Long Term Scenario III (Mm3).

Unmet Demand (Cubic Meter)													
Scenario: SHORT TERM SCENARIO THREE, All months (12), Monthly Average													
UNMET	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
Adaba Wereda	1.2	1.0	1.2	1.1	0.2	0.2	0.6	0.4	0.1	0.0	0.6	1.1	7.8
Agarfa	0.9	0.8	0.9	0.8	0.2	0.2	0.5	0.3	0.1	0.0	0.4	0.8	5.8
Bule Hora Wereda	2.1	1.8	2.0	1.1	0.5	1.5	2.1	1.6	1.3	0.4	1.0	1.8	17.1
Dinsho Wereda	0.3	0.3	0.3	0.3	0.1	0.1	0.2	0.1	0.0	0.0	0.2	0.3	2.2
Dugda Dawa Wereda	1.2	1.0	1.2	0.6	0.3	0.9	1.2	1.0	0.8	0.3	0.6	1.1	10.2
Gasera Wereda	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Ginir Wereda	1.2	1.0	1.2	1.1	1.2	1.1	1.2	1.2	1.1	1.2	1.1	1.2	13.9
Goba Wereda	0.3	0.2	0.3	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.2	0.3	2.4
Moyale Wereda	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.9
Sinana Wereda	0.9	0.7	0.9	0.6	0.3	0.5	0.5	0.3	0.2	0.5	0.6	0.8	6.8
Irr_Welmel	0.0	0.0	0.0	0.0	0.8	6.0	0.0	0.0	0.0	0.0	12.3	10.2	29.4
Irr_Yadot	2.1	1.0	5.5	0.0	2.5	2.0	0.8	0.2	0.3	0.0	5.5	7.0	27.0
Irr_Agarfa	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	1.3
Irr_Berber	1.2	2.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2
Irr_D.Mena	2.9	3.5	3.2	0.0	0.7	1.0	0.7	0.2	0.5	0.0	1.3	2.0	16.1
Irr_Dinsho	2.6	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	2.2	7.3
Irr_Goba	3.9	4.6	3.6	0.2	1.2	2.4	2.3	1.6	1.7	1.3	1.9	2.4	27.3
SUM	21.4	19.6	21.9	6.1	8.2	16.3	10.4	7.1	6.2	3.9	26.9	31.9	**179.8**

6. CONCLUSION AND RECOMMENDATIONS

6.1.Conclusion

This study analyzed the effects of future development and climate changes using different scenarios on Genale Dawa river basin water allocation using the WEAP model. It analyzes the effect of climate change on water availability and supply delivered and also future development which depends on the water release from rivers connections on the basin.

First the meteorological missed data due to misreading and failed of the gauging instruments were filled by a multi-regression method using Microsoft excel. The filled data consistencies were then checked by a double mass curve. For the RCM data the bias was checked and evaluated using R2 and NSE. The WEAP model also calibrated and validated using simulated and observed streamflow data of, Chenemesa Gauge, Halowey Gauge, Nr. Bore Dimtu Gauge, and Melka Guba Gauge stations. The performance evaluation of the model confirmed that the statistical measure parameters were very good and the model can be used to simulate future streamflow with the climate change and irrigation development effect in the basin.

The study found No quantity of unmet demand in the in reference Scenario Among the total water requirement of the (506.49Mm^3), all are met and there is no unmet demand from the years 1990 to 2018 for all cumulative demands.

Similarly in the coming future Development Scenario I Short term and Long term analysis period among the total water requirement The unmet Demand for domestic water demand of all wereda's in the Genale Dawa river basin in from the future Demand of 562.79Mm^3 for the 6.85 Million Population at the year of 2030 it became 10.12% of the total domestic demand is unmet and for that of Livestock, the unmet Demand is about 2.29 Mm^3 which is 3.6% of the total demand in the Short Term Scenario one. And the unmet Demand for irrigation Demand varies depending on the overall irrigation efficiency for the η=45% the unmet demand is 7.2Mm^3 (2.45 %) and for η=50% 4.7Mm^3 (1.78%) and the unmet demand for η=60% became 1.8Mm^3 (0.83%) from the total demand. The unmet Demand from the future Demand of 919.83Mm3 for the 11.20 Million Population at the year of 2050 it became 11.12% of the total domestic demand is unmet and for that of Livestock, the unmet Demand is about 2.29 Mm3 which is 4.6% of the total demand in the Long Term Scenario One. The unmet Demand for irrigation for the η=45% the unmet demand is

28.8Mm^3 (6.24 %) and for η=50% which is 20.7Mm^3 (5.5%) and the unmet demand for η=60% became 14.4Mm^3 (4.62%) from the total demand.

And for the Climate change scenario II The total net amount of water delivered to the Demand sites from the water required to meet the demands of all the sites from 2019 to 2030 was 759.6Mm^3 and 83.35 Mm^3 which is (27.53%) of total Demand is Unmet in the analysis. And for the period 2030 to 2050 the water demand was about 759.6Mm3 and 72.02Mm3 which is (9.48%) of the total demand is found Unmet in the analysis.

For scenario three (combination scenario) both the future development and climate change effect on the sectional demand are considered and analyzed. Based on the simulation results from the total demand of 916.13 Mm^3 in 2030 and 1412.Mm^3 at 2050 the total unmet demand is found to be 100.5Mm^3 and 179.8Mm3 which is 10.97% and 12.73% of the total demand respectively.

6.2.Recommendations

The following recommendations can be derived from the results obtained and its analysis

- This study was carried out using various models, computer programs and model inputs with less good quality climatic data obtained from National Meteorological Agency each of which possesses a certain degree of uncertainty; therefore, these results should be taken with care and should be taken as an initial assessment to picture water allocation under future developments and climate change and demand analysis in the study area.
- The current study is mainly concerned with the surface water resources in the basin. However with the increase of scarcity of water, groundwater resources in the basin will come to play a major role in future water resources development. A detailed assessment of groundwater resources in the basin is required for acquiring data needed for future studies on groundwater use.
- The conservational measure structures on the upper part of the basin should be constructed like bunds; terraces, planting trees, etc. and farmers should be encouraged on climate change adaptation measures through crop tolerating to water scarcity in the future should be cultivated.
- The limited data availability prevented the incorporation of water quality concerns into the current analysis. Studies on water quality of the Genale Dawa River basin and its tributaries are needed for future water allocation studies.

7. Reference

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Annex 1

1.1.Summary of a modern Irrigation scheme in the Genale Dawa River basin

List of Exist Irrigation schemes in the basin

Name of Scheme	X	Y	Z	Verified Area (ha)
Ababa	489763	673787	1474	32.22
Arda Tare	693588	786299	1578	123.35
BadessaAdibar	493027	665765	1465	34.12
Bamo	607445	777340	2619	128.71
BoltuGirisa	488373	689490	1560	70.6
Bora GalmoSirima	628571	744446	1155	396.15
Burkitu	599082	776210	2960	111.36
Burkitu-mada	417368	600479	1632	21.74
Chiri	584487	709703	1356	168.76
Darahonsho	464880	479844	1329	16.74
Deyu	606700	720020	1242	68.82
Dinik	691727	782832	1517	209.69
Doshe	488703	674129	1511	32.03
Gabe Keku	622506	752385	1275	104.66
Gaguro	690622	784121	1631	71.91
Gobaya	645259	745259	1198	193.15
Gumguma	590063	701840	1209	63.93
Hambella 1 & 2	616608	734850	1254	123
HayaOda	600045	704419	1142	104.6
Hila	490683	677129	1452	40.6
KabiraEllu	616241	779551	2465	59.1
Kame	462886	707475	2292	4.95
Lola	605127	782879	2518	44.44
MalkaButa	678125	770041	1581	44.94
MiyesaHanchabi	550055	643008	1157	1.27
Shawe	575012	713144	1466	257.55
Tebela	697756	788709	1483	98.41

1.2.Average Kc values of different land use/cover types in GD River Basin (GDMP)

LuLc	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Forest	0.65	0.66	0.77	0.77	0.78	0.78	0.78	0.78	0.77	0.78	0.77	0.7
Wood Land					0.35	0.64	1	1.06	1.04	0.52		
Shrub/Bush	0.65	0.66	0.77	0.77	0.78	0.78	0.78	0.78	0.77	0.78	0.77	0.7
Grass Land					0.35	0.64	1	1.06	1.04	0.52		
Barren Land	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Water Body	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Crop Land	0.82	0.85	0.8	0.92	0.91	0.4	0.81	0.96	0.87	0.68	0.9	1.01

1.3. Summary of Wereda population Statistics in the Genale Dawa River basin (CSA, 1990 and 2017 projection).

No	Wereda	Region	Zone	Pop. No 1990	Pop. No 2017
1	Adaba	Oromia	West Arsi	97856	180576
2	Adola	Oromia	Guji	134343	139942
3	Afder	Somali	Afder	6526	38061
4	Agarfa	Oromia	Bale	66610	134276
5	Arbe Gona	SNNP	Sidama	135453	167991
6	Arero	Oromia	Borena	21572	62236
7	Aroresa	SNNP	Sidama	94923	205446
8	Bare	Somali	Afder	80797	120022
9	Bdolobay	Somali	Afder	71940	108525
10	Bensa	SNNP	Sidama	186343	309231
11	Berbere	Oromia	Bale	38617	117207
12	Bona Zuria	SNNP	Sidama		149946
13	Bore	Oromia	Guji	119120	252223
14	Bule Hora	Oromia	Borena		348433
15	Bursa	SNNP	Sidama		125505
16	Chereti/weyib	Somali	Afder	65853	115248
17	Chire	SNNP	Sidama	160246	165247
18	Dawe Kachen	Oromia	Bale		39466
19	Dilo	Oromia	Borena		47162
20	Dinsho	Oromia	Bale		50779
21	Dire	Oromia	Borena	86341	95452
22	Dodola	Oromia	West Arsi	126495	258198
23	Dolo- Mena	Oromia	Bale	81011	117688
24	Dolo- Odo	Somali	Liben	138412	145655
25	Dugida Dawa	Oromia	Borena		189271
26	Filtu	Somali	Liben	112465	168452
27	Gasera	Oromia	Bale	2820	101119

28	Ginir	Oromia	Bale	97739	184314
29	Girja	Oromia	Guji		64154
30	Goba	Oromia	Bale	59028	51836
31	Gololcha-Wereda	Oromia	Bale	119499	130199
32	Goro	Oromia	Bale	71256	108611
33	Goro Bekekesa	Somali	Afder		66045
34	Goro Bekeksa-Wereda	Oromia	West Arsi	71256	66045
35	Goro Dola	Oromia	Guji	71256	100672
36	Gura Damole	Somali	Afder	3090	25533
37	Gura Damole	Oromia	Bale	19015	25533
38	Hambela Wamena	Oromia	Guji		134089
39	Harena- Buluk	Oromia	Bale	81011	105321
40	Hula	SNNP	Sidama	178644	159841
41	Kercha	Oromia	Guji		292557
42	Kokosa	Oromia	West Arsi	88834	184968
43	Liben	Oromia	Guji	111696	177022
44	Meda-Welabo	Oromia	Bale	61919	125069
45	Miyu	Oromia	Borena		65711
46	Moyale	Oromia	Borena	66495	39630
47	Moyale Town	Somali	Liben	66495	326833
48	Nensebo	Oromia	West Arsi	48024	147783
49	Odo- Shakiso	Oromia	Guji	91785	273932
50	Rayitu	Oromia	Bale	31056	43279
51	Serer	Somali	Afder		74234
52	Sinana	Oromia	Bale	137354	150814
53	Teletel	Oromia	Borena	35128	91326
54	Udet	Somali	Liben		55826
55	Uraga	Oromia	Guji	170518	226765
56	Wadera	Oromia	Guji		65912
57	Yabelo	Oromia	Borena	56878	135912

Annex 2

Station name: Konso

Element: Monthly total rainfall (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	21.5	22.8	97.3	238.5	214.3	19.1	3.3	9.4	47.3	112.5	28.6	18.0	832.6
1988	20.8	17.0	32.1	191.8	54.3	72.5	77.8	47.4	142.2	68.6	14.1	11.6	750.2
1989	38.6	97.9	121.1	158.9	112.0	22.7	34.6	32.9	105.8	108.1	17.5	96.2	946.3
1990	11.5	145.9	178.4	157.8	73.8	10.4	10.0	11.9	41.1	40.8	28.2	16.9	726.7
1991	35.5	37.4	148.6	95.1	166.6	46.3	0.0	49.2	24.3	72.3	67.9	37.4	780.6
1992	7.9	23.3	54.7	159.5	138.3	68.5	42.6	4.9	92.4	112.1	38.6	38.4	781.2
1993	107.5	169.9	1.8	168.7	106.3	39.4	1.0	1.6	14.9	90.1	29.6	24.7	755.4
1994	549.6	4.2	81.8	171.1	137.1	16.7	29.7	69.3	15.7	109.3	64.6	16.7	1265.8
1995	10.2	7.1	31.1	171.7	31.8	87.7	22.8	1.4	44.1	55.8	66.3	3.2	533.2
1996	32.7	24.0	161.1	205.4	74.0	76.7	19.8	35.8	94.9	80.6	10.1	0.0	815.1
1997	5.8	0.0	52.6	259.1	74.8	22.3	79.3	28.2	15.0	193.4	229.7	64.2	1024.4
1998	122.9	125.5	45.1	118.3	123.9	53.9	1.5	25.0	40.1	120.7	32.2	0.0	809.1
1999	7.6	3.5	148.5	106.0	4.9	12.4	31.5	41.8	38.3	68.3	11.6	66.9	541.3
2000	0.0	0.0	28.3	87.1	98.2	5.0	10.3	18.3	17.9	84.8	37.5	68.1	455.5
2001	33.2	4.1	98.4	352.0	119.0	39.4	19.8	63.1	50.3	137.8	81.2	1.9	1000.1
2002	43.0	15.7	86.9	112.0	77.9	14.0	0.0	3.4	43.1	92.9	28.2	228.7	745.8
2003	3.8	14.2	80.2	231.6	210.4	25.7	27.2	85.0	30.1	41.4	44.0	35.3	828.9
2004	33.4	13.0	54.2	112.6	123.3	4.9	6.2	0.3	56.3	42.1	83.5	33.2	563.0
2005	25.0	2.4	81.8	145.0	273.4	9.5	19.4	16.2	61.8	109.9	57.6	0.0	802.0
2006	3.1	65.9	142.2	177.5	41.9	32.0	5.0	100.3	14.6	141.2	181.8	75.4	980.9
2007	13.4	3.8	55.1	154.7	84.2	77.6	12.3	115.6	181.7	71.2	70.2	0.0	839.8
2008	3.7	4.3	43.2	128.8	68.6	10.1	44.8	54.3	144.9	192.7	29.0	0.5	724.9
2009	44.4	16.3	61.5	82.6	93.4	23.3	11.9	1.4	51.1	63.2	90.3	38.8	578.2
2010	44.0	56.6	163.1	220.1	180.3	24.9	18.5	23.2	57.9	73.9	26.1	20.2	908.8
2011	0.0	24.8	62.7	79.9	177.0	24.8	68.9	50.5	61.0	137.6	281.0	70.5	1038.7
2012	0.0	2.6	36.2	217.3	55.5	17.6	66.6	46.9	180.9	128.1	79.0	54.5	885.2
2013	18.4	11.1	77.9	168.7	119.0	20.0	11.1	55.0	113.7	53.4	115.2	8.6	772.0
2014	1.9	83.6	104.4	52.5	114.2	59.9	31.2	41.3	37.7	114.8	94.0	0.8	736.3
2015	0.0	15.9	59.8	233.9	99.9	125.1	43.8	31.0	32.1	97.2	100.5	88.5	927.7
2016	10.8	53.0	56.3	285.4	179.1	123.7	0.0	14.2	32.7	65.6	0.0	2.9	823.7
2017	0.0	13.7	52.5	49.0	244.6	12.7	57.8	58.0	85.7	173.6	57.5	0.0	805.1
2018	0.0	56.8	157.1	304.5	135.4	60.7	6.7	69.4	22.8	56.2	25.8	23.2	918.6
Mean	39.1	35.5	83.0	168.7	119.0	39.4	25.5	37.7	62.3	97.2	66.3	35.8	==

Station name: Robe
Element: Monthly total rainfall (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	69.7	69.9	82.5	106.3	102.3	69.3	66.6	67.7	74.1	85.1	70.9	69.1	933.4
1988	69.6	68.9	71.5	98.5	75.2	78.3	79.2	74.1	90.1	77.7	68.5	68.0	919.5
1989	2.4	37.9	136.2	209.3	22.9	90.7	134.6	147.2	117.0	64.9	15.9	76.8	1055.8
1990	3.4	220.1	75.8	211.0	79.2	44.4	131.0	172.7	110.0	26.1	10.0	2.1	1085.8
1991	7.3	47.2	160.4	64.6	74.9	35.6	165.8	173.9	70.4	15.4	0.2	12.0	827.7
1992	81.5	26.7	18.4	73.1	102.1	79.9	166.4	167.2	61.6	66.2	63.4	54.6	961.1
1993	114.9	117.0	0.0	129.6	58.0	67.3	115.1	127.2	108.4	82.6	0.0	0.6	920.7
1994	0.0	0.0	43.3	53.8	38.0	91.8	174.3	79.0	104.2	34.0	22.4	3.7	644.5
1995	0.0	18.3	124.8	189.2	41.1	49.0	151.6	223.6	71.1	17.9	0.0	14.3	900.9
1996	11.4	0.0	82.4	83.1	109.1	112.9	132.4	209.6	90.8	13.0	9.8	36.1	890.6
1997	75.4	0.0	60.8	83.7	25.4	83.5	134.3	183.9	39.1	149.5	153.0	9.8	998.4
1998	46.3	56.8	77.9	61.6	107.8	71.6	202.2	416.8	110.8	153.0	2.1	3.2	1310.1
1999	8.5	1.8	94.6	53.4	96.0	76.5	227.9	204.8	46.6	124.6	15.2	0.0	949.9
2000	1.0	0.0	3.5	124.4	135.6	48.5	113.0	177.1	89.6	136.6	12.3	108.2	949.8
2001	0.8	41.6	93.1	69.8	120.5	89.1	138.3	189.8	64.7	52.5	11.4	10.1	881.7
2002	65.0	2.5	135.9	152.4	32.2	34.4	76.3	122.8	152.8	43.9	0.0	83.9	902.1
2003	12.3	0.0	44.1	142.4	26.1	90.3	195.5	262.8	83.7	32.1	9.1	48.2	946.6
2004	26.7	29.1	57.4	115.0	35.6	89.6	135.9	141.0	93.2	46.1	7.7	3.0	780.3
2005	41.1	2.0	58.7	136.1	174.9	132.1	136.5	139.5	125.2	42.1	39.7	2.2	1030.1
2006	23.5	28.5	80.0	185.1	60.9	60.1	231.5	210.5	125.1	68.9	10.7	45.0	1129.8
2007	0.9	38.5	54.5	87.9	169.7	135.4	130.0	239.4	177.1	58.8	25.0	0.0	1117.2
2008	0.6	1.4	5.7	62.2	95.8	155.9	194.7	156.6	91.6	64.8	83.1	8.5	920.9
2009	82.3	0.0	12.8	58.8	57.2	40.6	106.1	230.5	101.8	140.2	17.5	47.9	895.7
2010	10.6	139.4	108.0	59.0	137.6	67.5	199.3	198.6	73.8	5.5	0.0	3.9	1003.2
2011	0.0	17.2	27.2	67.7	144.2	81.6	172.5	133.7	130.6	4.2	84.6	0.0	863.5
2012	0.0	0.0	31.0	108.4	67.5	39.0	135.1	141.3	192.1	28.5	1.6	5.0	749.5
2013	21.6	0.0	150.1	113.4	85.6	119.8	169.3	203.6	68.3	70.0	32.9	0.0	1034.6
2014	0.0	7.7	71.1	68.8	85.3	21.4	118.6	185.4	78.4	91.4	5.1	0.0	733.2
2015	0.0	0.0	6.2	31.9	104.0	86.1	96.8	110.1	67.4	22.8	45.5	3.1	573.9
2016	23.4	0.0	10.5	218.6	110.2	41.2	216.2	246.0	102.3	35.1	27.4	23.8	1054.7
2017	0.0	15.6	89.3	25.9	222.9	28.6	151.4	162.7	191.7	32.7	26.5	0.0	947.3
2018	0.0	75.7	92.6	117.5	88.9	76.3	67.2	175.3	62.6	71.7	0.0	3.5	831.3
Mean	25.0	33.2	67.5	105.1	90.2	74.6	145.8	177.3	98.9	61.2	27.2	23.3	

Station name: Kebere Mengest

Element: Monthly total rainfall (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	26.5	33.1	129.8	180.1	334.8	137.8	11.2	15.6	105.6	321.7	61.6	0.0	1357.7
1988	14.5	0.0	29.2	197.4	175.4	61.1	48.4	28.1	92.0	207.5	20.7	9.0	883.3
1989	15.8	4.4	213.8	251.5	181.8	34.5	60.4	58.6	201.3	280.9	144.4	97.5	1544.9
1990	2.8	147.2	166.2	315.0	166.5	19.2	54.4	18.2	65.4	120.9	136.9	29.8	1242.5
1991	37.0	36.5	110.2	118.0	166.1	56.8	23.4	46.1	70.3	40.8	24.6	25.8	755.6
1992	29.3	4.4	21.5	366.3	251.3	61.6	19.4	27.1	130.9	301.4	46.0	24.7	1283.9
1993	64.9	32.0	5.3	203.2	383.9	44.1	2.4	6.2	34.2	206.7	0.0	9.1	992.0
1994	0.0	0.0	68.3	227.6	457.1	16.8	10.7	20.8	80.5	128.4	44.0	32.6	1086.8
1995	0.0	16.3	145.9	223.5	83.9	11.1	31.5	29.1	156.1	260.2	152.0	0.9	1110.5
1996	2.1	3.4	129.0	292.2	320.1	211.0	56.6	9.4	70.4	151.3	78.0	1.8	1325.3
1997	0.0	0.0	39.6	223.9	47.5	19.3	80.1	21.3	55.7	213.3	184.2	18.4	903.3
1998	90.6	75.3	35.4	182.8	173.7	26.5	54.5	22.2	70.0	226.9	35.5	0.0	993.4
1999	0.0	0.0	140.0	161.1	59.7	18.9	15.8	32.5	32.3	164.8	12.4	30.8	668.3
2000	0.0	0.0	15.4	197.9	264.4	15.9	7.4	56.9	28.1	210.9	71.3	11.4	879.6
2001	10.0	12.8	66.8	308.5	193.9	49.5	17.8	53.6	91.5	191.0	73.0	4.3	1072.7
2002	15.2	0.0	115.0	87.4	167.0	5.4	11.7	3.1	83.2	247.8	27.1	108.6	871.5
2003	43.6	0.0	67.5	246.3	276.2	52.0	27.4	53.7	13.8	66.3	30.4	52.2	929.4
2004	65.7	16.9	48.5	174.6	11.8	13.6	21.1	11.6	101.6	117.6	252.5	17.9	853.4
2005	100.8	31.7	142.2	320.8	358.3	24.0	28.5	29.2	92.0	281.1	137.3	0.0	1545.9
2006	0.0	30.3	107.9	152.1	111.1	43.6	2.5	94.2	28.4	279.2	64.3	33.7	947.3
2007	7.3	18.4	85.5	252.3	125.4	124.2	57.0	59.7	128.8	156.8	19.3	12.8	1047.5
2008	1.7	0.0	101.0	132.9	147.3	18.0	63.0	49.6	160.0	155.1	42.0	12.4	883.0
2009	56.5	29.0	18.3	114.4	102.5	41.1	37.6	43.5	84.7	62.6	97.3	27.0	714.6
2010	5.6	79.5	194.0	289.0	269.6	1.7	12.8	82.3	30.3	120.6	51.8	28.7	1165.9
2011	12.8	31.1	68.1	97.5	189.3	45.6	61.1	28.1	107.7	136.7	251.7	69.3	1099.0
2012	0.0	0.0	0.5	287.8	260.0	10.9	37.3	43.3	103.7	260.1	106.3	3.2	1113.1
2013	21.3	0.0	222.2	283.8	283.8	96.8	48.7	19.3	61.0	192.8	107.2	0.0	1336.9
2014	0.0	37.0	76.6	198.5	110.0	20.5	66.4	38.0	72.7	136.2	100.6	19.2	875.6
2015	0.0	0.0	26.3	200.9	185.3	50.1	37.5	20.4	30.5	154.6	56.2	6.4	768.2
2016	30.7	64.4	68.5	292.3	187.0	7.9	139.9	9.8	59.2	79.6	21.8	23.9	985.1
2017	18.6	32.3	74.8	64.1	257.4	18.7	86.9	50.8	166.2	178.0	71.5	18.5	1038.0
2018	18.5	76.9	165.8	296.6	146.6	80.3	0.0	8.8	14.8	25.9	45.1	3.8	883.1
Mean	21.6	25.4	90.6	216.9	201.5	45.0	38.5	34.1	82.0	177.4	80.2	22.9	

Station name: Dello Mena
Element: Monthly total rainfall (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	2.3	16.0	80.9	93.3	354.4	19.1	1.8	14.9	75.7	255.1	49.2	1.3	964.0
1988	2.8	18.1	74.4	204.9	142.3	43.4	44.5	57.3	84.5	181.9	16.5	34.6	905.2
1989	2.9	2.7	160.4	259.5	155.1	31.7	11.9	60.8	177.0	236.1	110.7	95.4	1304.1
1990	0.7	71.9	167.1	274.0	120.4	4.7	12.0	37.4	74.9	106.3	10.2	24.0	903.6
1991	32.1	35.2	191.3	171.9	78.9	22.0	22.4	0.9	12.6	53.5	30.9	24.9	676.6
1992	26.6	9.4	28.6	311.7	196.2	82.5	0.0	21.0	18.0	217.3	6.8	57.4	975.5
1993	77.1	0.9	12.2	130.6	84.1	7.3	0.0	7.2	30.6	212.2	4.8	0.0	567.0
1994	0.0	0.0	35.9	270.4	309.7	10.4	9.2	7.8	79.7	113.4	47.3	2.0	885.8
1995	0.0	48.0	193.4	387.4	114.7	81.0	19.9	13.2	65.7	226.2	111.8	47.4	1308.7
1996	10.1	9.5	141.7	279.7	254.0	182.2	57.5	22.6	80.4	129.3	64.6	21.4	1253.0
1997	2.9	0.0	50.1	159.9	90.3	10.9	25.0	35.5	101.1	293.0	273.7	31.5	1073.9
1998	148.4	199.1	26.5	174.7	159.7	12.0	8.4	50.3	15.4	472.3	19.5	0.0	1286.3
1999	1.5	3.1	122.6	226.6	109.6	13.3	24.3	14.4	32.7	133.8	27.2	0.0	709.1
2000	6.8	0.0	6.8	173.6	370.6	10.5	3.5	6.9	32.9	226.8	36.8	41.2	916.4
2001	0.4	21.4	64.6	232.6	249.8	30.1	4.7	42.8	132.3	270.1	136.6	5.7	1191.1
2002	49.8	0.0	115.0	145.1	121.0	11.5	15.2	0.5	132.5	249.1	28.5	72.0	940.2
2003	10.5	0.0	46.0	325.7	247.3	38.1	21.2	26.9	80.1	78.1	104.6	84.1	1062.6
2004	32.0	4.5	7.5	162.0	64.1	28.6	22.3	46.7	111.6	126.0	174.4	27.8	807.5
2005	15.0	22.1	86.9	252.0	507.8	26.1	26.6	29.4	90.9	229.4	114.1	0.0	1400.2
2006	5.2	44.4	94.7	254.2	147.8	64.7	10.9	69.5	86.8	250.0	148.1	22.7	1199.0
2007	2.3	6.4	138.8	145.5	172.2	106.5	21.3	38.6	151.5	182.8	181.0	0.0	1146.9
2008	2.5	0.0	0.8	128.5	236.1	39.3	18.3	32.2	68.6	214.3	181.0	0.0	921.6
2009	56.3	22.7	20.0	174.9	185.7	12.3	0.6	11.9	158.2	168.4	47.2	79.4	937.6
2010	50.4	115.9	350.7	91.7	397.3	7.3	34.3	64.8	109.7	101.4	57.0	0.0	1380.5
2011	0.0	1.0	0.0	29.1	34.8	30.2	75.3	47.5	91.3	173.8	180.3	0.0	663.3
2012	0.0	0.0	17.2	350.5	181.5	2.3	8.1	27.8	89.7	157.2	154.6	15.7	1004.6
2013	32.6	0.0	252.3	303.7	169.5	24.5	56.3	48.2	75.2	191.4	199.8	0.0	1353.5
2014	0.0	6.0	165.7	149.3	0.0	0.0	14.0	36.1	71.7	136.2	81.2	13.0	673.3
2015	0.0	0.4	1.7	159.7	244.7	63.3	18.5	1.2	57.2	338.8	67.0	6.6	959.1
2016	1.1	58.9	15.2	366.2	260.7	38.6	14.0	63.0	22.5	291.0	66.6	16.6	1214.4
2017	0.0	5.5	20.0	59.7	181.6	21.0	25.9	41.2	181.4	203.3	124.2	0.0	863.8
2018	0.0	74.8	165.6	299.1	145.9	78.3	5.9	38.5	68.7	117.5	8.7	0.0	1003.0
Mean	17.9	24.9	89.2	210.9	190.2	36.1	19.8	31.8	83.2	198.0	89.5	22.6	

Station name: Hagere selam
Element: Monthly total rainfall (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	59.6	67.5	153.4	212.4	257.0	108.4	57.0	80.1	126.5	190.8	75.3	47.7	1435.8
1988	38.3	47.5	52.4	121.5	127.2	150.3	190.9	121.5	171.6	143.5	9.8	13.4	1187.9
1989	38.5	20.4	106.2	145.6	80.4	111.8	77.4	145.9	152.3	151.9	47.9	75.2	1153.5
1990	30.4	174.5	99.9	199.1	109.6	147.9	69.9	82.6	79.0	73.8	58.8	9.5	1135.0
1991	56.9	53.9	90.2	39.5	138.8	185.6	113.0	60.5	251.3	61.8	57.8	8.1	1117.4
1992	78.4	45.8	39.7	194.4	126.8	140.6	135.8	163.4	72.0	288.7	64.8	70.3	1420.7
1993	109.9	134.2	30.4	171.2	206.5	70.8	64.8	83.1	146.0	159.7	12.0	27.5	1216.1
1994	7.0	13.1	113.3	184.8	219.3	62.9	212.4	140.6	103.0	38.1	43.7	6.5	1144.7
1995	21.6	59.3	170.9	157.4	51.5	72.3	90.1	147.5	128.7	90.1	27.4	19.5	1036.3
1996	102.7	28.0	8.3	234.7	202.5	244.6	82.1	147.7	101.4	78.8	39.7	16.3	1286.8
1997	73.7	0.0	146.7	229.4	136.3	100.9	82.0	111.8	25.6	239.3	188.3	38.7	1372.7
1998	70.8	64.4	34.7	161.9	228.4	71.1	108.8	175.7	156.3	243.6	14.2	13.7	1343.6
1999	28.7	25.3	164.7	217.1	209.7	89.5	117.1	199.6	74.4	349.5	33.3	8.5	1517.4
2000	0.0	0.0	18.0	139.0	161.0	84.1	41.1	190.1	240.0	442.4	61.6	30.0	1407.3
2001	74.2	45.3	122.8	193.7	161.5	86.0	75.2	209.5	155.0	179.3	60.2	7.7	1370.4
2002	33.7	43.1	132.8	106.9	163.5	85.1	130.7	39.1	115.1	172.9	13.0	133.3	1169.2
2003	69.6	11.7	74.7	94.7	74.4	185.3	77.1	117.5	198.0	36.6	41.6	36.4	1017.6
2004	80.6	41.5	25.2	184.3	182.3	64.8	104.7	169.2	14.7	150.4	102.4	35.9	1156.0
2005	70.5	29.5	82.5	123.3	324.3	104.3	87.5	142.9	145.1	253.2	64.9	0.0	1428.0
2006	33.4	76.4	56.5	161.1	131.8	136.8	112.7	133.1	44.4	177.5	86.8	60.7	1211.2
2007	84.2	51.7	53.3	209.5	196.2	256.7	117.2	278.5	183.5	84.7	67.4	2.0	1584.9
2008	0.0	23.3	47.4	109.4	159.7	168.5	90.0	158.0	212.3	143.6	114.4	5.0	1231.6
2009	91.9	36.3	30.6	126.6	179.6	69.9	46.6	249.2	72.9	142.8	29.6	77.3	1153.3
2010	25.9	181.6	200.7	263.1	329.9	111.1	96.3	130.6	193.2	214.5	3.6	6.1	1756.6
2011	2.4	2.1	24.5	264.7	368.4	150.2	143.3	154.5	150.2	199.4	259.7	51.5	1770.9
2012	2.4	2.1	24.5	264.7	162.3	52.9	138.5	78.8	187.6	145.1	39.2	34.5	1132.6
2013	5.9	8.0	201.7	322.4	196.8	116.9	151.8	167.4	99.4	156.4	119.2	0.0	1545.8
2014	23.0	47.4	98.6	146.2	105.2	262.3	111.0	229.3	245.2	201.2	110.6	16.9	1596.8
2015	30.0	22.6	35.7	244.1	244.9	113.8	58.5	135.8	122.1	116.4	84.4	34.8	1243.1
2016	29.5	10.5	75.3	199.8	283.0	179.6	133.5	182.2	159.6	176.8	47.8	49.4	1527.0
2017	1.0	5.2	50.4	71.6	273.0	51.9	218.8	206.0	365.1	141.1	78.4	34.0	1496.4
2018	4.6	104.4	141.1	242.8	148.3	106.5	64.9	135.7	72.0	87.2	46.7	34.4	1188.7
Mean	43.1	46.1	84.6	179.3	185.6	123.2	106.3	149.0	142.6	166.6	65.8	31.4	

Station name: Neghelle
Element: Monthly total rainfall (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	0.0	14.9	80.3	175.0	296.0	22.0	0.0	1.3	19.0	107.0	98.0	0.0	813.5
1988	0.0	2.6	33.3	295.6	51.8	0.0	7.7	0.0	15.3	119.8	0.0	2.3	528.4
1989	12.4	0.0	202.0	160.0	88.6	0.0	22.8	0.0	58.6	132.0	12.6	12.2	701.2
1990	2.7	78.0	140.1	271.1	59.4	1.6	18.2	16.7	50.1	76.3	57.8	20.1	792.1
1991	25.0	25.9	107.9	100.6	110.4	24.3	0.0	21.0	20.9	40.6	28.9	23.2	528.7
1992	12.6	7.3	25.9	227.3	160.3	47.9	4.7	11.8	74.4	67.4	0.8	36.1	676.5
1993	9.3	61.2	2.2	244.5	191.2	8.8	6.6	0.0	0.0	135.8	3.0	5.9	668.5
1994	0.0	0.0	30.7	146.7	207.6	1.4	16.8	2.2	48.1	131.0	30.3	8.6	623.4
1995	0.0	24.4	98.1	289.8	52.5	10.7	9.1	5.9	54.1	145.6	48.7	0.0	738.9
1996	1.8	0.8	146.8	274.5	75.8	7.5	4.4	0.1	26.2	182.0	54.4	0.6	774.9
1997	0.2	0.0	33.9	96.3	42.2	43.6	3.3	0.0	67.3	203.8	106.1	27.3	624.0
1998	60.7	17.5	11.5	114.0	130.3	22.8	13.4	5.1	1.4	68.4	20.0	6.5	471.6
1999	0.0	0.0	105.5	27.1	64.7	2.0	2.6	1.1	6.6	135.5	12.0	1.7	358.8
2000	0.8	0.0	0.0	105.1	134.8	0.3	2.2	6.0	4.5	169.4	66.1	23.1	512.3
2001	0.0	9.7	76.4	213.3	94.2	2.9	3.2	5.4	49.7	112.3	37.6	2.2	606.9
2002	4.9	0.0	119.7	67.9	93.5	0.9	1.7	2.5	68.2	206.4	6.2	119.6	691.5
2003	9.7	0.0	25.3	242.3	192.9	2.1	2.9	17.9	7.1	50.5	21.2	43.5	615.4
2004	49.8	9.5	27.4	225.7	56.0	5.1	0.0	0.3	19.3	138.1	127.0	5.2	663.4
2005	33.9	7.5	68.5	225.3	339.7	4.6	5.8	1.0	2.7	100.2	54.6	0.0	843.8
2006	0.0	25.2	119.0	301.8	102.6	1.3	3.3	23.6	5.1	149.2	45.4	15.9	792.4
2007	0.9	2.5	45.6	171.8	109.1	17.3	11.6	8.0	18.7	98.1	23.3	4.5	511.4
2008	0.0	0.0	27.1	198.7	85.8	3.6	6.9	2.7	43.9	309.2	98.8	0.0	776.7
2009	14.4	17.5	31.8	127.2	131.6	2.5	1.1	0.0	46.0	129.0	35.1	12.9	549.1
2010	3.2	24.9	121.2	116.5	41.3	0.8	3.7	7.7	30.6	128.0	25.2	0.0	503.1
2011	0.0	1.2	0.5	62.0	148.9	2.2	5.5	1.1	19.8	120.9	257.9	19.6	639.6
2012	0.0	0.0	0.0	206.9	62.3	1.0	2.4	5.2	52.8	128.4	79.1	4.6	542.7
2013	1.5	0.0	0.0	174.1	176.3	39.9	1.2	23.6	44.9	155.5	116.1	0.0	733.1
2014	0.0	5.9	54.9	167.0	81.5	8.4	39.1	32.9	24.9	159.5	71.5	9.8	655.5
2015	0.0	0.0	24.0	191.8	144.0	11.0	0.0	12.8	26.5	144.6	55.1	1.1	611.0
2016	13.3	49.7	38.9	242.4	149.9	32.4	44.8	7.0	12.0	94.5	19.3	10.6	714.7
2017	7.8	17.1	42.4	44.6	176.7	12.0	2.0	10.3	32.8	144.3	62.1	5.6	557.7
2018	7.5	51.9	126.5	233.1	109.4	54.8	6.6	20.6	21.4	43.1	23.0	6.3	704.2
Mean	8.5	14.2	61.5	179.4	123.8	12.4	7.9	7.9	30.4	128.9	53.0	13.4	

Station name: Ginir
Element: Monthly total rainfall (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	15.5	27.8	109.0	171.6	292.2	37.6	15.5	35.6	77.9	167.9	57.6	12.0	1020.2
1988	11.0	20.4	53.1	206.6	93.0	61.2	94.2	81.2	106.9	143.8	9.4	17.9	898.7
1989	0.0	46.0	88.2	214.5	38.6	10.8	27.4	31.6	141.9	150.1	94.3	67.9	911.3
1990	5.9	61.0	87.9	260.4	184.6	13.7	15.4	3.5	68.0	99.6	82.3	7.4	889.7
1991	0.0	41.2	110.8	180.8	156.0	12.7	56.4	22.7	44.5	61.2	28.4	58.2	772.9
1992	84.8	3.0	41.8	231.8	158.4	85.5	29.0	62.9	63.2	176.0	86.7	68.5	1091.5
1993	73.8	118.4	0.0	143.6	31.2	32.2	17.6	39.4	57.6	162.3	18.1	17.9	712.0
1994	90.2	11.3	59.2	211.8	0.0	35.6	28.3	25.8	63.3	197.2	125.0	36.0	883.6
1995	0.0	8.6	193.3	161.8	82.5	25.7	12.1	2.7	30.7	142.6	16.0	3.6	679.6
1996	29.2	0.0	87.8	288.1	270.5	80.4	23.4	46.5	56.7	84.5	22.9	4.9	994.9
1997	0.0	0.0	27.5	158.2	34.3	71.3	12.3	22.9	105.7	301.6	241.3	71.2	1046.3
1998	200.5	96.5	18.6	188.8	137.5	36.0	39.0	9.0	53.1	146.1	25.7	1.3	952.1
1999	0.0	0.0	125.8	151.5	72.8	18.3	45.8	26.7	95.4	163.1	26.5	0.0	725.9
2000	13.3	8.1	22.0	126.6	89.3	29.7	0.0	55.0	85.7	229.0	40.8	23.5	723.1
2001	0.0	0.0	60.9	66.1	101.3	36.6	1.1	57.3	114.5	182.6	17.0	22.5	659.9
2002	44.5	0.0	127.5	133.1	43.5	24.6	6.3	0.0	122.0	242.9	26.0	41.1	811.5
2003	1.1	0.0	10.3	159.8	105.5	53.9	17.1	68.6	32.4	103.3	68.5	93.1	713.6
2004	85.8	0.0	3.9	218.9	79.5	2.7	0.0	18.1	93.7	183.9	78.1	76.0	840.6
2005	6.4	0.0	57.5	200.2	190.7	35.3	27.8	41.0	78.2	172.9	80.9	0.0	891.0
2006	5.2	31.8	81.1	346.8	139.6	77.6	3.2	16.7	126.8	404.3	82.2	102.0	1417.3
2007	26.9	0.3	45.1	263.1	107.5	56.2	21.9	91.1	124.4	123.3	57.3	9.0	926.1
2008	8.7	0.0	0.0	220.7	91.2	50.0	40.5	68.4	102.2	212.3	206.8	0.0	1000.9
2009	38.9	406.0	19.1	245.9	113.1	22.2	5.4	2.7	225.2	159.8	83.4	39.0	1360.7
2010	0.0	108.8	312.0	315.2	547.8	25.0	50.2	15.0	105.8	181.3	39.5	0.0	1700.6
2011	3.0	2.0	0.0	109.1	214.6	79.9	39.7	63.3	130.3	145.3	173.9	35.3	996.4
2012	0.0	0.0	5.6	150.8	219.9	34.0	2.9	232.2	284.3	157.3	110.5	46.0	1243.5
2013	56.0	0.0	238.5	385.0	219.0	3.5	94.2	49.1	45.4	93.2	157.6	108.6	1450.1
2014	0.0	0.0	155.7	189.5	277.3	5.5	14.0	127.9	125.8	318.2	180.7	0.0	1394.6
2015	0.0	0.0	100.6	114.8	164.8	74.5	14.7	2.5	105.6	287.6	81.1	5.7	951.9
2016	6.5	13.4	14.5	279.8	141.8	52.0	12.5	41.0	72.3	199.0	65.4	33.0	931.2
2017	0.6	18.2	41.1	62.4	197.9	32.0	65.7	44.5	75.8	156.2	93.5	17.6	805.5
2018	12.5	75.6	147.4	261.5	134.6	78.5	1.0	180.0	42.0	197.5	15.8	0.0	1146.3
Mean	25.6	34.3	76.4	200.6	147.8	40.5	26.1	49.5	95.5	179.6	77.9	31.9	

Station name: Moyale
Element: Monthly total rainfall (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	4.8	12.0	65.0	140.0	203.0	13.3	2.0	4.7	29.0	96.5	44.7	3.7	618.4
1988	5.5	6.7	29.1	182.8	47.3	22.1	29.1	22.8	56.0	82.5	6.9	8.9	499.7
1989	7.8	35.6	109.8	143.7	60.9	1.3	18.5	7.0	75.7	99.2	32.3	43.7	635.6
1990	0.1	67.8	105.3	182.2	80.7	8.5	8.6	4.8	38.8	53.8	40.4	10.1	601.0
1991	9.6	23.5	98.8	103.5	106.6	2.5	8.2	24.0	5.8	40.3	26.1	30.7	479.5
1992	22.3	3.1	28.1	159.7	119.8	42.5	10.3	8.3	56.8	74.6	28.3	32.5	586.1
1993	44.1	81.6	3.0	140.2	75.1	15.2	2.2	4.6	6.5	96.5	10.3	8.2	487.6
1994	165.5	0.8	35.1	131.6	83.1	9.6	1.4	11.1	28.1	117.5	54.9	14.8	653.5
1995	2.0	4.3	78.5	167.7	43.0	26.6	6.2	3.4	25.4	91.6	35.5	1.2	485.4
1996	0.7	27.0	82.0	102.4	130.0	6.8	11.6	0.3	7.4	19.7	27.0	0.0	414.9
1997	0.0	0.0	24.7	228.3	6.1	14.4	8.0	2.4	10.0	504.7	254.0	39.5	1092.1
1998	129.0	68.1	8.4	130.8	129.8	47.7	11.1	15.8	0.9	12.4	38.4	29.9	622.3
1999	0.5	0.0	44.2	41.8	11.1	25.2	3.1	8.5	1.1	97.6	55.4	20.5	309.0
2000	23.0	0.0	0.0	48.5	105.9	2.5	10.2	11.6	16.9	81.8	71.6	64.8	436.8
2001	53.1	5.3	99.7	103.1	12.3	2.3	11.3	17.9	15.6	74.6	17.4	0.0	412.6
2002	19.2	0.0	35.6	148.3	54.4	16.3	0.1	2.4	24.9	117.3	34.6	90.9	544.0
2003	17.0	4.9	10.2	93.5	52.8	13.1	0.8	13.1	2.2	4.0	159.5	23.8	394.9
2004	38.5	16.5	26.7	199.6	15.0	10.5	3.1	0.7	12.6	122.4	98.3	19.9	563.8
2005	8.4	4.6	22.6	138.8	158.3	20.9	9.8	3.1	2.6	21.9	36.9	0.0	427.9
2006	0.5	2.9	26.7	333.5	78.2	5.0	2.2	10.2	68.9	328.7	158.7	28.2	1043.7
2007	3.4	29.6	37.6	145.0	34.4	18.1	38.1	17.2	47.0	69.4	54.8	54.2	548.8
2008	4.9	0.0	28.7	79.1	65.6	49.7	8.5	6.4	10.6	170.2	24.7	0.0	448.4
2009	52.4	1.9	22.9	81.4	83.0	9.2	0.0	2.5	78.1	86.7	38.0	17.7	473.8
2010	17.7	78.6	311.1	255.0	15.0	8.5	19.5	4.0	23.9	34.5	17.5	2.4	787.7
2011	2.7	18.6	0.8	33.4	62.9	16.1	17.6	0.5	17.1	146.5	198.0	1.4	515.6
2012	0.0	0.0	16.3	174.1	99.0	2.7	1.2	21.1	38.0	94.4	95.5	33.5	575.8
2013	0.0	0.0	250.0	206.7	99.0	6.8	11.2	14.9	1.4	72.5	83.0	30.0	775.6
2014	0.0	3.6	58.3	108.8	135.5	1.2	0.0	4.3	5.8	110.2	82.9	0.9	511.5
2015	0.0	0.0	31.6	92.2	106.9	8.3	26.0	4.3	0.0	121.2	133.2	58.6	582.3
2016	0.0	0.0	6.9	221.7	71.3	3.5	0.0	0.0	2.7	1.8	18.6	6.9	333.4
2017	0.0	0.8	42.1	47.2	203.9	1.8	6.0	15.8	30.5	41.1	37.6	37.6	464.4
2018	0.0	66.1	119.0	201.6	128.2	18.0	20.7	11.0	30.6	74.2	11.2	2.2	682.8
Mean	19.8	17.6	58.1	142.7	83.7	14.1	9.6	8.7	24.1	98.8	63.3	22.4	

Station name: Worka
Element: Monthly total rainfall (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	55.9	64.3	150.8	182.1	262.4	114.7	55.1	81.5	137.2	221.1	65.2	41.9	1432.0
1988	46.0	47.5	68.3	155.0	138.2	104.9	148.5	132.6	150.3	180.9	44.6	44.6	1261.3
1989	29.0	40.1	138.8	236.9	100.8	79.1	114.7	126.4	184.2	197.5	121.8	106.5	1475.8
1990	25.4	113.3	137.5	136.3	243.9	177.3	76.7	151.5	100.1	109.3	72.5	31.7	1375.5
1991	35.7	37.8	124.2	97.2	177.5	124.2	96.7	140.4	151.2	66.6	19.6	23.9	1095.0
1992	5.1	33.8	11.6	149.4	287.3	215.3	97.9	158.8	162.8	267.3	62.1	74.7	1526.1
1993	94.5	106.0	15.2	147.2	239.7	158.4	86.2	125.1	113.5	215.5	21.9	43.6	1366.8
1994	1.9	1.0	37.7	201.6	219.4	114.5	199.7	154.3	120.3	131.2	83.6	7.1	1272.3
1995	10.7	21.4	221.6	244.8	137.6	116.6	137.3	114.8	206.4	164.7	58.8	27.4	1462.1
1996	29.1	8.5	186.1	196.2	325.4	231.1	217.0	172.7	190.3	148.9	34.1	23.9	1763.3
1997	30.3	0.0	53.0	237.4	174.1	144.2	122.9	63.0	100.6	270.9	268.0	85.6	1550.0
1998	161.3	137.4	12.5	139.3	140.5	119.9	91.1	188.7	59.2	135.9	20.5	31.8	1238.1
1999	8.1	1.3	109.7	111.3	195.9	100.8	130.1	110.2	118.5	209.9	49.9	14.4	1160.1
2000	4.2	24.2	14.8	197.3	201.1	108.3	153.0	125.7	130.7	387.7	89.4	47.8	1484.2
2001	0.0	72.9	88.3	203.6	381.4	144.2	136.6	226.2	230.7	336.2	29.4	17.1	1866.6
2002	61.5	28.3	139.0	123.7	120.7	56.9	78.8	67.3	150.4	184.5	38.8	88.6	1138.5
2003	0.0	0.0	0.0	354.5	234.3	212.6	291.5	131.5	70.0	77.6	57.5	18.9	1448.4
2004	112.3	6.3	0.0	193.8	150.3	78.5	186.0	105.6	184.7	82.8	54.7	26.5	1181.5
2005	91.0	21.5	127.5	37.8	30.8	19.3	64.3	70.3	92.5	70.8	56.3	0.0	682.1
2006	6.1	59.5	53.9	205.1	132.6	104.0	102.8	157.4	116.0	256.2	70.6	81.8	1346.1
2007	17.3	52.2	41.2	210.3	158.5	153.1	123.0	182.3	177.8	135.5	65.6	26.0	1342.7
2008	26.2	25.5	67.4	137.6	153.9	110.1	117.0	151.9	157.6	120.2	140.6	28.7	1236.6
2009	83.4	135.2	38.5	161.2	116.8	67.1	78.0	149.7	161.5	135.9	83.0	71.9	1282.3
2010	30.9	161.4	249.4	243.8	362.8	73.3	115.2	152.8	120.4	137.6	48.4	32.4	1728.5
2011	27.7	34.1	55.0	134.9	210.6	102.9	138.8	128.3	176.1	121.4	157.1	53.5	1340.4
2012	22.6	22.3	32.9	228.8	214.8	56.2	114.6	186.0	206.0	172.9	82.4	38.6	1378.0
2013	52.4	22.5	250.8	276.1	215.1	204.5	231.8	143.4	86.5	155.8	136.5	46.4	1821.8
2014	0.0	0.0	27.5	163.7	55.5	4.8	0.0	31.5	152.0	188.1	110.5	34.8	768.4
2015	27.0	24.3	62.4	131.8	235.5	42.5	0.0	0.0	53.5	196.0	60.0	16.1	849.1
2016	0.4	35.7	23.0	82.6	20.4	30.7	132.7	0.0	138.0	206.0	0.0	0.0	669.5
2017	0.0	0.4	46.2	225.5	95.5	168.5	0.0	200.8	265.8	264.7	94.9	0.0	1362.3
2018	35.1	103.3	151.7	232.1	143.4	107.6	55.4	145.1	72.3	116.2	48.0	31.7	1241.9
Mean	35.3	45.1	85.5	180.6	183.6	113.9	115.4	127.4	141.8	177.1	73.3	38.1	

Station name: Finch Weha
Element: Monthly total rainfall (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	13.4	20.1	99.9	204.9	275.8	46.3	1.4	5.8	54.2	171.1	52.4	5.1	950.3
1988	9.8	6.0	30.9	220.9	86.9	50.1	51.4	29.1	96.8	120.0	8.2	5.7	715.8
1989	18.0	47.6	156.7	192.0	113.1	14.0	30.5	25.4	124.1	160.2	53.6	74.0	1009.3
1990	0.0	119.7	158.2	234.1	114.9	15.0	17.1	5.2	44.4	70.5	63.7	13.9	856.7
1991	23.7	30.3	127.4	113.4	159.9	37.1	6.1	39.5	33.4	55.1	40.1	31.0	696.9
1992	15.7	6.4	33.7	231.9	180.4	68.1	23.9	10.0	94.6	157.1	34.6	35.1	891.3
1993	71.4	111.6	1.3	191.9	181.3	33.1	7.5	3.5	13.6	138.1	10.9	12.6	776.8
1994	261.2	0.0	60.7	186.4	206.2	13.2	20.3	32.0	37.6	131.1	58.5	15.8	1022.8
1995	0.0	5.3	97.4	210.5	53.8	45.3	12.6	3.6	68.8	133.0	72.3	0.0	702.5
1996	0.0	13.5	125.6	80.0	209.0	86.2	7.2	34.9	27.9	43.3	32.1	0.0	659.7
1997	0.0	0.0	16.3	194.4	9.5	28.4	27.2	28.7	36.4	274.5	402.0	51.0	1068.4
1998	141.9	17.4	8.1	119.2	133.0	62.4	23.4	3.6	6.0	17.6	8.5	0.0	541.1
1999	0.0	0.0	56.9	78.4	12.9	15.3	20.8	3.2	60.5	33.9	18.1	37.4	337.4
2000	0.0	0.0	5.9	138.4	274.1	4.0	0.0	30.0	10.5	206.3	78.0	16.4	763.6
2001	16.6	0.0	54.1	206.7	81.1	36.6	3.5	43.5	75.3	48.8	99.6	0.0	665.8
2002	12.8	5.4	94.0	125.0	121.2	40.3	9.2	0.0	36.1	110.6	10.7	96.4	661.7
2003	22.4	5.7	76.7	350.9	242.3	0.0	0.0	37.0	23.0	63.1	51.4	79.5	952.0
2004	72.7	9.5	33.1	141.0	89.3	8.9	16.2	11.6	58.4	71.9	227.4	5.4	745.4
2005	21.6	9.5	78.3	158.9	364.6	17.0	9.5	17.1	31.1	162.5	41.1	0.0	911.2
2006	0.0	20.6	55.2	303.0	48.7	12.9	5.1	26.9	45.2	318.3	126.1	50.7	1012.7
2007	5.3	8.8	24.3	208.9	69.6	83.0	0.0	58.9	145.2	78.3	26.2	0.0	708.5
2008	2.6	0.0	59.0	127.9	42.1	30.2	22.5	14.1	109.8	176.2	109.5	0.0	693.9
2009	30.2	0.0	66.0	87.3	149.8	18.9	18.0	0.0	13.7	72.6	74.9	25.6	557.0
2010	12.0	41.5	89.6	382.8	187.5	202.0	51.0	52.6	25.5	115.1	2.0	1.3	1162.9
2011	0.0	12.5	3.9	150.2	136.4	33.6	12.2	122.6	81.4	123.4	249.1	0.0	925.3
2012	0.0	0.0	72.6	111.5	106.1	38.4	61.8	70.7	98.7	163.4	96.4	30.8	850.3
2013	11.8	0.0	165.2	244.0	179.1	7.3	24.7	46.7	145.7	108.6	113.7	16.6	1063.4
2014	0.0	76.2	113.6	198.6	85.5	27.7	16.7	31.1	29.6	262.5	112.5	16.6	970.6
2015	0.0	0.0	20.2	262.9	190.7	62.1	7.5	0.0	76.6	182.1	96.8	47.3	946.2
2016	5.8	36.6	24.9	318.1	151.0	53.4	32.9	24.0	32.5	72.1	9.1	4.8	765.2
2017	0.0	0.0	0.0	102.0	179.0	0.0	38.5	62.8	83.8	154.2	60.3	9.9	690.6
2018	0.0	22.7	132.1	438.1	142.9	56.2	3.6	44.9	21.0	65.3	23.6	6.2	956.5
Mean	24.0	19.6	66.9	197.3	143.1	39.0	18.2	28.7	57.5	126.9	77.0	21.5	

Station name: Wadera
Element: Monthly total rainfall (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	9.3	3.6	69.4	153.9	398.6	28.2	4.9	2.5	102.9	174.3	81.5	19.2	1048.3
1988	9.3	4.3	47.3	226.6	149.2	28.7	67.1	12.5	118.3	240.1	21.0	19.1	943.5
1989	4.2	10.0	32.9	297.6	128.3	8.4	18.0	1.5	158.7	220.9	194.1	85.8	1160.4
1990	16.9	108.3	102.4	231.2	91.3	3.1	11.8	0.0	46.5	121.2	195.5	77.8	1006.0
1991	0.0	4.2	130.4	124.8	244.1	0.0	18.6	19.8	70.0	224.2	17.8	0.0	854.0
1992	11.8	37.3	50.6	18.5	223.0	33.9	85.4	17.1	46.2	214.1	0.0	39.6	777.5
1993	64.6	38.9	11.5	293.0	385.0	7.4	0.0	0.0	20.5	224.0	8.0	0.0	1052.9
1994	0.0	0.0	43.0	203.4	270.5	6.5	2.7	6.5	71.2	105.7	53.6	0.0	763.1
1995	2.5	40.0	165.7	336.1	152.6	28.4	9.1	9.8	135.6	263.1	86.3	32.1	1261.3
1996	16.1	14.1	146.1	315.6	312.8	70.9	3.7	27.5	74.1	188.5	104.6	0.0	1274.0
1997	0.0	0.0	50.7	235.0	88.5	20.5	13.0	28.4	58.9	258.6	280.5	29.4	1063.5
1998	88.7	147.8	26.2	149.8	222.0	20.5	18.1	14.9	28.9	235.8	48.2	5.4	1006.3
1999	0.0	4.2	91.7	161.4	86.2	0.0	2.5	0.0	41.1	172.0	21.7	14.9	595.7
2000	0.0	0.0	0.0	118.4	18.4	0.0	1.4	28.4	39.7	241.9	147.7	10.9	606.8
2001	0.0	2.5	104.9	90.0	15.6	37.2	3.4	45.9	114.0	180.4	92.7	0.0	686.6
2002	32.3	0.0	141.3	87.0	122.0	15.1	5.1	0.0	102.3	263.7	5.4	137.7	911.9
2003	19.8	2.5	25.0	233.6	209.8	27.1	40.5	39.8	31.0	56.5	36.7	58.2	780.6
2004	29.3	8.3	16.1	308.2	53.6	10.6	22.2	6.6	69.2	149.9	156.6	28.6	859.2
2005	57.5	0.0	85.4	150.7	247.0	8.9	16.9	20.9	52.1	181.0	89.0	0.0	909.4
2006	0.0	33.8	90.7	263.9	128.7	48.5	9.8	43.0	46.6	291.1	87.3	44.3	1087.8
2007	4.5	14.2	97.5	128.6	157.5	56.2	35.6	12.4	281.9	115.1	39.2	16.6	959.3
2008	0.0	0.0	49.7	112.7	50.3	33.0	28.8	37.6	108.9	261.6	75.7	0.0	758.2
2009	46.9	113.3	13.9	47.5	131.7	26.4	10.3	25.9	81.3	177.3	46.2	33.5	754.1
2010	10.8	83.6	245.7	249.9	276.1	13.9	12.3	33.2	67.8	149.8	42.4	11.9	1197.3
2011	0.0	15.5	0.0	171.3	265.5	48.5	39.2	25.1	81.2	164.1	251.5	45.4	1107.2
2012	1.2	1.2	13.9	257.1	194.7	13.1	13.4	61.6	124.6	194.3	109.3	20.4	1004.7
2013	21.7	1.8	185.1	301.6	231.9	69.7	57.0	26.0	46.8	163.6	134.3	28.3	1268.0
2014	2.5	9.8	80.9	187.3	130.7	25.6	24.5	43.4	86.3	189.9	120.0	13.3	914.2
2015	4.5	3.5	45.1	186.7	184.8	34.3	5.7	0.0	38.8	206.6	73.8	12.2	795.8
2016	9.5	41.6	41.1	243.5	153.3	32.1	56.8	0.0	53.8	144.9	26.5	15.0	818.0
2017	4.2	12.9	45.5	87.1	201.4	42.7	31.3	46.1	119.7	184.6	82.5	14.4	872.4
2018	12.8	77.6	156.3	270.7	142.2	72.3	6.8	49.7	31.4	83.7	33.1	7.0	943.5
Mean	15.0	26.1	75.2	195.1	177.1	27.2	21.1	21.4	79.7	188.8	86.3	25.7	

Station name: Bidere
Element: Monthly total rainfall (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	4.1	10.0	92.5	185.6	335.6	53.7	0.0	0.0	76.9	134.9	58.3	10.0	961.6
1988	18.0	7.0	49.2	175.4	90.7	15.9	50.6	6.6	70.2	155.9	44.3	0.0	683.8
1989	1.1	42.3	221.5	311.4	198.7	0.0	15.2	8.9	115.2	113.4	71.4	36.6	1135.7
1990	8.1	67.9	98.5	174.8	74.1	1.4	19.4	3.4	30.2	105.4	90.5	4.1	677.8
1991	14.3	14.8	126.5	139.7	163.5	6.4	10.0	19.8	29.6	63.6	54.4	7.3	649.9
1992	13.3	17.3	146.4	36.2	211.0	64.9	18.9	19.1	69.7	184.5	19.2	39.9	840.3
1993	51.5	47.6	0.0	199.6	215.4	24.0	0.0	8.3	17.2	189.3	4.1	3.1	760.0
1994	48.5	0.0	32.0	211.0	224.9	12.3	2.5	14.4	60.5	143.0	64.4	7.1	820.6
1995	0.0	16.1	153.6	283.9	106.9	35.3	13.2	4.6	92.5	208.5	75.8	13.0	1003.5
1996	0.0	8.5	141.7	263.8	260.9	85.4	36.8	9.1	62.0	131.1	61.0	0.0	1060.4
1997	0.0	0.0	46.5	166.3	84.5	8.0	18.3	0.1	65.0	378.0	258.9	40.5	1066.1
1998	137.4	0.0	22.8	147.3	133.1	26.5	25.0	9.0	1.0	172.9	41.9	10.1	727.0
1999	0.0	0.0	103.1	253.0	47.6	2.4	9.6	0.0	12.2	146.1	33.1	8.0	615.1
2000	5.6	0.0	11.3	133.5	127.8	0.0	0.0	4.6	1.8	173.6	71.2	18.0	547.4
2001	2.6	20.0	68.8	159.1	189.3	18.5	9.2	46.7	127.7	179.4	87.8	7.1	916.2
2002	6.9	0.0	159.5	190.9	66.8	20.0	9.0	0.0	66.2	177.5	33.0	153.1	882.9
2003	7.8	0.0	24.3	316.5	205.5	6.1	11.7	38.0	37.3	158.1	23.9	70.5	899.7
2004	39.5	0.0	30.8	396.5	55.9	2.3	0.0	6.0	42.3	120.1	129.4	9.6	832.4
2005	57.7	0.0	16.1	184.5	229.6	9.6	0.0	0.0	11.5	85.3	88.3	0.0	682.6
2006	0.0	28.6	75.3	292.5	60.6	9.0	4.6	104.7	38.0	358.0	15.9	39.2	1026.4
2007	0.0	5.0	88.4	207.5	85.4	46.1	4.2	5.6	29.1	121.5	20.8	0.0	613.6
2008	0.0	0.0	26.6	177.7	73.1	1.3	2.0	9.0	69.2	165.9	159.8	43.8	728.4
2009	46.3	118.3	38.6	124.4	116.8	2.0	2.1	0.0	125.8	136.4	57.2	31.6	799.4
2010	13.4	123.3	323.3	303.0	249.6	0.0	10.9	25.4	55.5	106.7	41.4	5.1	1257.6
2011	0.0	11.9	7.1	72.4	142.9	28.7	36.1	9.3	53.8	161.2	137.3	25.4	686.0
2012	0.0	0.0	0.0	541.6	500.1	0.0	0.0	21.7	106.2	172.5	120.1	21.0	1483.3
2013	32.4	0.0	297.1	321.2	23.0	10.0	15.6	18.4	25.3	136.9	105.7	0.0	985.6
2014	0.0	0.0	80.7	165.2	148.2	50.0	2.0	7.7	54.8	163.7	110.6	6.6	789.4
2015	0.0	0.0	40.9	138.9	178.0	20.6	3.9	2.0	20.8	222.9	36.4	0.0	664.5
2016	0.0	0.0	39.0	256.3	122.2	0.0	0.0	0.0	0.0	67.2	94.2	10.0	588.8
2017	0.0	0.0	0.0	134.6	195.5	36.1	0.0	33.3	98.4	162.3	78.3	13.2	751.7
2018	6.3	77.3	155.3	256.8	143.4	56.2	3.8	39.2	33.7	95.8	19.5	0.0	887.2
Mean	16.1	19.2	84.9	216.3	158.1	20.4	10.5	14.8	53.1	159.1	72.1	19.8	

Station name: Filtu
Element: Monthly total rainfall (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	0	9	92	146	89	0	0	0	19	50	45	9	459
1988	0	0	26	162	73	6	0	0	22	50	24	7	370
1989	2	6	49	112	161	0	0	0	20	92	53	6	501
1990	5	6	42	134	38	0	0	0	28	56	19	13	341
1991	6	7	119	163	84	0	5	0	31	52	51	16	534
1992	6	27	102	231	36	0	0	0	19	50	35	10	516
1993	0	5	81	129	72	0	11	0	16	41	21	23	399
1994	11	0	12	106	55	0	0	0	15	50	45	20	314
1995	10	22	9	127	185	0	0	0	16	56	21	7	453
1996	0	0	16	125	134	0	0	0	20	118	40	19	472
1997	0	12	68	157	39	0	0	0	24	92	29	13	434
1998	0	0	50	135	100	0	0	4	15	57	47	8	416
1999	0	0	42	160	66	2	0	0	21	171	169	16	647
2000	7	12	22	83	108	7	0	0	10	54	19	8	330
2001	0	0	101	65	38	0	0	0	10	69	21	16	320
2002	0	0	11	50	130	0	0	0	18	114	33	10	366
2003	0	6	26	103	36	0	0	4	20	96	46	9	346
2004	5	0	31	124	53	0	5	0	33	102	44	13	410
2005	0	6	15	225	83	0	2	0	18	45	94	28	516
2006	12	0	19	122	32	0	0	0	20	107	88	11	411
2007	0	12	45	124	144	0	0	0	32	40	36	8	441
2008	0	13	30	169	44	0	0	0	28	172	75	27	558
2009	0	6	31	122	54	16	0	0	34	84	84	7	438
2010	0	0	10	170	56	0	0	0	19	102	66	5	428
2011	5	0	13	109	70	0	0	0	19	98	42	13	369
2012	0	42	160	126	49	0	0	0	20	64	20	9	490
2013	0	0	9	53	98	5	0	0	18	123	200	24	530
2014	0	0	10	190	57	3	0	0	30	99	58	6	453
2015	6	0	123	239	74	0	6	0	25	75	88	0	636
2016	0	11	48	89	100	0	8	7	16	117	62	6	464
2017	0	6	33	120	72	0	0	0	19	135	59	0	444
2018	0	11	19	243	38	0	4	0	17	37	50	11	430
Mean	2	7	46	138	77	1	1	0	21	83	56	12	

Station name: Sede
Element: Monthly total rainfall (mm)

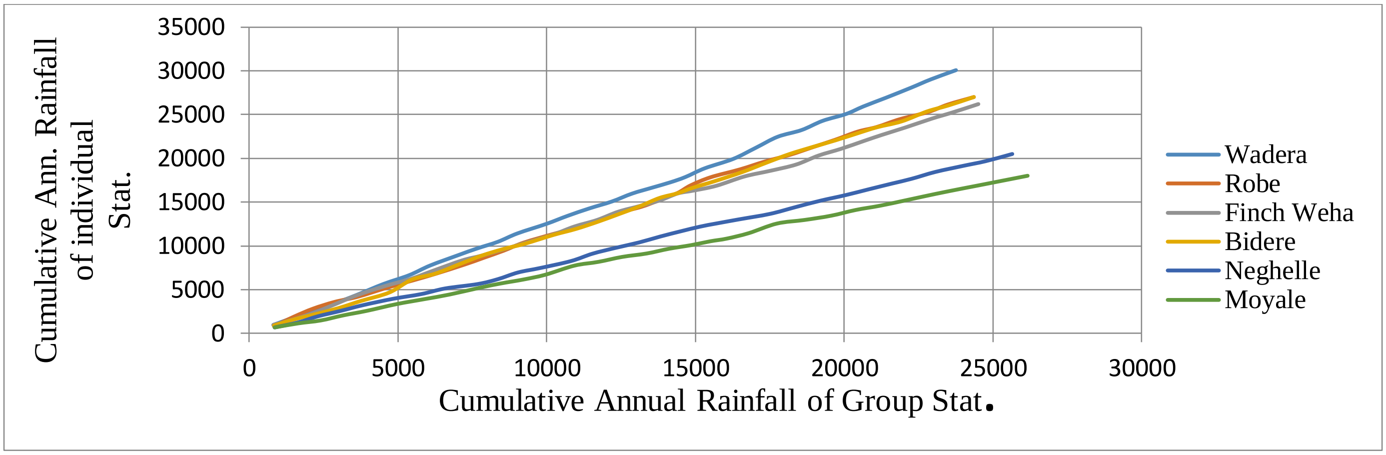
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1985	0.0	1.0	41.0	79.0	35.0	0.0	0.0	3.0	0.0	11.0	47.0	5.0	222.0
1986	0.0	0.0	11.0	81.0	44.0	2.0	0.0	0.0	0.0	14.0	24.0	0.0	176.0
1987	0.0	0.0	19.0	53.0	138.0	0.0	0.0	0.0	0.0	17.0	30.0	3.0	260.0
1988	0.0	0.0	13.0	118.0	14.0	0.0	0.0	0.0	0.0	18.0	13.0	5.0	181.0
1989	0.0	0.0	12.0	106.0	78.0	0.0	0.0	0.0	0.0	18.0	85.0	10.0	309.0
1990	0.0	0.0	27.0	140.0	11.0	0.0	0.0	0.0	0.0	19.0	21.0	6.0	224.0
1991	0.0	0.0	22.0	70.0	41.0	0.0	0.0	0.0	0.0	19.0	9.0	17.0	178.0
1992	0.0	0.0	7.0	79.0	12.0	0.0	0.0	0.0	2.0	21.0	16.0	14.0	151.0
1993	0.0	0.0	5.0	41.0	108.0	0.0	0.0	0.0	0.0	24.0	14.0	0.0	192.0
1994	0.0	0.0	8.0	77.0	36.0	0.0	0.0	0.0	0.0	25.0	90.0	7.0	243.0
1995	0.0	0.0	28.0	114.0	16.0	0.0	0.0	0.0	0.0	25.0	28.0	6.0	217.0
1996	0.0	0.0	22.0	67.0	40.0	0.0	0.0	0.0	0.0	27.0	23.0	6.0	185.0
1997	0.0	0.0	24.0	148.0	20.0	0.0	0.0	0.0	0.0	31.0	187.0	30.0	440.0
1998	3.0	0.0	8.0	79.0	61.0	0.0	0.0	0.0	0.0	32.0	9.0	6.0	198.0
1999	0.0	0.0	43.0	42.0	14.0	0.0	0.0	0.0	0.0	34.0	27.0	16.0	176.0
2000	0.0	0.0	0.0	13.0	66.0	0.0	0.0	0.0	0.0	34.0	15.0	6.0	134.0
2001	0.0	0.0	18.0	28.0	15.0	0.0	0.0	0.0	0.0	34.0	35.0	0.0	130.0
2002	0.0	0.0	11.0	130.0	15.0	0.0	0.0	0.0	0.0	42.0	45.0	6.0	249.0
2003	0.0	0.0	6.0	121.0	41.0	0.0	0.0	0.0	0.0	42.0	83.0	28.0	321.0
2004	0.0	0.0	5.0	67.0	11.0	0.0	0.0	0.0	0.0	45.0	68.0	0.0	196.0
2005	0.0	0.0	11.0	64.0	49.0	0.0	0.0	0.0	0.0	46.0	16.0	0.0	186.0
2006	0.0	0.0	11.0	105.0	32.0	0.0	0.0	0.0	0.0	47.0	91.0	28.0	314.0
2007	0.0	2.0	9.0	51.0	43.0	8.0	0.0	0.0	0.0	66.0	52.0	0.0	231.0
2008	0.0	0.0	7.0	98.0	22.0	0.0	0.0	0.0	0.0	68.0	45.0	0.0	240.0
2009	0.0	3.0	5.0	44.0	33.0	0.0	0.0	0.0	0.0	68.0	20.0	0.0	173.0
2010	0.0	3.0	58.0	93.0	14.0	0.0	0.0	0.0	0.0	72.0	10.0	0.0	250.0
2011	0.0	0.0	0.0	13.0	22.0	0.0	0.0	0.0	0.0	88.0	159.0	19.0	301.0
2012	0.0	0.0	5.0	48.0	19.0	0.0	0.0	0.0	0.0	113.0	39.0	8.0	232.0
2013	0.0	0.0	66.0	136.0	20.0	0.0	0.0	0.0	0.0	117.0	95.0	0.0	434.0
2014	0.0	0.0	11.0	64.0	33.0	0.0	0.0	0.0	0.0	139.0	82.0	0.0	329.0
2015	0.0	0.0	11.0	83.0	23.0	0.0	0.0	0.0	0.0	152.0	53.0	0.0	322.0
2016	0.0	3.0	6.0	153.0	20.0	0.0	0.0	0.0	0.0	234.0	20.0	14.0	450.0
Mean	0.1	0.4	16.6	81.4	35.8	0.3	0.0	0.1	0.1	54.4	48.5	7.5	

Station name: Wachile
Element: Monthly total rainfall (mm)

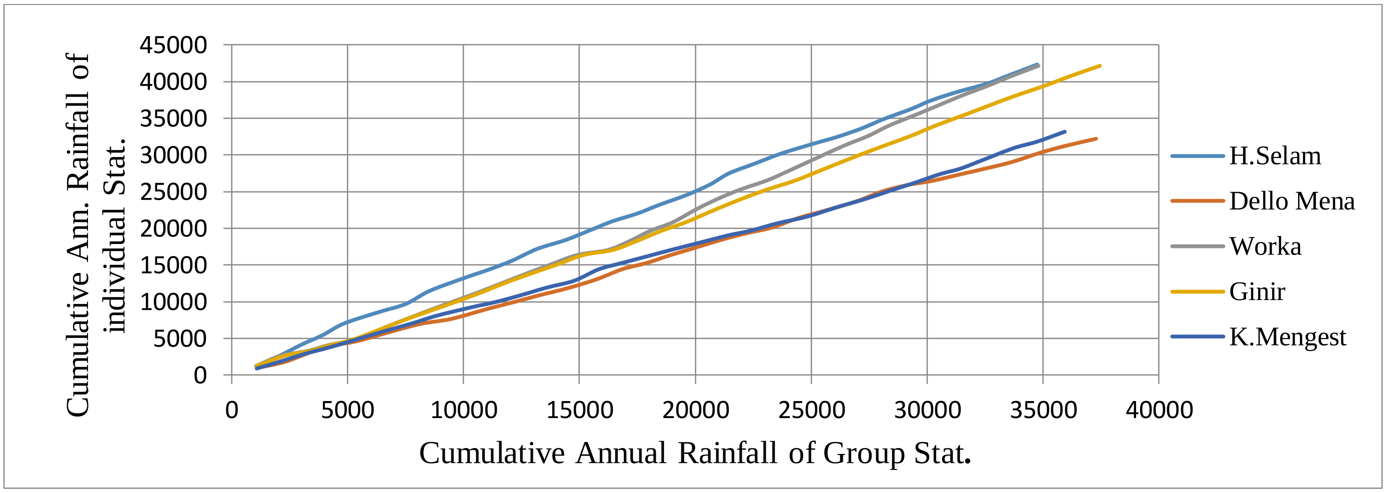
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1987	10	11	75	226	128	7	9	6	12	59	28	10	581
1988	9	8	42	229	48	13	11	5	14	63	30	14	486
1989	9	17	71	89	133	11	8	7	13	60	34	10	462
1990	10	10	49	228	33	9	9	8	24	53	22	12	467
1991	19	17	149	237	122	9	14	6	17	90	56	36	772
1992	11	71	90	235	30	6	9	5	10	85	20	12	584
1993	10	12	65	115	109	6	30	8	10	58	24	16	463
1994	10	18	27	129	63	8	14	6	14	55	25	25	394
1995	30	28	32	100	195	9	10	0	10	72	26	10	522
1996	6	5	67	158	106	6	12	5	32	67	63	23	550
1997	6	18	97	155	76	7	15	7	14	44	26	13	478
1998	10	9	116	146	94	9	16	6	19	91	34	8	558
1999	6	6	62	221	37	7	10	6	15	79	122	59	630
2000	30	40	35	106	162	10	12	8	10	94	36	9	552
2001	10	6	107	46	31	7	10	7	14	71	23	14	346
2002	8	0	14	55	123	0	9	6	17	81	44	24	381
2003	15	11	45	226	50	5	7	9	13	107	42	15	545
2004	10	5	70	140	66	7	6	0	35	62	39	64	504
2005	15	0	40	331	161	5	8	6	12	84	58	23	743
2006	26	8	27	189	28	0	7	0	12	91	68	14	470
2007	16	8	43	100	189	6	9	0	11	132	48	8	570
2008	7	16	50	163	61	6	7	10	22	76	95	39	552
2009	10	11	37	185	52	25	8	10	27	107	53	5	530
2010	8	0	58	135	46	11	14	0	15	109	42	6	444
2011	21	7	29	144	83	5	7	0	11	202	36	19	564
2012	13	25	105	196	68	0	8	8	13	109	15	7	567
2013	6	9	15	67	52	11	8	0	19	133	207	29	556
2014	6	13	19	201	99	0	7	8	24	83	63	20	543
2015	16	6	174	295	57	6	13	5	20	60	111	6	769
2016	7	24	81	105	91	6	30	16	13	77	54	10	514
2017	9	4	25	179	49	6	7	6	22	175	73	14	569
2018	8	13	27	301	39	5	8	0	12	189	48	11	661
Mean	12	14	61	170	84	7	11	5	16	91	52	18	

2.2. Graphs Plotted To Check Consistency of the Stations

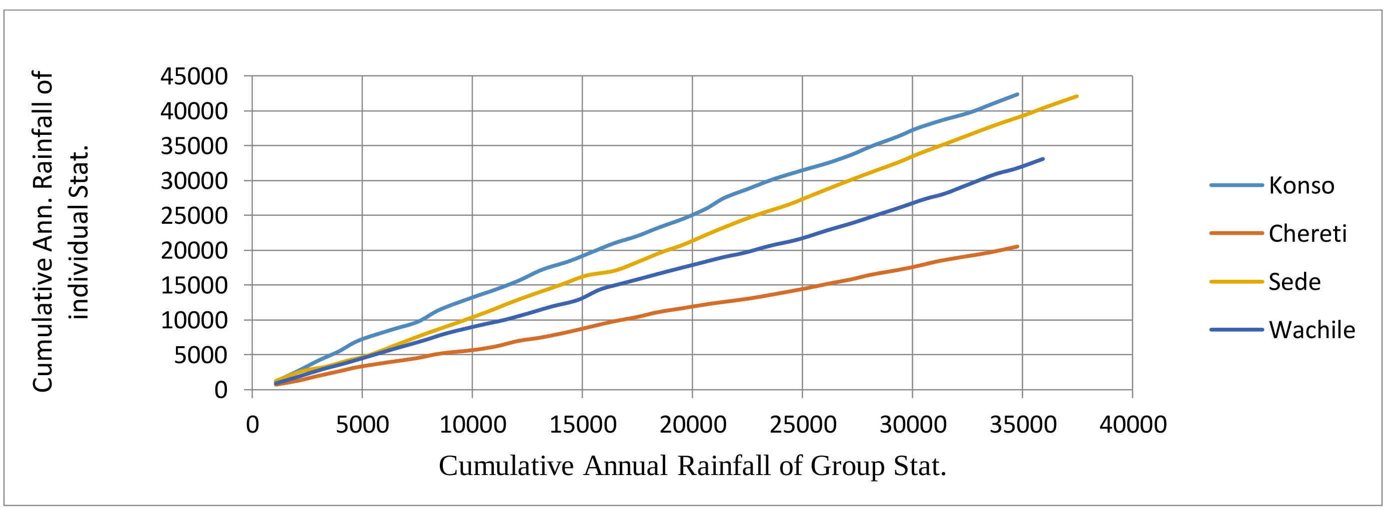
Consistency Test Wadera, Robe, Finch Weha, Bidere, Neghelle, Moyale metrological stations



Consistency Test H.Selam, Dello Mena, Worka, Ginir, K.Mengest metrological stations

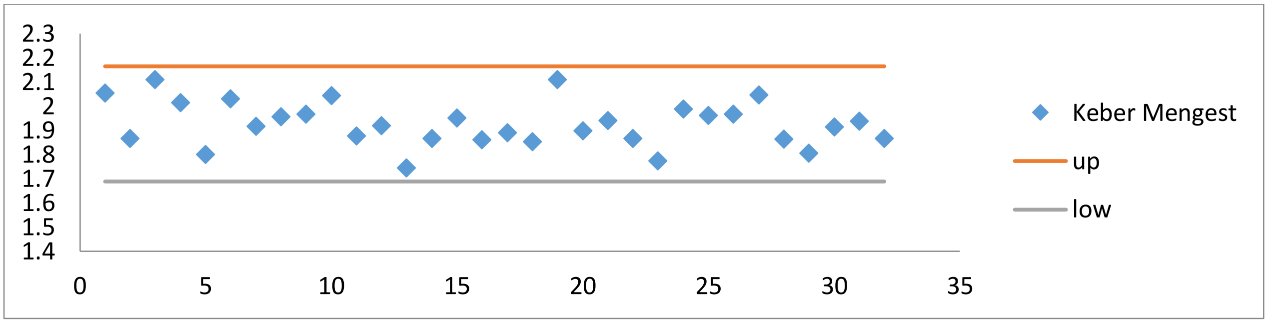


Consistency Test Konso, Chereti, Sede, and Wachille metrological stations

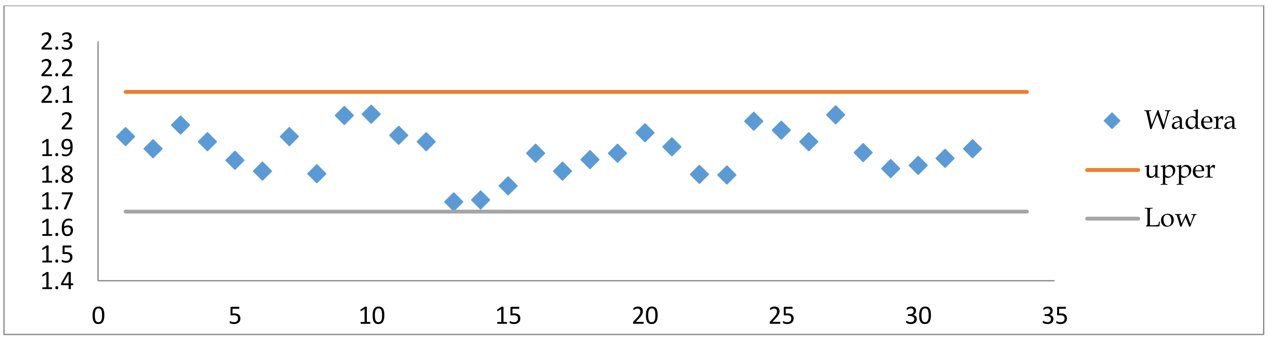


2.3 Outlier Test for selected stations

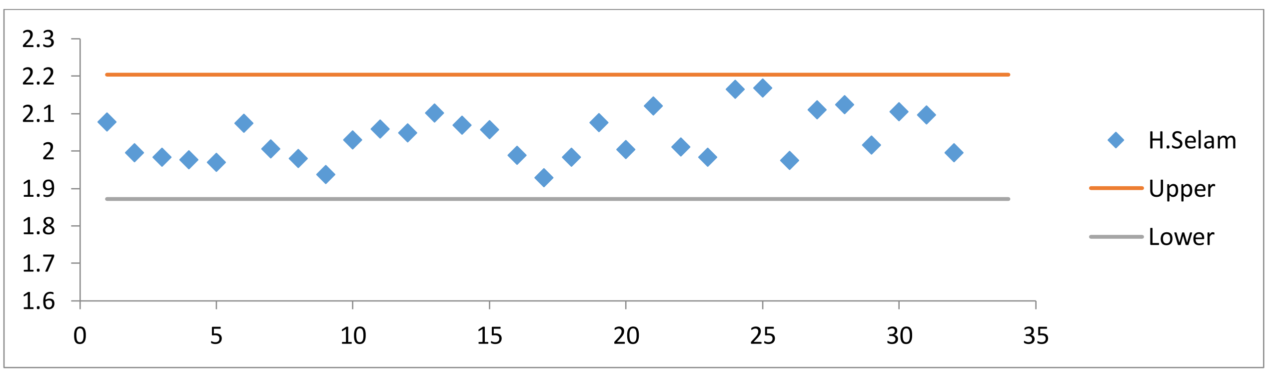
A) Outlier Test for Kebere Menegest



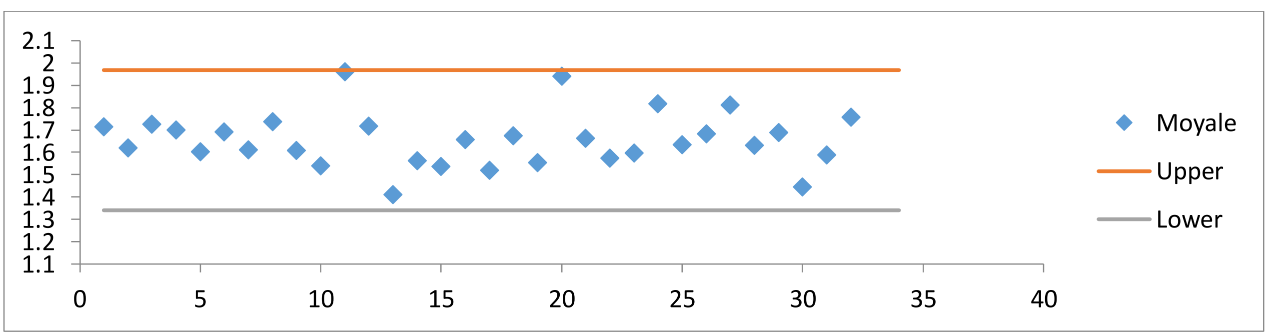
B) Outlier Test for Wadera



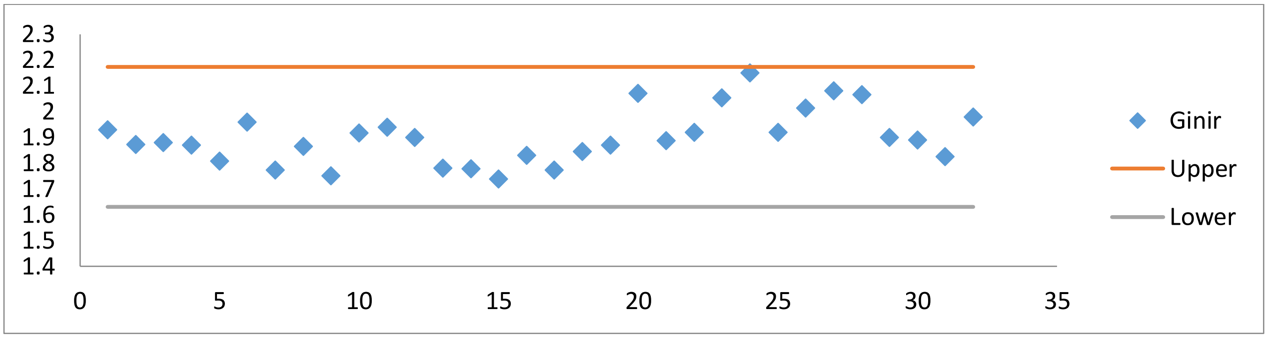
C) Outlier Test for Hagere Selam



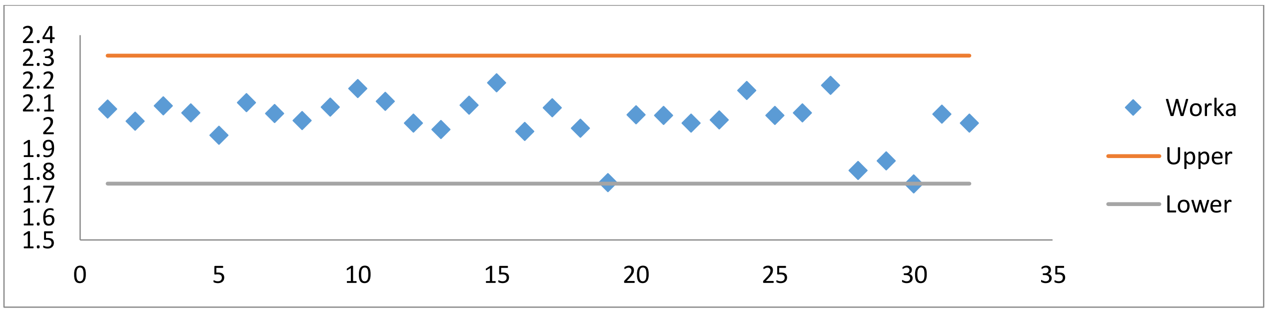
D) Outlier Test for Moyale



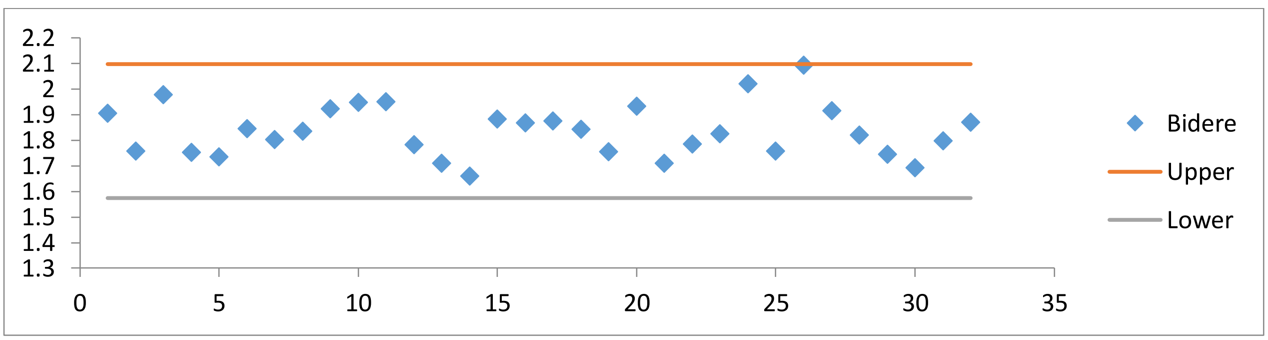
E) Outlier Test for Ginir



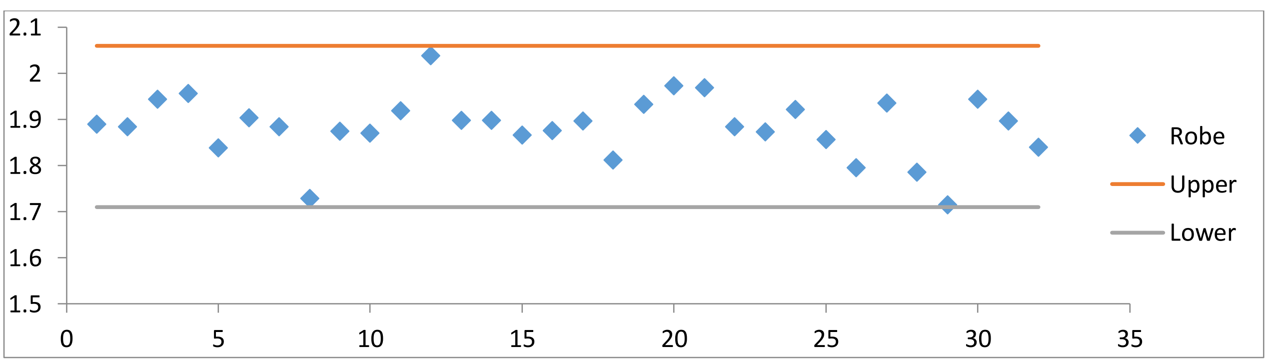
F) Outlier Test for Worka



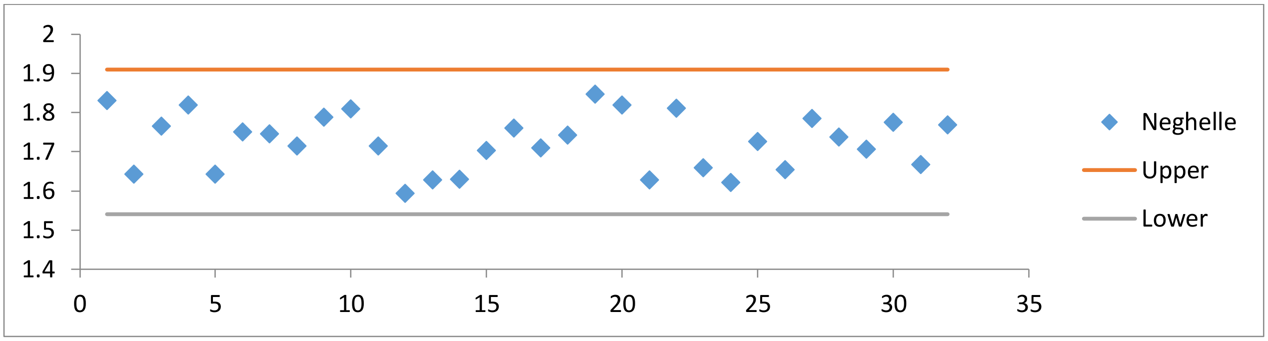
G) Outlier Test for Bidere



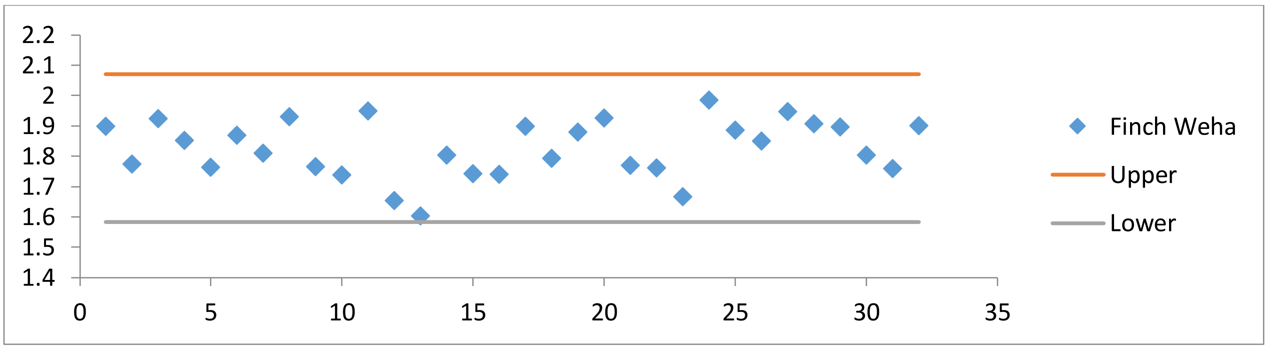
H) Outlier Test for Robe



I) Outlier Test for Neghelle

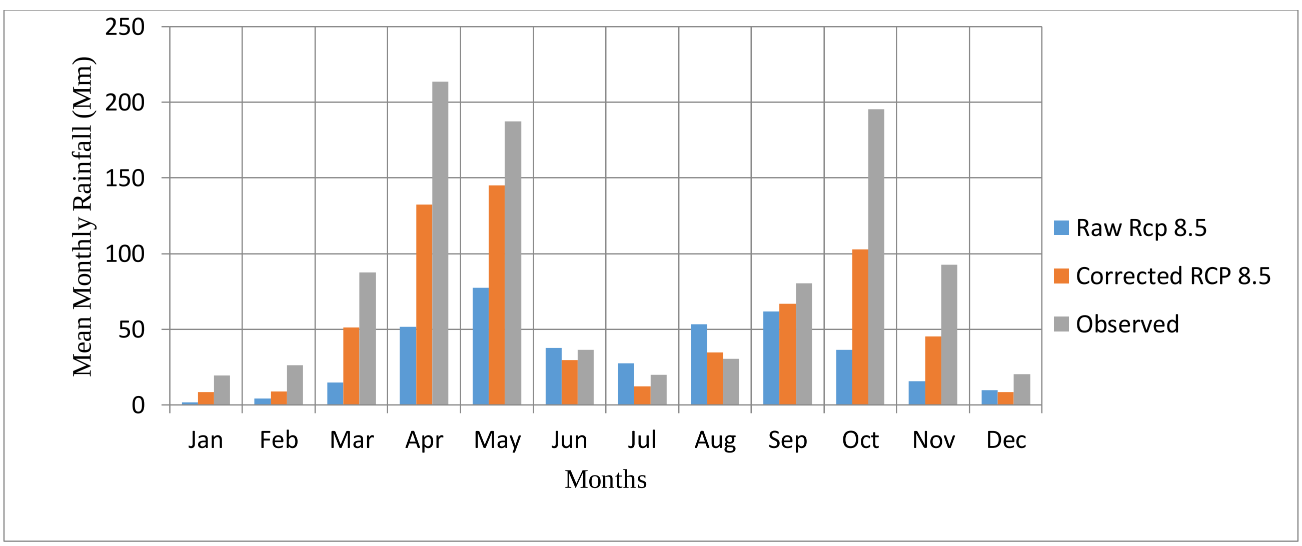


J) Outlier Test for Finch Weha

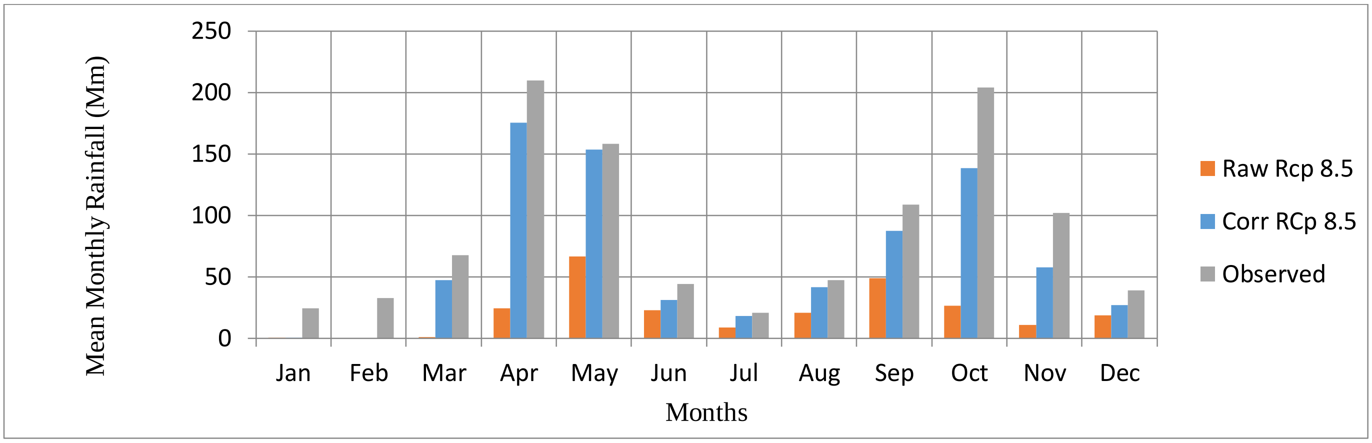


2.4 CORDEX AFRICA RCM 8.5 bias Correction evaluation of station

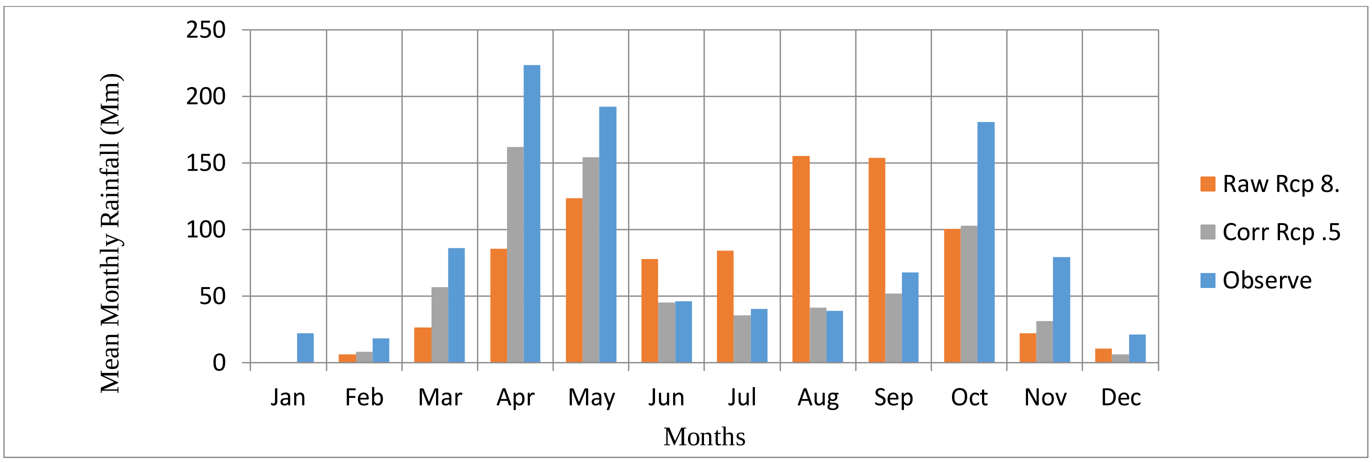
A) Bias Correction Result Dello Mena



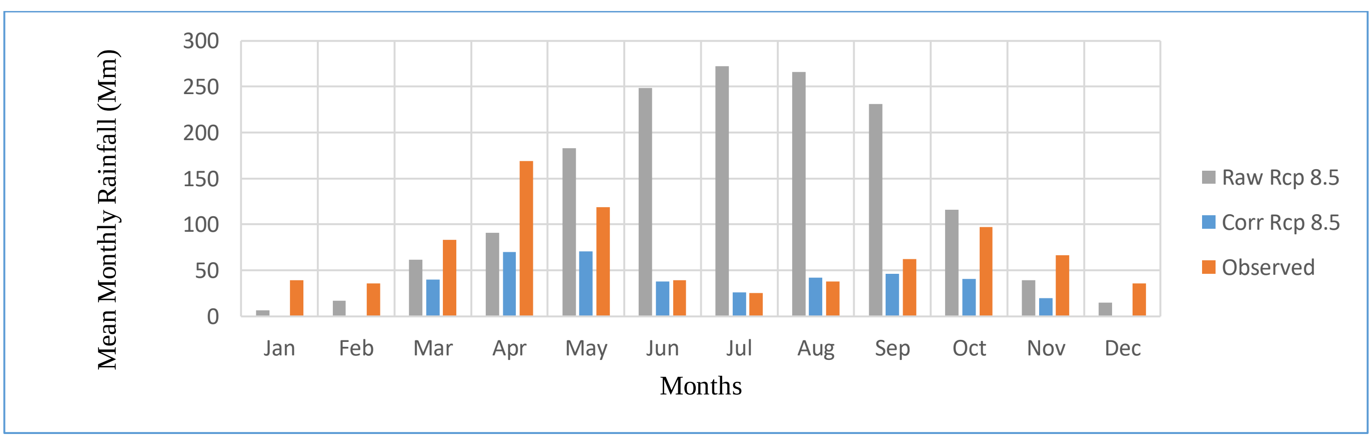
B) Bias Correction Result Ginir



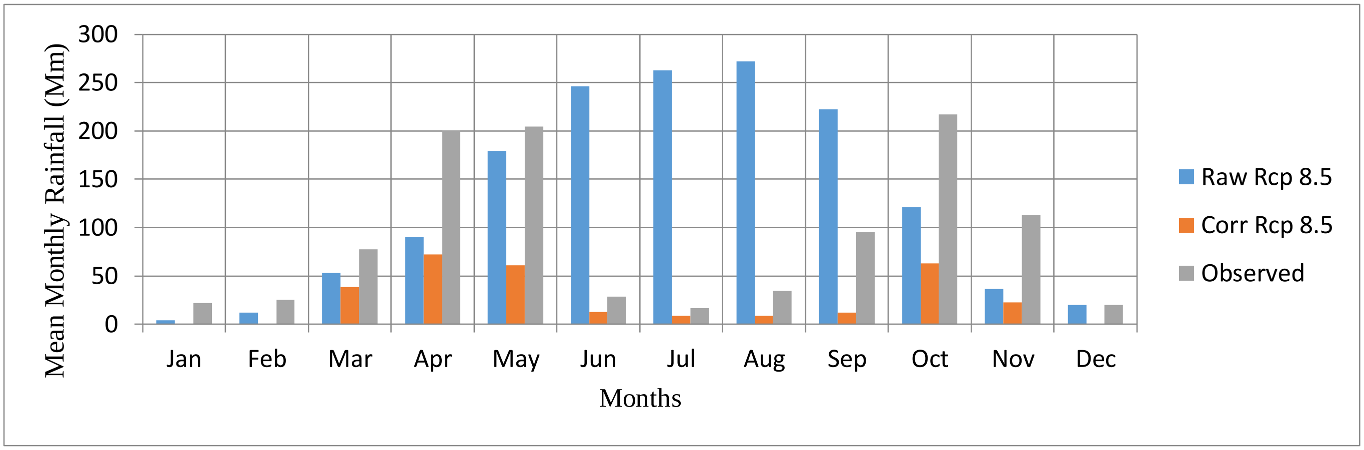
C) Bias Correction Result Kebere Mengest



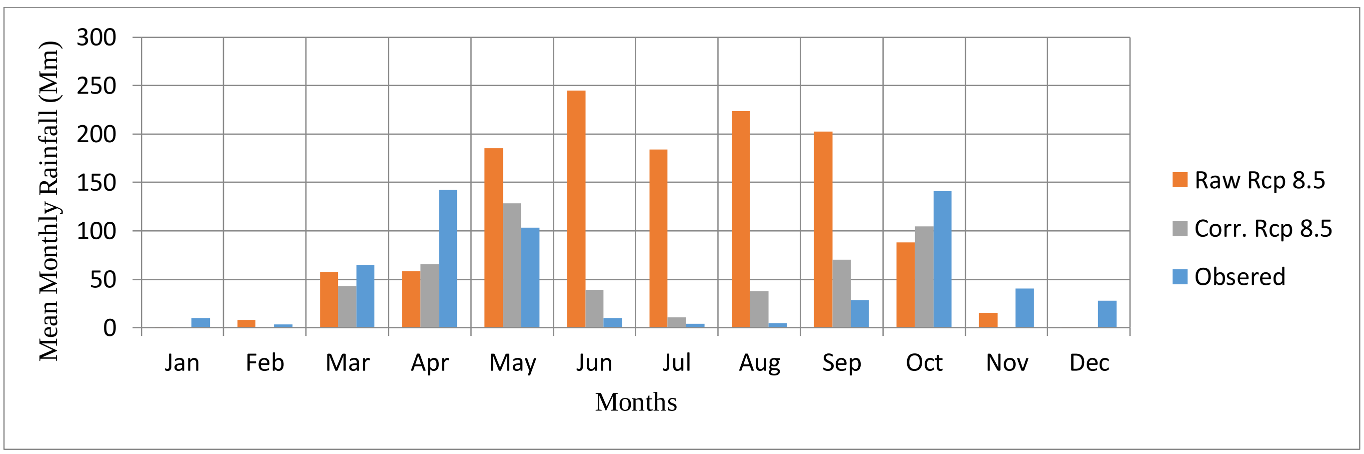
D) Bias Correction Result Konso



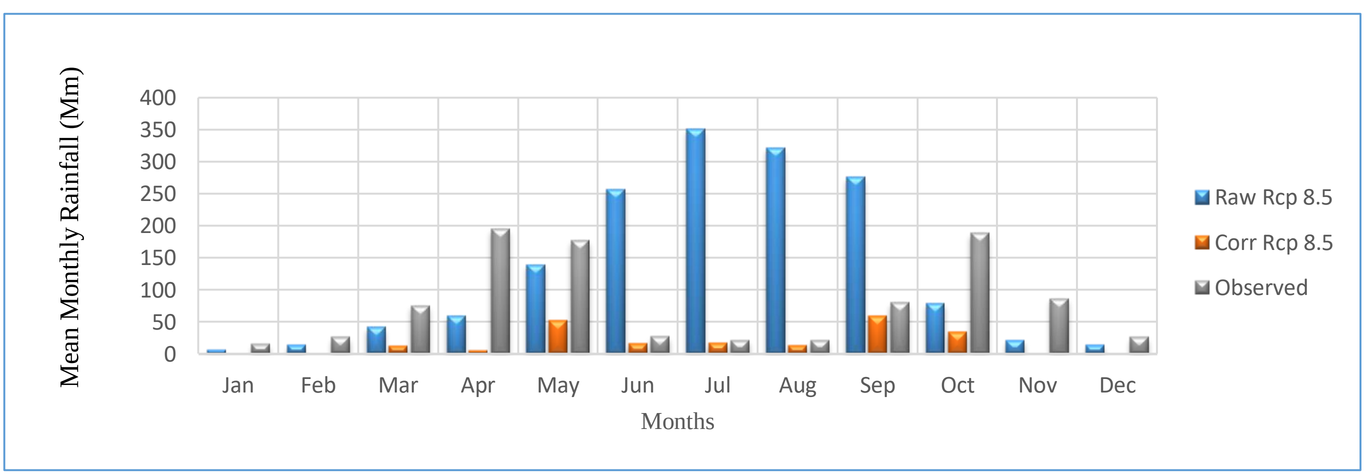
D) Bias Correction Result. Moyale



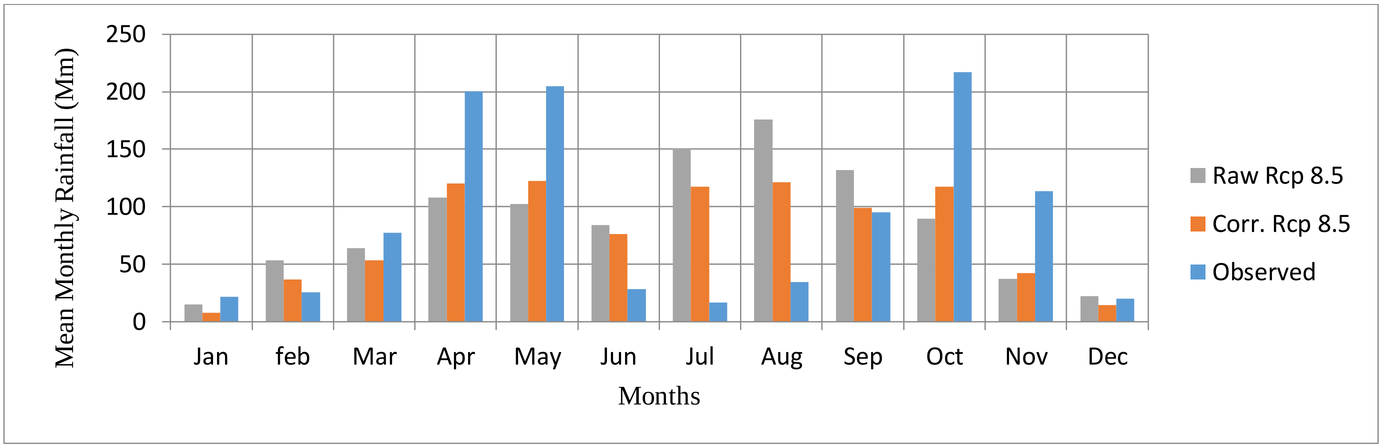
F) Bias Correction Result Neghelle



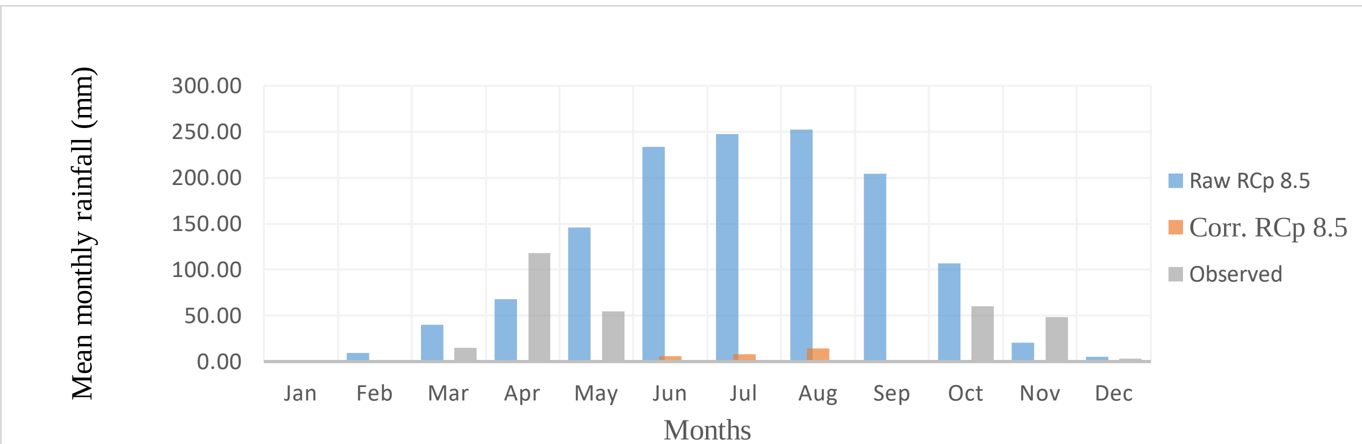
G) Bias Correction Result Wadera



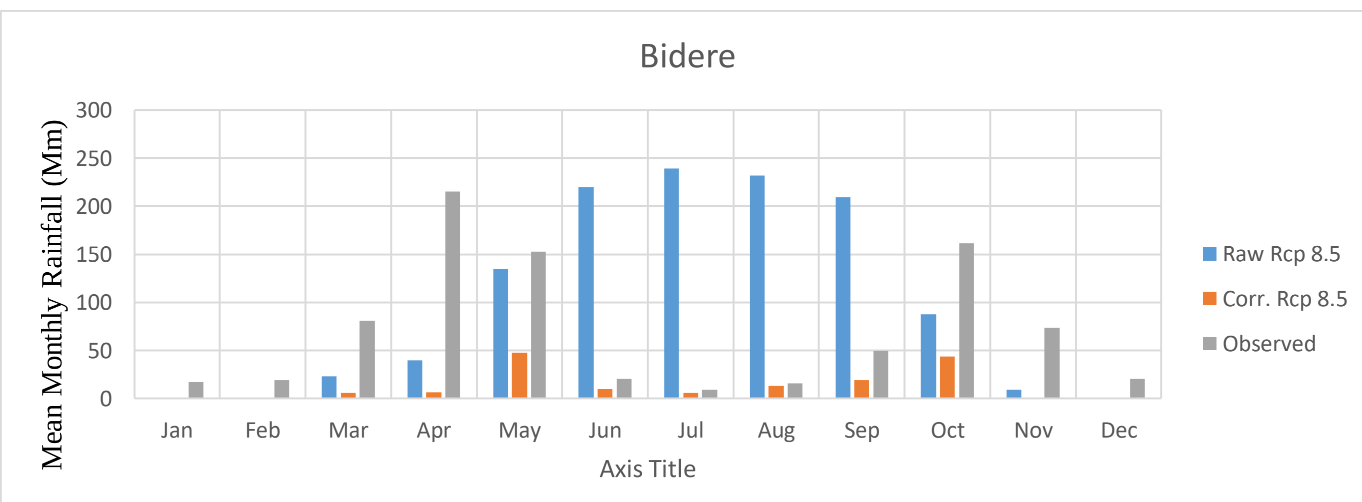
H) Bias Correction Result Worka



I) Bias Correction Result Cheretti



J) Bias Correction Result Bidere Station



3. WEAP SCENARIO DEVELOPMENT RESULTS

3.1.SCENARIO ONE DEVELOPMENT SCENARIO

3.1.1. SHORT TERM (2018 – 2030) Scenario I development Scenario

3.1.1.1.Domestic Demand Analysis

Water Demand (not including loss, reuse, and DSM) (Cubic Meter)			
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: SHORT TERM SCENARIO I, All months (12), Annual Total			
POPULATION	Demand in m^3 (@2030)	POPULATION	Demand in m^3 (@2030
Adaba Wereda	20934818	Goba Wereda	6009532
Adola Wereda	16223974	Gololcha Wereda	12806906
Afder Wereda	18434035	Goro Baqaqsa Wereda	7380445
Agarfa	15567094	Goro Dola Wereda	11671263
Arero Wereda	6121787	Goro Wereda	12591659
Aroresa Wereda	23429068	Gura Damole Wereda	2853280
Bare Wereda	13412306	Harena Wereda	12210238
Bdolo Bay Wereda	10666640	Hudet Wereda	6366399
Berbere Wereda	13588224	Liben Wereda	20009204
Bore Wereda	24809686	Medawelabo Wereda	14262872
Bule Hora Wereda	39735309	Mena Wereda	13643988
Dawe Wereda	4575434	Moyale Wereda	4594447
Dinsho Wereda	5886990	Rayitu Wereda	5017488
Dire Wereda	9502537	Shakiso Wereda	31239213
Dolo Odo Wereda	16276761	Sinana Wereda	17484403
Dugda Dawa Wereda	21942860	Teltele Wereda	10587748
Elkere Wereda	11357694	Uraga Wereda	26289673
Filtu Wereda	18824297	Wadera Wereda	7641413
Gasera Wereda	11723085	Yabelo Wereda	15756761
Ginir Wereda	21368177	**Sum**	562797708.7
		MMC	562.79

3.1.1.2.Livestock Analysis

Water Demand (not including loss, reuse, and DSM) (Cubic Meter)	
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: SHORT TERM SCENARIO I, All months (12), Annual Total.	
LIVESTOCK	Demand in m^3 (@2030)
Liv Bale	1852463.052
Liv Bare	5026969.401
Liv Bdolo	4545430.753
Liv Chereti	4827017.792
Liv Dire	1953924.068
Liv Guji	15774405.34
Liv Moyale	2433937.67
Liv Sidama	6729795.948
LIV Yab	2782160.071
Liv_Areo	1448063.262
Liv_Liben	15965696.06
TOTAL LIV.DEMAND	63339863.42
TOTAL LIV.DEMAND MMC	**63.33986342**

3.1.1.3.IRRIGATION ANALYSIS

Water Demand (not including loss, reuse, and DSM) (Cubic Meter)													
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: SHORT TERM SCENARIO I, All months (12), Monthly Average													
					η = 45%								
DEMAND	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Sum**
Irr_Adola	1.4	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.0	4.0
Irr_Agarfa	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	1.4
Irr_Berber	6.3	7.4	5.8	0.5	2.9	4.2	4.9	5.3	5.6	2.4	3.3	3.9	52.6
Irr_D.Mena	6.0	7.1	5.6	0.4	2.8	4.0	4.6	5.1	5.4	2.3	3.1	3.7	50.2
Irr_Dinsho	2.6	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.2	7.8
Irr_Ginir	6.6	3.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.6	19.9
Irr_Goba	3.9	4.6	3.6	0.3	1.8	2.6	3.0	3.3	3.5	1.5	2.0	2.4	32.8
Irr_Harena	0.4	0.5	0.4	0.0	0.2	0.3	0.3	0.4	0.4	0.2	0.2	0.3	3.7
Irr_Medawelabo	1.3	1.6	1.2	0.1	0.6	0.9	1.0	1.1	1.2	0.5	0.7	0.8	11.2
Irr_wadera	1.9	1.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.5	5.7
Irr_Welmel	4.6	2.8	5.2	0.0	12.0	18.2	4.6	2.3	6.6	0.0	27.3	21.3	104.8
TOTAL	35.6	30.8	24.7	1.3	20.3	30.3	18.5	17.5	22.7	6.9	42.4	43.0	**294.1**

Supply Delivered (Cubic Meter)													
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: SHORT TERM SCENARIO I, All months (12), Monthly Average													
η = 45%													
SUPPLY.D	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
Irr_Adola	1.4	0.9	0.3	0	0	0	0	0	0	0	0.4	1	4
Irr_Agarfa	0.4	0.2	0.1	0	0	0	0	0	0	0	0.2	0.4	1.28
Irr_Berber	6.2	7.2	5.8	0.5	2.91	4.2	4.9	5.3	5.6	2.4	3.3	3.9	52.3
Irr_D.Mena	5.7	6.5	5.4	0.4	2.78	4	4.6	5.1	5.4	2.3	3.1	3.7	49.1
Irr_Dinsho	2	1.2	0.5	0	0	0	0	0	0	0	1.2	2	7.02
Irr_Ginir	6.6	3.2	1.4	0	0	0	0	0	0	0	3.3	5.6	19.9
Irr_Goba	2.5	2.8	3	0.3	1.81	2.6	3	3.3	3.5	1.5	2	2.2	28.5
Irr_Harena	0.4	0.5	0.4	0	0.2	0.3	0.3	0.4	0.4	0.2	0.2	0.3	3.67
Irr_Medawelabo	1.3	1.6	1.2	0.1	0.62	0.9	1	1.1	1.2	0.5	0.7	0.8	11.2
Irr_wadera	1.9	1.3	0.5	0	0	0	0	0	0	0	0.6	1.5	5.72
Irr_Welmel	4.6	2.8	5.2	0	12	18	4.6	2.3	6.6	0	27	21	104
TOTAL	33	28	24	1.3	20.3	30	18	18	23	6.9	42	42	**287**

UNMET Demand (Cubic Meter)													
All Demand Sites, Scenario: SHORT TERM SCENARIO I, All Sources (116), All months (12), Monthly Average													
η = 45%													
UNMET DEMAND	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
Irr_Adola	0	0	0	0	0	0	0	0	0	0	0	0	0
Irr_Agarfa	0.1	0	0	0	0	0	0	0	0	0	0	0	0.14
Irr_Berber	0.1	0.2	0	0	0	0	0	0	0	0	0	0	0.26
Irr_D.Mena	0.4	0.6	0.1	0	0	0	0	0	0	0	0	0	1.05
Irr_Dinsho	0.6	0	0	0	0	0	0	0	0	0	0	0.1	0.77
Irr_Ginir	0	0	0	0	0	0	0	0	0	0	0	0	0
Irr_Goba	1.4	1.8	0.7	0	0	0	0	0	0	0	0.1	0.2	4.23
Irr_Harena	0	0	0	0	0	0	0	0	0	0	0	0	0
Irr_Medawelabo	0	0	0	0	0	0	0	0	0	0	0	0	0
Irr_wadera	0	0	0	0	0	0	0	0	0	0	0	0	0
Irr_Welmel	0	0	0	0	0	0.2	0	0	0	0	0.2	0.4	0.76
TOTAL	2.5	2.6	0.8	0	0	0.2	0	0	0	0	0.3	0.8	**7.22**

Water Demand (not including loss, reuse, and DSM) (Cubic Meter)													
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: SHORT TERM SCENARIO I, All months (12), Monthly Average													
η = 50%													
DEMAND	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
Irr_Adola	1.2	0.8	0.3	0	0	0	0	0	0	0	0.3	0.9	3.6
Irr_Agarfa	0.4	0.2	0.1	0	0	0	0	0	0	0	0.2	0.4	1.28
Irr_Berber	5.7	6.7	5.2	0.4	2.62	3.8	4.4	4.8	5.1	2.2	3	3.5	47.3
Irr_D.Mena	5.4	6.4	5	0.4	2.5	3.6	4.2	4.6	4.8	2.1	2.8	3.3	45.1
Irr_Dinsho	2.3	1.1	0.5	0	0	0	0	0	0	0	1.2	2	7.02
Irr_Ginir	5.9	2.9	1.2	0	0	0	0	0	0	0	3	5	18
Irr_Goba	3.5	4.2	3.3	0.3	1.63	2.4	2.7	3	3.2	1.4	1.8	2.2	29.5
Irr_Harena	0.4	0.5	0.4	0	0.18	0.3	0.3	0.3	0.4	0.2	0.2	0.2	3.31
Irr_Medawelabo	1.2	1.4	1.1	0.1	0.56	0.8	0.9	1	1.1	0.5	0.6	0.7	10.1
Irr_wadera	1.7	1.1	0.4	0	0	0	0	0	0	0	0.5	1.3	5.15
irr_welmel	4.1	2.5	4.7	0	10.8	16	4.1	2	5.9	0	25	19	94.3
TOTAL	32	28	22	1.2	18.3	27	17	16	20	6.3	38	39	**265**

Supply Delivered													
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: SHORT TERM SCENARIO I, All months (12), Monthly Average													
η = 50%													
SUPPLY.D	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
Irr_Adola	1.2	0.8	0.3	0	0	0	0	0	0	0	0.3	0.9	3.6
Irr_Agarfa	0.3	0.2	0.1	0	0	0	0	0	0	0	0.2	0.3	1.16
Irr_Berber	5.7	6.6	5.2	0.4	2.62	3.8	4.4	4.8	5.1	2.2	3	3.5	47.3
Irr_D.Mena	5.3	6.1	4.9	0.4	2.5	3.6	4.2	4.6	4.8	2.1	2.8	3.3	44.6
Irr_Dinsho	1.8	1.1	0.5	0	0	0	0	0	0	0	1.1	1.8	6.38
Irr_Ginir	5.9	2.9	1.2	0	0	0	0	0	0	0	3	5	18
Irr_Goba	2.5	2.7	2.8	0.3	1.63	2.4	2.7	3	3.2	1.4	1.8	2	26.3
Irr_Harena	0.4	0.5	0.4	0	0.18	0.3	0.3	0.3	0.4	0.2	0.2	0.2	3.31
Irr_Medawelabo	1.2	1.4	1.1	0.1	0.56	0.8	0.9	1	1.1	0.5	0.6	0.7	10.1
Irr_wadera	1.7	1.1	0.4	0	0	0	0	0	0	0	0.5	1.3	5.15
Irr_Welmel	4.1	2.5	4.7	0	10.8	16	4.1	2	5.9	0	25	19	94.2
TOTAL	30	26	22	1.2	18.3	27	17	16	20	6.3	38	38	**260**

UNMET Demand (Cubic Meter)													
All Demand Sites, Scenario: SHORT TERM SCENARIO I, All Sources (116), All months (12), Monthly Average													
η = 50%													
SUPPLY.D	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
Irr_Adola	0	0	0	0	0	0	0	0	0	0	0	0	0
Irr_Agarfa	0.1	0	0	0	0	0	0	0	0	0	0	0	0.12
Irr_Berber	0	0.1	0	0	0	0	0	0	0	0	0	0	0.07
Irr_D.Mena	0.2	0.3	0.1	0	0	0	0	0	0	0	0	0	0.54
Irr_Dinsho	0.5	0	0	0	0	0	0	0	0	0	0	0.1	0.64
Irr_Ginir	0	0	0	0	0	0	0	0	0	0	0	0	0
Irr_Goba	1.1	1.4	0.4	0	0	0	0	0	0	0	0	0.2	3.15
Irr_Harena	0	0	0	0	0	0	0	0	0	0	0	0	0
Irr_Medawelabo	0	0	0	0	0	0	0	0	0	0	0	0	0
Irr_wadera	0	0	0	0	0	0	0	0	0	0	0	0	0
Irr_Welmel	0	0	0	0	0	0.1	0	0	0	0	0	0.1	0.15
TOTAL	1.8	1.8	0.5	0	0	0.1	0	0	0	0	0.1	0.4	4.67

Water Demand (not including loss, reuse, and DSM) (Cubic Meter)													
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: SHORT TERM SCENARIO I, All months (12), Monthly Average													
η = 60%													
DEMAND	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
Irr_Adola	1	0.7	0.3	0	0	0	0	0	0	0	0.3	0.8	3
Irr_Agarfa	0.4	0.2	0.1	0	0	0	0	0	0	0	0.2	0.3	1.07
Irr_Berber	4.7	5.6	4.4	0.4	2.19	3.2	3.6	4	4.2	1.8	2.5	2.9	39.5
Irr_D.Mena	4.5	5.3	4.2	0.3	2.08	3	3.5	3.8	4	1.7	2.4	2.8	37.6
Irr_Dinsho	1.9	0.9	0.4	0	0	0	0	0	0	0	1	1.6	5.85
Irr_Ginir	4.9	2.4	1	0	0	0	0	0	0	0	2.5	4.2	15
Irr_Goba	2.9	3.5	2.7	0.2	1.36	2	2.3	2.5	2.6	1.1	1.5	1.8	24.6
Irr_Harena	0.3	0.4	0.3	0	0.15	0.2	0.3	0.3	0.3	0.1	0.2	0.2	2.76
Irr_Medawelabo	1	1.2	0.9	0.1	0.47	0.7	0.8	0.9	0.9	0.4	0.5	0.6	8.4
Irr_wadera	1.4	1	0.4	0	0	0	0	0	0	0	0.4	1.1	4.29
Irr-Welmel	3.5	2.1	3.9	0	8.98	14	3.4	1.7	4.9	0	20	16	78.6
Total	27	23	19	1	15.2	23	14	13	17	5.2	32	32	221

Supply Delivered													
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: SHORT TERM SCENARIO I, All months (12), Monthly Average													
					η = 60%								
SUPPLY.D	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
Irr_Adola	1	0.7	0.3	0	0	0	0	0	0	0	0.3	0.8	3
Irr_Agarfa	0.3	0.2	0.1	0	0	0	0	0	0	0	0.2	0.3	0.99
Irr_Berber	4.7	5.6	4.4	0.4	2.19	3.2	3.6	4	4.2	1.8	2.5	2.9	39.5
Irr_D.Mena	4.5	5.3	4.2	0.3	2.08	3	3.5	3.8	4	1.7	2.4	2.8	37.6
Irr_Dinsho	1.6	0.9	0.4	0	0	0	0	0	0	0	0.9	1.6	5.43
Irr_Ginir	4.9	2.4	1	0	0	0	0	0	0	0	2.5	4.2	15
Irr_Goba	2.5	2.7	2.6	0.2	1.36	2	2.3	2.5	2.6	1.1	1.5	1.8	23.2
Irr_Harena	0.3	0.4	0.3	0	0.15	0.2	0.3	0.3	0.3	0.1	0.2	0.2	2.76
Irr_Medawelabo	1	1.2	0.9	0.1	0.47	0.7	0.8	0.9	0.9	0.4	0.5	0.6	8.4
Irr_wadera	1.4	1	0.4	0	0	0	0	0	0	0	0.4	1.1	4.29
Irr-Welmel	3.5	2.1	3.9	0	8.98	14	3.4	1.7	4.9	0	20	16	78.6
Total	26	22	18	1	15.2	23	14	13	17	5.2	32	32	**219**

UNMET Demand (Cubic Meter)													
All Demand Sites, Scenario: SHORT TERM SCENARIO I, All Sources (116), All months (12), Monthly Average													
					η = 60%								
UNMET	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
Irr_Adola	0	0	0	0	0	0	0	0	0	0	0	0	0
Irr_Agarfa	0.1	0	0	0	0	0	0	0	0	0	0	0	0.08
Irr_Berber	0	0	0	0	0	0	0	0	0	0	0	0	0
Irr_D.Mena	0	0	0	0	0	0	0	0	0	0	0	0	0.02
Irr_Dinsho	0.3	0	0	0	0	0	0	0	0	0	0	0.1	0.41
Irr_Ginir	0	0	0	0	0	0	0	0	0	0	0	0	0
Irr_Goba	0.4	0.8	0.1	0	0	0	0	0	0	0	0	0	1.33
Irr_Harena	0	0	0	0	0	0	0	0	0	0	0	0	0
Irr_Medawelabo	0	0	0	0	0	0	0	0	0	0	0	0	0
Irr_wadera	0	0	0	0	0	0	0	0	0	0	0	0	0
Irr-Welmel	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0.8	0.8	0.1	0	0	0	0	0	0	0	0	0.1	**1.84**

3.1.2. LONG TERM (2031 – 2050) Scenario I development Scenario

3.1.2.1. Domestic Demand Analysis at 2050

Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: LONG TERM SCENARIO I, All months (12), Annual Total							
Weredas	Demand MMC	Weredas	Demand MMC	Weredas	Demand MMC	Weredas	Demand MMC
Adaba	35.6	Gasera	19.9	Medawelabo	23.6	Dawe	7.8
Adola	27.6	Ginir	36.3	Mena	23.2	Dinsho	10.0
Afder	25.8	Goba	10.2	Moyale	7.8	Dire	14.9
Agarfa	26.5	Gololcha	16.9	Rayitu	8.5	Dolo Odo	26.2
Arero	8.1	Goro Baqaqsa	11.9	Shakiso	51.8	Dugda Dawa	37.3
Aroresa	38.8	Goro Dola	19.8	Sinana	29.7	Elkere	18.3
Bare	21.6	Goro	21.4	Teltele	18.0	Filtu	30.2
Bdolo Bay	17.1	Gura Damole	4.6	Uraga	44.7	Bule Hora	65.9
Berbere	23.1	Harena	20.8	Wadera	13.0	Liben	32.7
Bore	32.8	Hudet	10.6	Yabelo	26.8	**Sum**	**919.8**

3.1.2.2. Livestock Demand Analysis at 2050

Water Demand (not including loss, reuse, and DSM) (Cubic Meter)	
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: LONG TERM SCENARIO I, All months (12), Annual Total.	
LIVESTOCK	**Demand in m^3 (@2050)**
Liv Bale	2260357
Liv Bare	6133858
Liv Bdolo	5546289
Liv Chereti	5889879
Liv Dire	2384159
Liv Guji	19247772
Liv Moyale	2969867
Liv Sidama	8211630
LIV Yab	3394764
Liv_Areo	2151746
Liv_Liben	19481183
TOTAL LIV.DEMAND	77671504
TOTAL LIV.DEMAND MMC	**77.6715**

3.1.2.3.IRRIGATION ANALYSIS

Water Demand (not including loss, reuse, and DSM) (Cubic Meter)													
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: LONG TERM SCENARIO I, All months (12), Monthly Average													
η = 45%													
DEMAND	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Sum**
Irr_Adola	1.4	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.0	4.0
Irr_Agarfa	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	1.4
Irr_Berber	6.3	7.4	5.8	0.5	2.9	4.2	4.9	5.3	5.6	2.4	3.3	3.9	52.6
Irr_D.Mena	6.0	7.1	5.6	0.4	2.8	4.0	4.6	5.1	5.4	2.3	3.1	3.7	50.2
Irr_Dinsho	2.6	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.2	7.8
Irr_Ginir	6.6	3.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.6	19.9
Irr_Goba	3.9	4.6	3.6	0.3	1.8	2.6	3.0	3.3	3.5	1.5	2.0	2.4	32.8
Irr_Harena	0.4	0.5	0.4	0.0	0.2	0.3	0.3	0.4	0.4	0.2	0.2	0.3	3.7
Irr_Medawelabo	1.3	1.6	1.2	0.1	0.6	0.9	1.0	1.1	1.2	0.5	0.7	0.8	11.2
Irr_wadera	1.9	1.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.5	5.7
Irr_Welmel	4.6	2.8	5.2	0.0	12.0	18.2	4.6	2.3	6.6	0.0	27.3	21.3	104.8
Irr_Yadot	4.5	1.9	9.6	0.0	10.6	7.8	5.3	3.6	2.9	0.0	13.0	13.1	72.1
Irr_Bale Gadula	0.9	0.3	3.9	2.7	6.0	7.0	1.6	4.0	4.9	0.6	8.7	7.6	48.2
TOTAL	40.9	33.0	38.2	4.0	36.9	45.0	25.4	25.1	30.5	7.6	64.1	63.6	**414.4**

Supply Delivered													
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: LONG TERM SCENARIO I, All months (12), Monthly Average													
η = 45%													
SCHEME	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Sum**
Irr_Adola	1.4	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.0	4.0
Irr_Agarfa	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.6
Irr_Berber	6.1	7.0	5.7	0.5	2.9	4.2	4.9	5.3	5.6	2.4	3.3	3.9	51.9
Irr_D.Mena	5.9	6.6	4.7	0.4	2.7	4.0	4.6	5.0	5.4	2.3	3.0	3.2	47.9
Irr_Dinsho	0.3	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.8	3.0
Irr_Ginir	6.6	3.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.6	19.9
Irr_Goba	0.6	1.0	1.1	0.3	1.7	2.3	2.9	3.3	3.5	1.4	1.2	0.8	20.1
Irr_Harena	0.4	0.5	0.4	0.0	0.2	0.3	0.3	0.4	0.4	0.2	0.2	0.3	3.7
Irr_Medawelabo	1.3	1.6	1.2	0.1	0.6	0.9	1.0	1.1	1.2	0.5	0.7	0.8	11.2
Irr_wadera	1.9	1.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.5	5.7
Irr_Welmel	4.6	2.8	5.2	0.0	12.0	17.9	4.6	2.3	6.6	0.0	27.3	21.2	104.4
Irr_Yadot	4.4	1.8	8.0	0.0	10.4	7.7	5.2	3.5	2.9	0.0	12.5	11.4	67.9
Irr_Bale Gadula	0.9	0.3	3.9	2.7	6.0	7.0	1.6	4.0	4.9	0.6	8.7	7.6	48.2
TOTAL	34.5	27.5	32.9	4.0	36.5	44.2	25.1	24.9	30.5	7.5	62.5	58.3	**388.5**

UNMET Demand (Cubic Meter)													
All Demand Sites, Scenario: LONG TERM SCENARIO I, All Sources (116), All months (12), Monthly Average													
η = 45%													
UNMET DEMAND	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Sum**
Irr_Adola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_Agarfa	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.9
Irr_Berber	0.2	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Irr_D.Mena	0.1	0.5	0.9	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.5	2.3
Irr_Dinsho	2.3	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.3	4.8
Irr_Ginir	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_Goba	3.3	3.6	2.5	0.0	0.1	0.4	0.2	0.0	0.0	0.1	0.9	1.6	12.6
Irr_Harena	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_Medawelabo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_wadera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_Welmel	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Irr_Yadot	0.1	0.1	1.5	0.0	0.2	0.1	0.0	0.1	0.0	0.0	0.5	1.6	4.3
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	6.4	5.5	5.3	0.0	0.3	0.9	0.2	0.2	0.0	0.1	1.7	5.3	**25.8**

Water Demand (not including loss, reuse, and DSM) (Cubic Meter)													
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: LONG TERM SCENARIO I, All months (12), Monthly Average													
η = 50%													
DEMAND	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Sum**
Irr_Adola	1.2	0.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.9	3.6
Irr_Agarfa	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	1.3
Irr_Berber	5.7	6.7	5.2	0.4	2.6	3.8	4.4	4.8	5.1	2.2	3.0	3.5	47.3
Irr_D.Mena	5.4	6.4	5.0	0.4	2.5	3.6	4.2	4.6	4.8	2.1	2.8	3.3	45.1
Irr_Dinsho	2.3	1.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	2.0	7.0
Irr_Ginir	5.9	2.9	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	5.0	18.0
Irr_Goba	3.5	4.2	3.3	0.3	1.6	2.4	2.7	3.0	3.2	1.4	1.8	2.2	29.5
Irr_Harena	0.4	0.5	0.4	0.0	0.2	0.3	0.3	0.3	0.4	0.2	0.2	0.2	3.3
Irr_Medawelabo	1.2	1.4	1.1	0.1	0.6	0.8	0.9	1.0	1.1	0.5	0.6	0.7	10.1
Irr_wadera	1.7	1.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.3	5.1
Irr_Welmel	4.1	2.5	4.7	0.0	10.8	16.4	4.1	2.0	5.9	0.0	24.6	19.1	94.3
Irr_Yadot	4.0	1.7	8.6	0.0	9.5	7.0	4.7	3.3	2.6	0.0	11.7	11.8	64.9
Irr_Bale Gadula	0.8	0.2	3.6	2.4	5.4	6.3	1.5	3.6	4.4	0.6	7.8	6.8	43.4
TOTAL	36.8	29.7	34.4	3.6	33.2	40.5	22.8	22.6	27.5	6.8	57.7	57.3	**373.0**

Supply Delivered													
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: LONG TERM SCENARIO I, All months (12), Monthly Average													
η = 50%													
SCHEME	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Sum**
Irr_Adola	1.2	0.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.9	3.6
Irr_Agarfa	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.5
Irr_Berber	5.6	6.4	5.2	0.4	2.6	3.8	4.4	4.8	5.1	2.2	3.0	3.5	46.9
Irr_D.Mena	5.4	6.0	4.4	0.4	2.5	3.6	4.2	4.5	4.8	2.1	2.8	3.0	43.6
Irr_Dinsho	0.2	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.8	2.8
Irr_Ginir	5.9	2.9	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	5.0	18.0
Irr_Goba	0.6	1.0	1.1	0.3	1.6	2.1	2.6	3.0	3.2	1.2	1.1	0.8	18.6
Irr_Harena	0.4	0.5	0.4	0.0	0.2	0.3	0.3	0.3	0.4	0.2	0.2	0.2	3.3
Irr_Medawelabo	1.2	1.4	1.1	0.1	0.6	0.8	0.9	1.0	1.1	0.5	0.6	0.7	10.1
Irr_wadera	1.7	1.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.3	5.1
Irr_Welmel	4.1	2.5	4.7	0.0	10.8	16.2	4.1	2.0	5.9	0.0	24.6	19.1	94.1
Irr_Yadot	4.0	1.6	7.6	0.0	9.4	6.9	4.7	3.2	2.6	0.0	11.5	10.7	62.2
Irr_Bale Gadula	0.8	0.2	3.6	2.4	5.4	6.3	1.5	3.6	4.4	0.6	7.8	6.8	43.4
TOTAL	31.3	25.1	30.3	3.6	32.9	39.9	22.7	22.5	27.5	6.7	56.6	53.2	**352.3**

UNMET Demand (Cubic Meter)													
All Demand Sites, Scenario: LONG TERM SCENARIO I, All Sources (116), All months (12), Monthly Average													
η = 50%													
UNMET DEMAND	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Sum**
Irr_Adola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_Agarfa	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.8
Irr_Berber	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Irr_D.Mena	0.0	0.3	0.6	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.3	1.5
Irr_Dinsho	2.1	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.2	4.2
Irr_Ginir	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_Goba	2.9	3.2	2.2	0.0	0.0	0.3	0.1	0.0	0.0	0.1	0.7	1.4	10.9
Irr_Harena	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_Medawelabo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_wadera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_Welmel	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Irr_Yadot	0.0	0.1	1.1	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.2	1.0	2.7
Irr_Bale Gadula	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	5.5	4.6	4.1	0.0	0.2	0.6	0.1	0.2	0.0	0.1	1.1	4.1	**20.7**

Water Demand (not including loss, reuse, and DSM) (Cubic Meter)													
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: LONG TERM SCENARIO I, All months (12), Monthly Average													
η = 60%													
DEMAND	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Sum**
Irr_Adola	1.0	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.8	3.0
Irr_Agarfa	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	1.1
Irr_Berber	4.7	5.6	4.4	0.4	2.2	3.2	3.6	4.0	4.2	1.8	2.5	2.9	39.5
Irr_D.Mena	4.5	5.3	4.2	0.3	2.1	3.0	3.5	3.8	4.0	1.7	2.4	2.8	37.6
Irr_Dinsho	1.9	0.9	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.6	5.8
Irr_Ginir	4.9	2.4	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	4.2	15.0
Irr_Goba	2.9	3.5	2.7	0.2	1.4	2.0	2.3	2.5	2.6	1.1	1.5	1.8	24.6
Irr_Harena	0.3	0.4	0.3	0.0	0.2	0.2	0.3	0.3	0.3	0.1	0.2	0.2	2.8
Irr_Medawelabo	1.0	1.2	0.9	0.1	0.5	0.7	0.8	0.9	0.9	0.4	0.5	0.6	8.4
Irr_wadera	1.4	1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.1	4.3
Irr_Welmel	3.5	2.1	3.9	0.0	9.0	13.7	3.4	1.7	4.9	0.0	20.5	16.0	78.6
Irr_Yadot	3.3	1.4	7.2	0.0	7.9	5.8	3.9	2.7	2.2	0.0	9.7	9.8	54.1
Irr_Bale Gadula	0.7	0.2	3.0	2.0	4.5	5.2	1.2	3.0	3.7	0.5	6.5	5.7	36.1
TOTAL	30.7	24.8	28.6	3.0	27.6	33.8	19.0	18.9	22.9	5.7	48.1	47.7	**310.8**

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Supply Delivered													
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: LONG TERM SCENARIO I, All months (12), Monthly Average													
η = 60%													
SCHEME	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Sum**
Irr_Adola	1.0	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.8	3.0
Irr_Agarfa	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.4
Irr_Berber	4.7	5.5	4.4	0.4	2.2	3.2	3.6	4.0	4.2	1.8	2.5	2.9	39.3
Irr_D.Mena	4.5	5.1	3.9	0.3	2.1	3.0	3.5	3.8	4.0	1.7	2.3	2.7	36.9
Irr_Dinsho	0.2	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.7	2.4
Irr_Ginir	4.9	2.4	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	4.2	15.0
Irr_Goba	0.6	0.9	1.0	0.2	1.3	1.8	2.2	2.5	2.6	1.1	1.0	0.8	16.1
Irr_Harena	0.3	0.4	0.3	0.0	0.2	0.2	0.3	0.3	0.3	0.1	0.2	0.2	2.8
Irr_Medawelabo	1.0	1.2	0.9	0.1	0.5	0.7	0.8	0.9	0.9	0.4	0.5	0.6	8.4
Irr_wadera	1.4	1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.1	4.3
Irr_Welmel	3.5	2.1	3.9	0.0	9.0	13.6	3.4	1.7	4.9	0.0	20.5	16.0	78.5
Irr_Yadot	3.3	1.4	6.7	0.0	7.9	5.8	3.9	2.7	2.2	0.0	9.7	9.5	53.1
Irr_Bale Gadula	0.7	0.2	3.0	2.0	4.5	5.2	1.2	3.0	3.7	0.5	6.5	5.7	36.1
TOTAL	26.3	21.3	26.0	3.0	27.5	33.5	18.9	18.8	22.9	5.6	47.4	45.2	**296.4**

UNMET Demand (Cubic Meter)													
All Demand Sites, Scenario: LONG TERM SCENARIO I, All Sources (116), All months (12), Monthly Average													
η = 60%													
UNMET DEMAND	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Sum**
Irr_Adola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_Agarfa	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6
Irr_Berber	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Irr_D.Mena	0.0	0.2	0.3	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.7
Irr_Dinsho	1.7	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.9	3.4
Irr_Ginir	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_Goba	2.3	2.5	1.7	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.5	1.0	8.4
Irr_Harena	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_Medawelabo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_wadera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_Welmel	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Irr_Yadot	0.0	0.1	0.5	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.3	1.0
Irr_Bale Gadula	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	4.4	3.4	2.7	0.0	0.1	0.3	0.1	0.1	0.0	0.1	0.8	2.5	**14.4**

3.2. SCENARIO II / CLIMATE CHANGE SCENARIO

3.2.1. Short Term Scenario II (2018 – 2030).

3.2.1.1. Domestic Demand Analysis

Water Demand (not including loss, reuse, and DSM) (Cubic Meter)							
Levels, All Branches, Branch: Demand Sites and Catchments, Scenario: SHORT TERM SCENARIO TWO, All months (12), Annual Total, Levels: 1							
Wereda	DEMAND MMC	**Wereda**	DEMAND MMC	**Wereda**	DEMAND MMC	**Wereda**	DEMAND MMC
Adaba	14.83	Dawe	3.24	Goba	4.26	Mena	9.66
Adola	11.49	Dinsho	4.17	Gololcha	10.69	Moyale	3.25
Afder	14.83	Dire	7.09	Goro Baqaqsa	5.42	Rayitu	3.55
Agarfa	11.02	Dolo Odo	11.96	Goro Dola	8.27	Shakiso	22.49
Arero	5.11	Dugda Dawa	15.54	Goro	8.92	Sinana	12.38
Aroresa	16.87	Elkere	8.34	Gura Damole	2.10	Teltele	7.50
Bare	9.85	Filtu	13.83	Harena	8.65	Uraga	18.62
Bdolo Bay	7.84	Gasera	8.30	Hudet	4.58	Wadera	5.41
Berbere	9.62	Ginir	15.13	Liben	14.53	Yabelo	11.16
Bore	20.71	Medawelabo	10.27	Bule Hora	28.61	**Sum**	410.07

Supply Delivered for Domestic Water Demand													
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: SHORT TERM SCENARIO II, All months (12), Monthly Average													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**SUM**
Supply.D	33.57	30.99	33.51	32.98	34.67	33.31	34.04	34.08	33.27	34.66	33.02	33.63	401.72

3.2.1.2. Livestock Demand Analysis

Water Demand (not including loss, reuse, and DSM) (Cubic Meter)													
Levels, All Branches, Branch: Demand Sites and Catchments, Scenario: SHORT TERM SCENARIO TWO, All months (12), Monthly Average, Levels: 1													
DEMAD	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
Liv Bale	0.14	0.13	0.14	0.13	0.14	0.13	0.14	0.14	0.13	0.14	0.13	0.14	1.63
Liv Bare	0.37	0.34	0.37	0.36	0.37	0.36	0.37	0.37	0.36	0.37	0.36	0.37	4.42
Liv Bdolo	0.34	0.31	0.34	0.33	0.34	0.33	0.34	0.34	0.33	0.34	0.33	0.34	3.99
Liv Chereti	0.36	0.33	0.36	0.35	0.36	0.35	0.36	0.36	0.35	0.36	0.35	0.36	4.24
Liv Dire	0.15	0.13	0.15	0.14	0.15	0.14	0.15	0.15	0.14	0.15	0.14	0.15	1.72
Liv Guji	1.18	1.07	1.18	1.14	1.18	1.14	1.18	1.18	1.14	1.18	1.14	1.18	13.86
Liv Moyale	0.18	0.17	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	2.14
Liv Sidama	0.50	0.46	0.50	0.49	0.50	0.49	0.50	0.50	0.49	0.50	0.49	0.50	5.91
LIV Yab	0.21	0.19	0.21	0.20	0.21	0.20	0.21	0.21	0.20	0.21	0.20	0.21	2.44
Liv_Areo	0.10	0.09	0.10	0.09	0.10	0.09	0.10	0.10	0.09	0.10	0.09	0.10	1.12
Liv_Liben	1.19	1.08	1.19	1.15	1.19	1.15	1.19	1.19	1.15	1.19	1.15	1.19	14.03
TOTAL	4.71	4.29	4.71	4.56	4.71	4.56	4.71	4.71	4.56	4.71	4.56	4.71	55.50

3.2.1.3. Irrigation Demand Analysis

Water Demand (not including loss, reuse, and DSM) (Cubic Meter)													
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: SHORT TERM SCENARIO II, All months (12), Monthly Average													
η = 45%													
DEMAND	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Sum**
Irr_Adola	1.4	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.0	4.0
Irr_Agarfa	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	1.4
Irr_Berber	6.3	7.4	5.8	0.5	2.9	4.2	4.9	5.3	5.6	2.4	3.3	3.9	52.6
Irr_D.Mena	6.0	7.1	5.6	0.4	2.8	4.0	4.6	5.1	5.4	2.3	3.1	3.7	50.2
Irr_Dinsho	2.6	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.2	7.8
Irr_Ginir	6.6	3.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.6	19.9
Irr_Goba	3.9	4.6	3.6	0.3	1.8	2.6	3.0	3.3	3.5	1.5	2.0	2.4	32.8
Irr_Harena	0.4	0.5	0.4	0.0	0.2	0.3	0.3	0.4	0.4	0.2	0.2	0.3	3.7
Irr_Medawelabo	1.3	1.6	1.2	0.1	0.6	0.9	1.0	1.1	1.2	0.5	0.7	0.8	11.2
Irr_wadera	1.9	1.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.5	5.7
Irr_Welmel	4.6	2.8	5.2	0.0	12.0	18.2	4.6	2.3	6.6	0.0	27.3	21.3	104.8
TOTAL	35.6	30.8	24.7	1.3	20.3	30.3	18.5	17.5	22.7	6.9	42.4	43.0	**294.1**

Supply Delivered													
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: SHORT TERM SCENARIO II, All months (12), Monthly Average													
η = 45%													
SUPPLY.D	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
Irr_Adola	1.4	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.0	4.0
Irr_Agarfa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
Irr_Berber	5.2	5.2	5.1	0.5	2.9	4.2	4.9	5.3	5.6	2.4	3.3	3.9	48.5
Irr_D.Mena	3.8	3.9	3.8	0.4	2.6	3.9	4.5	4.8	5.2	2.3	3.1	3.6	41.9
Irr_Dinsho	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.4
Irr_Ginir	6.6	3.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.6	19.9
Irr_Goba	0.2	0.3	0.1	0.2	0.8	0.7	0.7	1.1	2.2	0.4	0.2	0.1	7.1
Irr_Harena	0.4	0.5	0.4	0.0	0.2	0.3	0.3	0.4	0.4	0.2	0.2	0.3	3.7
Irr_Medawelabo	1.3	1.6	1.2	0.1	0.6	0.9	1.0	1.1	1.2	0.5	0.7	0.8	11.2
Irr_wadera	1.9	1.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.5	5.7
Irr_welmel	4.6	2.8	5.2	0.0	11.5	12.6	4.6	2.3	6.6	0.0	14.0	12.4	76.6
TOTAL	25.4	19.8	18.1	1.2	18.7	22.7	15.9	15.0	21.2	5.8	26.1	29.2	**219.0**

UNMET Demand (Cubic Meter)													
All Demand Sites, Scenario: LONG TERM SCENARIO I, All Sources (116), All months (12), Monthly Average													
η = 45%													
UNMET	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
Irr_Adola	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_Agarfa	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	1.4
Irr_Berber	1.1	2.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1
Irr_D.Mena	2.3	3.1	1.8	0.0	0.2	0.1	0.2	0.3	0.2	0.0	0.0	0.1	8.3
Irr_Dinsho	2.6	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.2	7.4
Irr_Ginir	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_Goba	3.8	4.3	3.5	0.1	1.0	1.9	2.4	2.2	1.3	1.1	1.8	2.3	25.7
Irr_Harena	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_Medawelabo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irr_wadera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	10.2	11.1	6.6	0.1	1.2	2.1	2.5	2.5	1.5	1.1	3.0	4.9	**46.8**

3.2.2. Long Term Scenario II (2031 – 2050) I.e. demand is constant

3.2.2.1. Domestic Demand Analysis

Water Demand (not including loss, reuse, and DSM) (Cubic Meter)							
Levels, All Branches, Branch: Demand Sites and Catchments, Scenario: LONG TERM SCENARIO TWO, All months (12), Annual Total, Levels: 1							
Wereda	DEMAND MMC	**Wereda**	DEMAND MMC	**Wereda**	DEMAND MMC	**Wereda**	DEMAND MMC
Adaba	14.83	Dawe	3.24	Goba	4.26	Mena	9.66
Adola	11.49	Dinsho	4.17	Gololcha	10.69	Moyale	3.25
Afder	14.83	Dire	7.09	Goro Baqaqsa	5.42	Rayitu	3.55
Agarfa	11.02	Dolo Odo	11.96	Goro Dola	8.27	Shakiso	22.49
Arero	5.11	Dugda Dawa	15.54	Goro	8.92	Sinana	12.38
Aroresa	16.87	Elkere	8.34	Gura Damole	2.10	Teltele	7.50
Bare	9.85	Filtu	13.83	Harena	8.65	Uraga	18.62
Bdolo Bay	7.84	Gasera	8.30	Hudet	4.58	Wadera	5.41
Berbere	9.62	Ginir	15.13	Liben	14.53	Yabelo	11.16
Bore	20.71	Medawelabo	10.27	Bule Hora	28.61	**Sum**	410.07

Supply Delivered for Domestic Water Demand													
Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: LONG TERM SCENARIO II, All months (12), Monthly Average													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
Domestic Demand	33.7	31.0	33.7	32.9	34.4	33.2	33.9	34.1	33.1	34.5	33.1	33.9	401.4

3.2.2.2. Livestock Demand Analysis

Water Demand (not including loss, reuse, and DSM) (Cubic Meter)													
Levels, All Branches, Branch: Demand Sites and Catchments, Scenario: LONG TERM SCENARIO TWO, All months (12),Monthly Average, Levels: 1													
DEMAD	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
Liv Bale	0.14	0.13	0.14	0.13	0.14	0.13	0.14	0.14	0.13	0.14	0.13	0.14	1.63
Liv Bare	0.37	0.34	0.37	0.36	0.37	0.36	0.37	0.37	0.36	0.37	0.36	0.37	4.42
Liv Bdolo	0.34	0.31	0.34	0.33	0.34	0.33	0.34	0.34	0.33	0.34	0.33	0.34	3.99
Liv Chereti	0.36	0.33	0.36	0.35	0.36	0.35	0.36	0.36	0.35	0.36	0.35	0.36	4.24
Liv Dire	0.15	0.13	0.15	0.14	0.15	0.14	0.15	0.15	0.14	0.15	0.14	0.15	1.72
Liv Guji	1.18	1.07	1.18	1.14	1.18	1.14	1.18	1.18	1.14	1.18	1.14	1.18	13.86
Liv Moyale	0.18	0.17	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	2.14
Liv Sidama	0.50	0.46	0.50	0.49	0.50	0.49	0.50	0.50	0.49	0.50	0.49	0.50	5.91
LIV Yab	0.21	0.19	0.21	0.20	0.21	0.20	0.21	0.21	0.20	0.21	0.20	0.21	2.44
Liv_Areo	0.10	0.09	0.10	0.09	0.10	0.09	0.10	0.10	0.09	0.10	0.09	0.10	1.12
Liv_Liben	1.19	1.08	1.19	1.15	1.19	1.15	1.19	1.19	1.15	1.19	1.15	1.19	14.03
TOTAL	4.71	4.29	4.71	4.56	4.71	4.56	4.71	4.71	4.56	4.71	4.56	4.71	55.50

3.2.2.3. Irrigation Demand Analysis

Water Demand (not including loss, reuse, and DSM) (Cubic Meter)

Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: LONG TERM SCENARIO II, All months (12), Monthly Average

η = 45%

DEMAND	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
Irr_Adola	1.4	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.0	4.0
Irr_Agarfa	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	1.4
Irr_Berber	6.3	7.4	5.8	0.5	2.9	4.2	4.9	5.3	5.6	2.4	3.3	3.9	52.6
Irr_D.Mena	6.0	7.1	5.6	0.4	2.8	4.0	4.6	5.1	5.4	2.3	3.1	3.7	50.2
Irr_Dinsho	2.6	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.2	7.8
Irr_Ginir	6.6	3.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.6	19.9
Irr_Goba	3.9	4.6	3.6	0.3	1.8	2.6	3.0	3.3	3.5	1.5	2.0	2.4	32.8
Irr_Harena	0.4	0.5	0.4	0.0	0.2	0.3	0.3	0.4	0.4	0.2	0.2	0.3	3.7
Irr_Medawelabo	1.3	1.6	1.2	0.1	0.6	0.9	1.0	1.1	1.2	0.5	0.7	0.8	11.2
Irr_wadera	1.9	1.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.5	5.7
Irr_Welmel	4.6	2.8	5.2	0.0	12.0	18.2	4.6	2.3	6.6	0.0	27.3	21.3	104.8
TOTAL	35.6	30.8	24.7	1.3	20.3	30.3	18.5	17.5	22.7	6.9	42.4	43.0	**294.1**

Supply Delivered

Levels, All Branches, Branch: Demand Sites and Catchments, Levels: 1, Scenario: LONG TERM SCENARIO II, All months (12), Monthly Average

η = 45%

SUPPLY.D	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
Irr_Adola	1.4	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.0	4.0
Irr_Agarfa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2
Irr_Berber	5.6	5.8	5.4	0.5	2.9	4.2	4.9	5.3	5.6	2.4	3.3	3.9	49.9
Irr_D.Mena	4.6	4.6	4.6	0.4	2.6	3.8	4.6	5.1	5.2	2.3	3.1	3.6	44.6
Irr_Dinsho	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.1	1.0
Irr_Ginir	6.6	3.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	5.6	19.9
Irr_Goba	0.2	0.3	0.1	0.2	1.3	1.0	1.2	2.3	2.6	0.9	0.6	0.3	10.9
Irr_Harena	0.4	0.5	0.4	0.0	0.2	0.3	0.3	0.4	0.4	0.2	0.2	0.3	3.7
Irr_Medawelabo	0.6	0.7	0.5	0.0	0.3	0.4	0.4	0.5	0.5	0.2	0.3	0.4	4.8
Irr_wadera	1.9	1.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.5	5.7
Irr_Welmel	4.6	2.8	5.2	0.0	11.1	12.2	4.6	2.3	6.6	0.0	15.2	11.1	75.6
TOTAL	26.0	20.3	18.5	1.2	18.4	21.9	16.0	15.9	21.0	6.0	27.7	27.6	**220.5**

3.3. SCENARIO III COMBINATION SCENARIO

3.3.1. Short Term Scenario III (2018 – 2030)

Unmet Demand (Cubic Meter)													
Scenario: SHORT TERM SCENARIO THREE, All months (12), Monthly Average													
UNMET	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
Adaba Wereda	0.6	0.4	0.6	0.4	0.1	0.0	0.3	0.2	0.0	0.0	0.4	0.5	3.5
Agarfa Wereda	0.4	0.3	0.4	0.3	0.0	0.0	0.2	0.2	0.0	0.0	0.3	0.4	2.6
Bule H. Wereda	0.9	0.6	0.9	0.5	0.1	0.6	0.8	0.8	0.6	0.0	0.6	0.8	7.3
Dinsho Wereda	0.2	0.1	0.2	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.2	1.0
Dugda.D Wereda	0.5	0.4	0.5	0.3	0.1	0.3	0.5	0.4	0.3	0.0	0.3	0.5	4.0
Ginir Wereda	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	2.1
Goba Wereda	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.1	0.7
Irr_Agarfa	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	1.4
Irr_Berber	1.4	2.5	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8
Irr_D.Mena	2.1	3.0	1.7	0.0	0.0	0.0	0.2	0.3	0.1	0.0	0.0	0.1	7.5
Irr_Dinsho	2.6	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.2	7.5
Irr_Goba	3.9	4.5	3.6	0.2	1.1	2.2	2.5	2.6	1.5	1.3	2.0	2.4	27.8
Sinana Wereda	0.3	0.2	0.3	0.1	0.1	0.1	0.2	0.0	0.0	0.2	0.2	0.3	2.0
Irr_Welmel	0.0	0.0	0.0	0.0	0.5	5.7	0.0	0.0	0.0	0.0	13.2	8.9	28.4
Sum	13.5	13.6	9.9	2.2	2.3	9.4	5.1	4.8	2.8	1.8	18.4	16.9	**100.5**

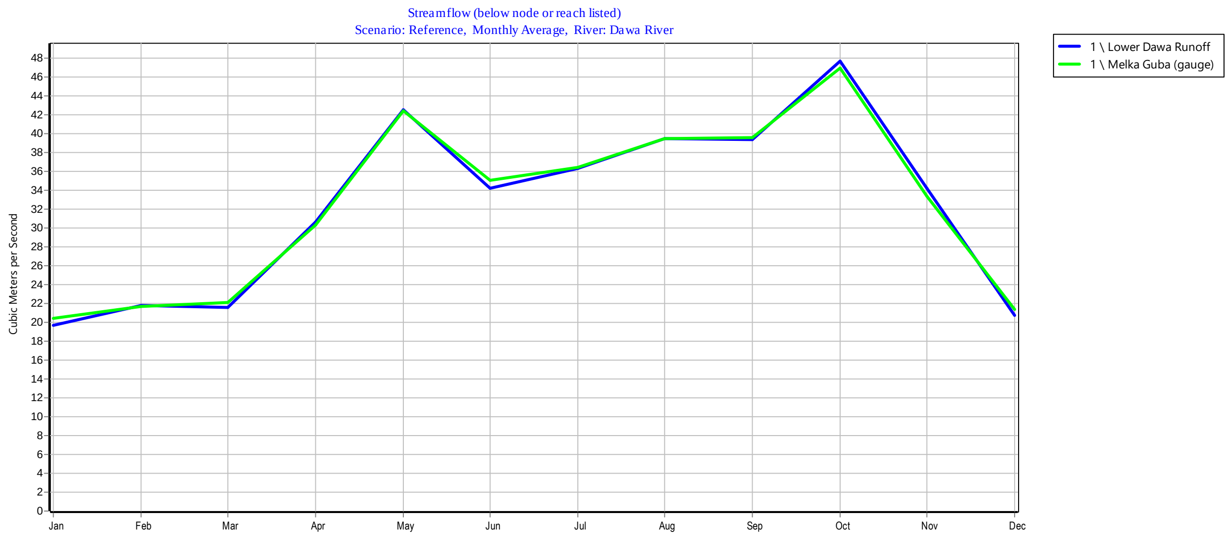
3.3.2. Long Term Scenario III (2031 – 2050)

Unmet Demand (Cubic Meter)													
Scenario: SHORT TERM SCENARIO THREE, All months (12), Monthly Average													
UNMET	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Sum**
Adaba Wereda	1.2	1.0	1.2	1.1	0.2	0.2	0.6	0.4	0.1	0.0	0.6	1.1	7.8
Agarfa	0.9	0.8	0.9	0.8	0.2	0.2	0.5	0.3	0.1	0.0	0.4	0.8	5.8
Bule Hora Wereda	2.1	1.8	2.0	1.1	0.5	1.5	2.1	1.6	1.3	0.4	1.0	1.8	17.1
Dinsho Wereda	0.3	0.3	0.3	0.3	0.1	0.1	0.2	0.1	0.0	0.0	0.2	0.3	2.2
Dugda Dawa Wereda	1.2	1.0	1.2	0.6	0.3	0.9	1.2	1.0	0.8	0.3	0.6	1.1	10.2
Gasera Wereda	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Ginir Wereda	1.2	1.0	1.2	1.1	1.2	1.1	1.2	1.2	1.1	1.2	1.1	1.2	13.9
Goba Wereda	0.3	0.2	0.3	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.2	0.3	2.4
Moyale Wereda	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.9
Sinana Wereda	0.9	0.7	0.9	0.6	0.3	0.5	0.5	0.3	0.2	0.5	0.6	0.8	6.8
Irr_Welmel	0.0	0.0	0.0	0.0	0.8	6.0	0.0	0.0	0.0	0.0	12.3	10.2	29.4
Irr_Yadot	2.1	1.0	5.5	0.0	2.5	2.0	0.8	0.2	0.3	0.0	5.5	7.0	27.0
Irr_Agarfa	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	1.3
Irr_Berber	1.2	2.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2
Irr_D.Mena	2.9	3.5	3.2	0.0	0.7	1.0	0.7	0.2	0.5	0.0	1.3	2.0	16.1
Irr_Dinsho	2.6	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	2.2	7.3
Irr_Goba	3.9	4.6	3.6	0.2	1.2	2.4	2.3	1.6	1.7	1.3	1.9	2.4	27.3
SUM	21.4	19.6	21.9	6.1	8.2	16.3	10.4	7.1	6.2	3.9	26.9	31.9	**179.8**

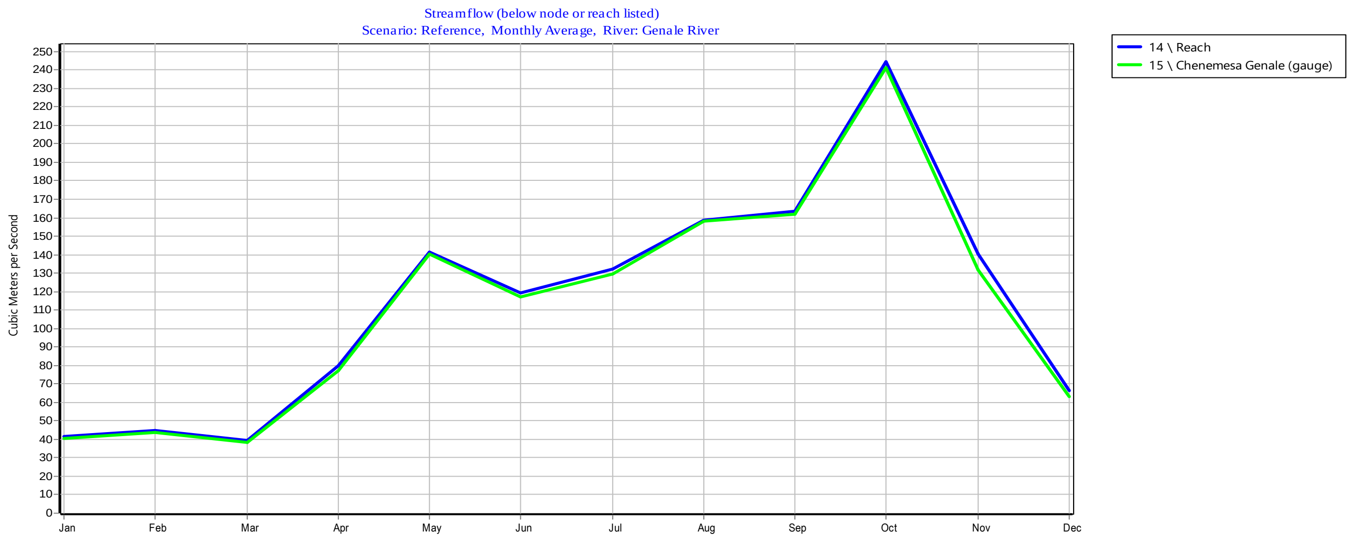
4. Calibration and Validation

4.1. Monthly Average Calibration of gauge stations

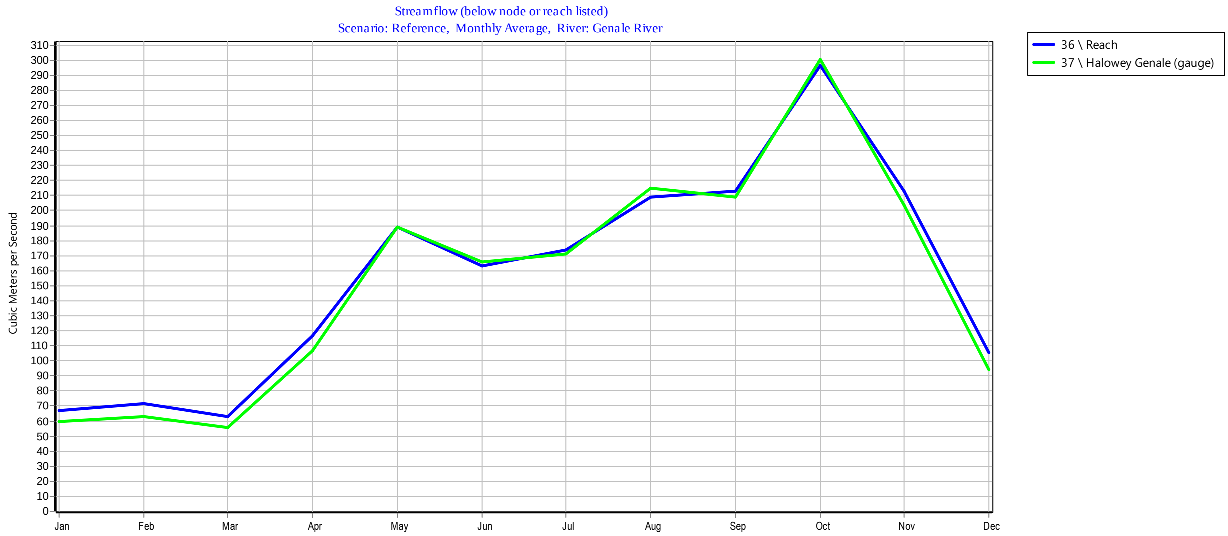
a. Melka Guba gauge – Dawa river



b. Chenemessa gauge station – U/S Genale river



c. Halewoy gauge D/S Genale river



d. Nr.Bore Dimtu gauge – Weyib river