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Title: Arjo Didessa reservoir water Evaluation and allocation system

MSc. Thesis

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Abstract

The Abay basin is one of the Ethiopian basins endowed with abundant surface water and groundwater resources that require proper management and have to be wisely utilized in a sustainable manner. Didessa River is one of the tributary of Abay basin. Evaluating the seasonal variation of this river will provide management and fair distribution of water resources in Didessa catchment.

Currently Arjo Didessa earthen dam is the reservoir found in the Upper Didessa River being utilized for Irrigation uses and in addition to irrigation uses different water users are found in Didessa catchment that will gain water from the same source. For this reason it needs evaluation and planning of the Didessa river water. To address water resources fairly to all users requires technical issues and specialized tools Arc view GIS tool to obtain hydrological and physical parameters and spatial information, Global Mapper to manipulate the DEM data in line with the shape files of the river basin and WEAP (water evaluation and planning) model to assess the consequences of climate change and irrigation expansion on current and future water use practices of Arjo reservoir.

Records of hydrology and meteorological data have been statistically tested and arranged as an input data source to fit the model. Meteorological and grid climatic data were correlated with multi-regression and distribution mapping (DM) method respectively. The demand and the supply of water resource, baseline data and the future development activities of the area were compared using the mainly two different scenarios climate change and irrigation expansion.

This study analyzed the model calibration, validation and its statistical measure were seen and the result shows that it is very good and the model can simulate the current and the future scenarios. After all of this done, the results revealed that unless the minimum flow requirements are maintained, the future irrigation demands are unmet in more or less. Due to the climate change the volume of reservoir evaporation in the (2016-2030) period was increased by 1.5%, in 2031-2050 periods was increased to 3.1%, and 2051-2080 period was increased to 4.3% when comparing with the current scenario. While compared with the baseline period, the first 15 years reservoir evaporation will increase but the Arjo Didessa Reservoir water has full supplement.

There should be more detailed water resource management activity, including sustainable abstractions. In addition to this, the new projects on the study area have to construct for additional demand supply or supply with irrigation expansions

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List of Abbreviations

ADRSB:	Arjo Didessa River Sub Basin
CDF:	Cumulative Distribution Function
DEM:	Digital Elevation Model
DM:	Distribution Mapping
GDP:	Gross Domestic Product
GTP:	Growth and Transformation Plan
FAO:	Food and Agriculture Organization
GIS:	Geographical Information System
Ha:	Hectare
ICTZ:	Inter-Tropical Convergence Zone
IPCC:	Intergovernmental Panel on Climate Change
Kc :	Crop coefficient
kms:	Kilometers
LOCI :	Local Intensity Correction
m:	Meter
masl:	Mean Above Sea Level
Mm3:	Million meter cube
M3/s:	Meter Cube per Second
OWWDSE:	Oromia Water Works Design and Supervision Enterprise
MoWIE:	Ministry of Water, Irrigation and Electricity
NMSA:	National Meteorological Services Agency
R2:	Coefficient of Determination
RCM:	Regional Climate Model
RCP:	Representative Concentration Pathway
RMSE:	Root Mean Square Error
SEI:	Stockholm Environment Institute
SN:	Scenarios
SRES:	Special Report on Emission Scenario
WWDSE:	Water Works Design and Supervision Enterprise
WEAP:	Water Evaluation and Planning System

1. Introduction

1.1. Background

Ethiopia has begun to effectively water resources development plan since few years ago. Though the development activities encompass all major river basins of the country, the huge agricultural and hydroelectric power potentials in the Upper Blue Nile Basin have attracted considerable attention. Didessa River is also one of the tributary of upper Nile sub basin: Hence, there are currently a number of water resources development projects in the construction and planning phases in Didessa River of the Abay Basin.

Arjo Didessa reservoir is upper Blue Nile basin reservoirs located in the southern Nile Basin West Ethiopia with an estimated drainage area of 3400km^2. Didessa river is fed by four major tributaries all of them rising in the highlands surrounding the basin. One diversion weir also is proposed at its downstream around 180km from Arjo Didessa reservoir to divert water for irrigation productions and for the realization of irrigation development works at Cawaqa and Benishangul border area. As recently Arjo Didessa master plan study Arjo Didessa has an estimated mean annual out flow of 417.15BCM.

Reservoir of Arjo Didessa water storage nearly satisfy the full current demand, but there is possibility of larger water shortages in the future due to irrigation expansion, climate change and population growth rate. Then providing evaluation and allocating water is very crucial. Reservoir water allocation should have to be prepared for sharing water resource in appropriate manner for downstream proposed reservoir and user expansion in the future. These policies accept some present delivery deficit to reduce the probability of greater water shortage in the future.

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 in worldwide level today (IPCC, Technical paper VI Climate change and Water., 2007). This change affecting certain components of the hydrological cycle, especially precipitation and temperature, this alters the spatial and temporal availability of water resources. It can change flow magnitude; variability and timing of the main flow event are among the most frequently mentioned hydrological issues (Habtom, 2009).

To address this need, the study assessed the impact of climate change and irrigation expansion and population growth on available water resources of Arjo reservoir in the upper sub-basin of the Didessa catchment 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 (Azman, Azman, B. (2007) Impact of Climate Change on Water Resources Availability in the Komati River Bas, 2007) WEAP 21 model is one of the useful tools for the 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 irrigation development on water allocation of Arjo Didessa reservoir was tested in this study.

1.2. Statement of problem

The recently conducted Arjo Didessa Integrated Master Plan Project studies by oromia water work and design enterprise has indicated that the Didessa reservoir have a potential to store water for 56000ha land area. Even though there is surplus water in storage there is an irrigational expansion and population growth and climate change within the basin. This also indicates that in future the development of all users competes for the same resource from upper Didessa sub basin. Moreover, different irrigation projects, sugarcane plantation and water supply are on plan to be expanded. Due to climate change and expansion of users continue in reduction of water resource capacity and scarcity of the water will occur. Therefore the water management of the reservoir is becoming very important. In addition to this in the future temperature projections of the IPCC mid-range scenario show that the mean annual temperature will increase in the range of 0.9 to 1.1C^0 by 2030, in the range of 1.7 to 2.1ºC by 2050, and in the range of 2.7 to 3.4ºC by 2080 in Ethiopia compared to the 1961 to 1990 (Emerta, climate change, growth, and poverty in Ethiopia., 2013).

Related with rainfall and temperature change and variability, there was a recurrent draught and flood events in the country. There was also observation of water level rise and dry up of lakes in some parts of the country depending on the general trend of the temperature and rainfall pattern of the regions.

Then to overcome these all problems and challenges, by using different literatures this research has been designed. The overall situation described so far is an indication how development planning and reservoir operation are serious issues in the Didessa river water allocation and operational system. This competition of water use will cause the conflict on water resource between different users.

1.3 Research questions

- What are the effects of climate change and irrigational expansion on the available reservoir water at Arjo Didessa?
- How much water required for schematic irrigation designed at downstream of the reservoir and for other users' upstream reservoir?
- What techniques could be used to fairly distribute water requirement.

1.4 Objectives of the Study

1.4.1General objective

The main aim of this thesis is to evaluate adequacy of water for different users at Arjo reservoir under climate change and downstream irrigation expansion scenarios using WEAP model.

1.4.2 Specific objectives

- To check balance of Arjo Didessa reservoir water demands and supplement in current and future scenario
- To predict future water demands and allocation based on different development scenarios.
- To analyses water required for irrigation, drinking and livestock at deferent scenario to ensure the sustainable development.

1.5 Limitation of the Study

The study focuses on the upper Didessa catchment respond to major stresses of climate change, population growth and irrigation expansion in terms of the water availability at the catchment scale. Aiming at the objective, this study did not take into account the other development; rather than irrigation water allocation at downstream of the reservoir under the two scenarios. Moreover, it was beyond the scope of this study to identify the problem of flooding, sediment and hydropower, water quality if it may be happened under future scenarios troubles.

1.6 The framework of the study

This study was done under six chapters. Chapter one provides the brief introduction of the study, statement of the problem, the research question, objective of the research and the outline of the hall thesis. Chapter two deal with brief explanation of literature review and some journals. In chapter three and four Detail description of the study area, and Dataset and Data Sources for WEAP Model were included in chapter three respectively. Chapter five is explains result and discussion part. Conclusions and recommendations are included in chapter six. The framework of the study is presented in graph as bellow

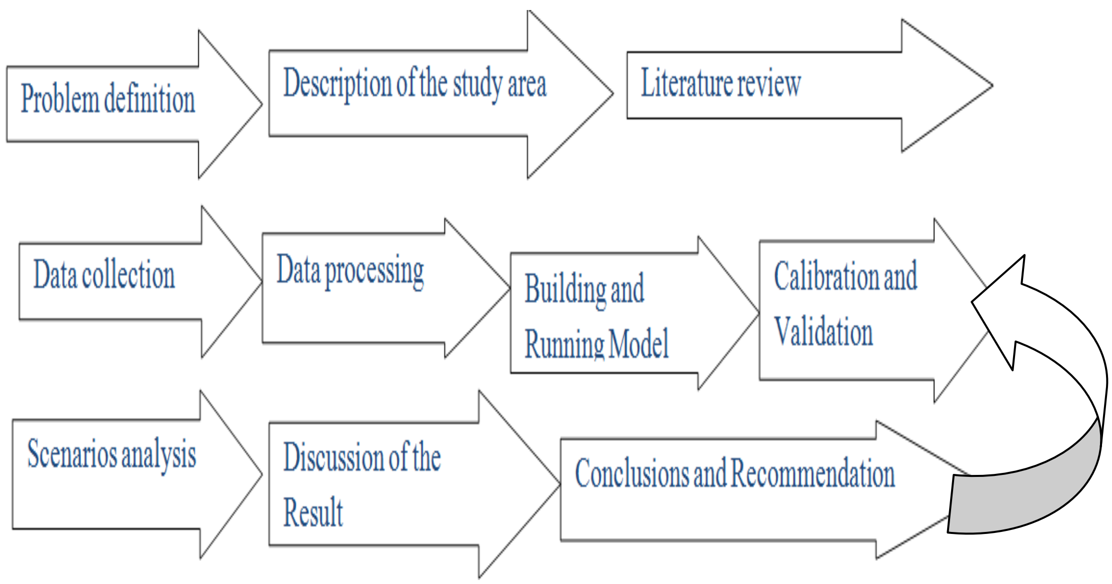


Figure 1:1The frame Works of the study

2. Literature review

2.1. Decision Making Technologies in Water Resources Management

The competition for available water resources in much of the developing world is growing rapidly due to ever-increasing and conflicting demands from agriculture, industry, urban water supply and energy production. The demand is fueled by factors such as population growth, urbanization, dietary changes and increasing consumption accompanying economic growth and industrialization. Climatic changes are expected to further increase the stress on water resources in many regions ((Samuelson, 1958)**.** The traditional fragmented approach is no longer viable and a more holistic and coordinated approach to water management is essential. River basin management engages the development, conservation, control, regulation, protection, allocation, and beneficial use of water in streams, rivers, lakes, and reservoirs. Public recreation, water quality, erosion and sedimentation, and protection and enhancement of fish, wildlife, and other environmental resources are important considerations in managing reservoir/river systems.

Nevertheless, the multi-interpedently objective and constraints of river basin systems has made it difficult to satisfy large number of possible design and operating policies. Thus the need to manage these complex integrated interests in a river basin or Reservoir system has led to a need for computer based Decision Support Systems (DDS) that can provide balanced use of water as well as allow the decision maker to easily modify operating policy and physical and economic characteristics of a particular river basin.

They use quantitative models and database elements for problem solving. They are an integral part of the decision-makers approach to problem identification and solution". According to him a DSS must help decision makers at the upper levels, must be flexible and respond to questions quickly, must provide a solution for "what if" scenarios and must consider the specific requirements of the decision makers. Particularly water allocation models are being widely used in order to assess the impacts of future development trends, water management strategies, climate change, etc on the availability of water resources (Simonovic, 1996).

2.2 Abbay master plan Review

The Blue Nile River (known as the Abbey in Ethiopia) is the most important tributary of the Nile River, providing over 62% of the Nile's flow at Aswan (World Bank, 2006). Both Egypt, and to a lesser extent Sudan, are almost wholly dependent on water that originates from the Nile. This dependency makes the challenges of water resources management in this region an international issue (Waterbury, 2002). The

Blue Nile rises in the Ethiopian highlands in the region of West Gojam and flows northward into Lake Tana, which is located at an elevation of just under 1,800 m. Didessa River on which the study is going on.

2.3 Arjo Didessa dam study

The Study Area of Arjo-Didessa Dam and Reservoir Project is located in Didessa Sub-basin of Abbay Basin, West Ethiopia, at the upper reach of Didessa River. Geographically, the reservoir area is situated between 8°12'29.51" - 8°31'28.52" N latitude and 36°39'43.89" - 36°48'30.77" E longitude, at an elevation range of 1318 meters a.s.l to a contour of 1359 meters a.s.l closing at the dam crest level. The total area of the reservoir at the dam crest level is about 98.6 km2 . Didessa Sub-basin of the Abbay Basin is one of such watersheds, where some large water management projects have been planned, among which Arjo-Didessa Irrigation Development Project is one of them. Arjo-Didessa Dam and Reservoir Project is aimed at developing a storage facility to supply water for about 80,000 hectares (ha) of the commanded area. Currently, the construction of the dam is underway on the upper reach of the river. The land area of the reservoir at the dam crest level (1359 meters above sea level/a.s.l) is about 98.6 km2 . The storage capacity of the reservoir at maximum water level (1357 meters a.s.l) and full reservoir capacity (1354 meters a.s.l), according to the project office, is, respectively, 2,256.3 million cubic meters (MCM) and 1,924.6 MCM. The project is planned on an area where several households have been relocated from drought-stricken zones of northern and eastern Oromia (OWWDSE, 2014.)

2.2. Reservoir operation

Reservoir operation is the method used to allocate water stored in the reservoir among different upstream and downstream users. It is an important element in water resources planning and management. Flood Risk Reduction: store inflow, pass inflow if reservoir is near full, Municipal and Industrial use – meet specified demand: release water from storage to meet water quality for municipal consumption or industrial discharge, Irrigation – meet seasonal diversion schedule: allocation of released water for agriculture, Navigation – maintain channel depth with flow:

release to maintain depth? May be a higher priority in some systems, Hydropower – meet demand: is the ability to generate constrained by pool levels or downstream constraints? Base load plant? Peaking plant?, Recreation – maintain pool during season: maintain reservoir in a certain elevation range but still meet minimum flow requirements or minimum release for in-river recreation and Environmental – temperature, dissolved oxygen, minimum flow: release for water quality for spawning and migrating fish, maintain aquatic habitat, or Endangered Species. A major difficulty in the operation of reservoirs is the often conflicting and unequal objectives that require optimal operation rule and strong decision support system.

2.4 Climate Change

Climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods. Due to natural variability and as a result of human activity (IPCC, climate change as aresult of human activity, 2007) Climate change is facing the entire world nowadays. It is now widely received that climate change is by now happening and further change is unavoidable. The global average combined land and ocean surface temperature data calculated shows a warming of $0.85c^0$ over the period 1880 to 2012 (IPCC, 2014). After 1970 strongly many studies discovery specifies that most of the increase in average global surface temperature over the last 50 years is attributable by human activities. It was estimated that, change and sea level is expected to rise at rate of about 1.7 mm/yr as the ocean expands as heat is gradually diffused downwards in the ocean (Endalkachew, 2012). The IPCC also notes that observations over the past century shows, changes were occurring in the amount, intensity, frequency and types of precipitation globally (IPCC, technecal peparIVclimate change and water, 2007a)

The IPCC was established in 1988 by the World Meteorological Organization and the United Nations Environment Program, and its role is to “assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation”. Among the different assessment that were carried out by the IPCC, the most recent which published in 2007, states the projected global surface warming lies within the range 0.6 to 4.0oc, whereas the projected see level rise lies within the range 18 to 59 cm at the end of next century (IPCC, 2007a). The major effect of climate change is increasing temperatures which will in turn increase evapotranspiration and thus crop water demand (FAO and MoWIE, 2013). The attempt to estimate the effect of temperature increase on irrigation water demand showed that water demand per hectare increased by about 2.15% in two decades (2030) and 4.38% in four decades (2050). Therefore, the effect of climate change on irrigation water demand is ignored in the scenario analysis although an attempt could be made in simulating.

2.4.1 Climate Change and Water Resources Management Assessment

A fundamental component of the project is climate change and water resources management assessment, which identifies and prioritizes the gaps of the current WRM system, the revisions to national WRM policy and strategy that are required to meet current and future water needs. It is hoped that the CC-WRMA could also produce the evidence base that is required to make the case for investments in the WRM institutional framework. The CC-WRMA was conducted in Ethiopia between December 2013 and October 2014. It consists of an indicator-based assessment of WRM systems, practices, capacities and outcomes, taking a 'pathways' or 'bottlenecks' approach to identify the underlying factors supporting or hindering progress towards AWRM. It primarily focused on the national level, although three basin-level case studies were also used to illustrate the concrete manifestations or consequences of the bottlenecks that emerged from the analysis. For these, we considered those river basins where RBAs have been established, namely the Awash and Abay (Blue Nile) River Basins and the Rift Valley Lakes (Lake Ziway). Its methodology built on the one adopted by the African Ministers' Council on Water – Water and Sanitation Program (AMCOW-WSP) Country Status Overviews (CSOs) for the WASH sector, which has international recognition ((AMCOW, 2011) and Water Sanitation Program (WSP) Country Status Overviews (CSOs) for the WASH sector,, 2011) and has been applied to assess water supply and sanitation coverage in Ethiopia in 2009/2010 (WSP, 2011).

2.4.2 Climate Change in Ethiopia

For the past four decades, the average annual temperature in Ethiopia has been increasing by 0.37C^0 every ten years, which is slightly lower than the average global temperature rising (Emerta. A, 2013) . According to Emerta, the greater part of the temperature rise was observed during the second half of the 1990's and temperature rise is more pronounced in the dry and hot spots of the country, which are located in the northern, northeastern, and eastern parts of the country. The lowland areas are the most affected, as these areas are largely dry and exposed to flooding during extreme precipitation in the highlands. Future temperature projections of the IPCC mid-range scenario show that the mean annual temperature will increase in the range of 0.9 to 1.1C^0 by 2030, in the range of 1.7 to 2.1ºC by 2050, and in the range of 2.7 to 3.4ºC by 2080 in Ethiopia compared to the 1961 to 1990 (Emerta, 2013).

However the country has both dry and wet periods over the past four decades, precipitation has a general decreasing trend since the 1990s (Abayneh A. , 2011) . The decrease in precipitation has multiple effects on water availability for irrigation and other farming uses, especially in the North, northeastern, and eastern lowlands of the country. The average change in rainfall is projected to be in the range of 1.4 to 4.5 percent, 3.1 to 8.4 percent, and 5.1 to 13.8 percent over20, 30, and 50 years, respectively, compared to the 1961 to 1990 usual. According to Abayneh, the overall trend in the entire country is more or less constant.

Related with rainfall and temperature change and variability, there was a recurrent draught and flood events in the country. There was also observation of water level rise and dry up of lakes in some parts of the country depending on the general trend of the temperature and rainfall pattern of the regions.

2.4.3 Meteorological Change

The other most important data for this research are the meteorological data which include the daily rainfall records, temperature, humidity and stream flow data. There are a number of rainfall recording stations distributed over the Didessa watershed. Out of all the available rainfall recording stations about eight daily rainfall recording stations were systematically selected to be used for this research. Moreover, it is required that as much as possible, the location of the stations must be fairly distributed over the catchment so that the stations can be good representatives when calculating the Areal rainfall. Even these stations do not have complete record that it is very difficult to use them for hydrological calculation related to rainfall-runoff relation except that they only give some idea about the nature of rainfall processes in those places. Some rainfall stations have very doubtful daily records due to a number of reasons. It is worth mentioning that information from previous researches about both rainfall and runoff records were helpful in the screening process of the Meteorological data.

2.4.4 Climate Scenarios

Demographic development, Socio-economic development, technological change, energy and land use, and emission of greenhouse gases and air pollutants are the driving force for the future climate change may occur with respect to a range of variables (IPCC, Driving force of climate change, 2000). These future scenarios of forcing agents (e.g., greenhouse gases and aerosols) are served in to the climate models as input, and the output of these climate models is further used in climate change analysis and hence, the assessment of impacts, adaptation and mitigation. Several sets of scenarios including the scenarios from the Special Report on Emission Scenarios (SRES) and more recently the Representative Concentration Pathway (Agizew, 2015) are used in climate research. In the following section, brief descriptions of the various scenarios were presented

RCP – Emission scenarios. Recently there has been an increasing interest in scenarios that clearly determine the impact of different climate-policies in addition to the no-climate-policy scenarios such as SRES (Agizew, 2015). The need for new scenarios encouraged the IPCC to request scientific communities to develop a new set of scenarios for the assessment of future climate change. Therefore a set of new scenarios is constructed containing emission, concentration and land-use trajectories referred to as “Representative Concentration Pathways” (RCP). In its name, the word “representative” signifies that this set of RCPs should be well-matched with the full range of emission scenarios (with and without climate policy) available in the current scientific literature.

The word “concentration” emphasizes that instead of emissions, concentrations are used as the primary product of the RCPs, designed as input to climate models. There are four RCPs scenarios existing. Among, the four RCP dynamically down scaled regional climate multi-model outputs of CORDEX-Africa which were (RCP 2.6, RCP 4.5, RCP 6 and RCP 8.5) the RCP 8.5 is used and selected because the concentrations emission of CO2 is higher than when compared to the other RCPs. Comparison of CO2 concentrations obtained by RCP emission scenarios are indicated in

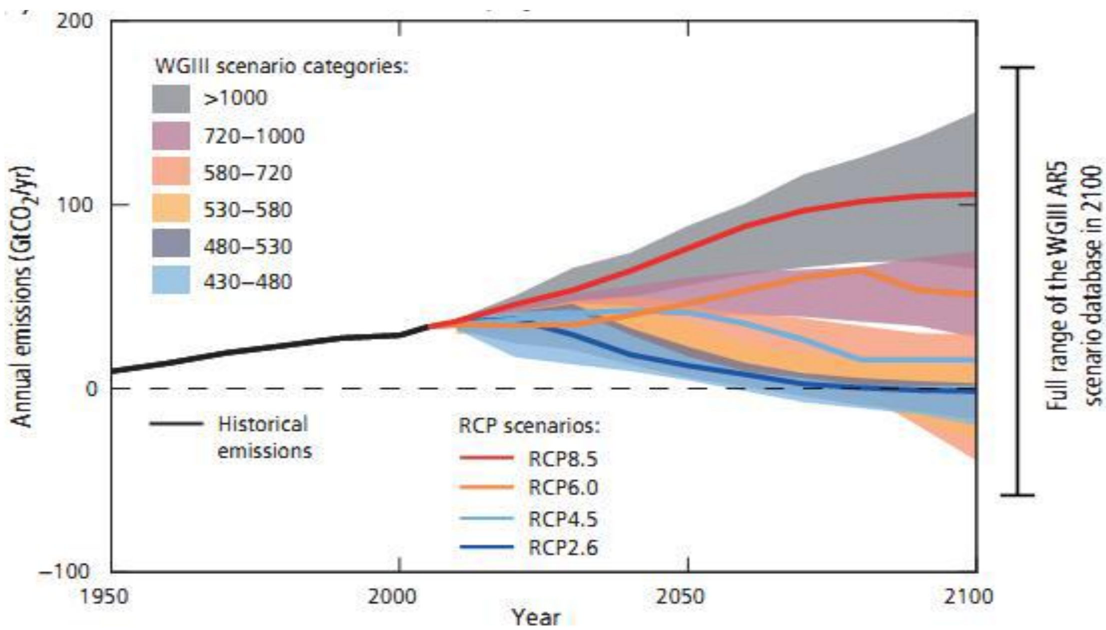


Figure 2: 1 Annual anthropogenic CO2 emission scenarios (IPCC, 2014)

Future climate will depend on committed warming caused by past anthropogenic emissions, as well as future anthropogenic emissions and natural climate variability. The global mean surface temperature change for the period 2016–2035 relative to 1986–2005 is similar for the four RCPs and will likely be in the range 0.3°C to 0.7°C (medium confidence). This assumes that there will be no major volcanic eruptions or changes in some natural sources (e.g., CH4 and N2O), or unexpected changes in total solar irradiance. By mid-21st century, the magnitude of the projected climate change is substantially affected by the choice of emissions scenario.

Relative to 1850–1900, global surface temperature change for the end of the 21st century (2081–2100) is projected to likely exceed 1.5°C for RCP4.5, RCP6.0 and RCP8.5 (high confidence). Warming is likely to exceed 2°C for RCP6.0 and RCP8.5 (high confidence), more likely than not to exceed 2°C for RCP4.5 (medium confidence), but unlikely to exceed 2°C for RCP2.6 (medium confidence). The increase of global mean surface temperature by the end of the 21st century (2081–2100) relative to 1986–2005 is likely to be 0.3°C to 1.7°C under RCP2.6, 1.1°C to 2.6°C under RCP4.5, 1.4°C to 3.1°C under RCP6.0 and 2.6°C to 4.8°C under RCP8.59 . The Arctic region will continue to warm more rapidly than the global mean. It is virtually certain that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales, as global mean surface temperature increases. It is very likely that heat waves will occur with a higher frequency and longer duration. Occasional cold winter extremes will continue to occur.

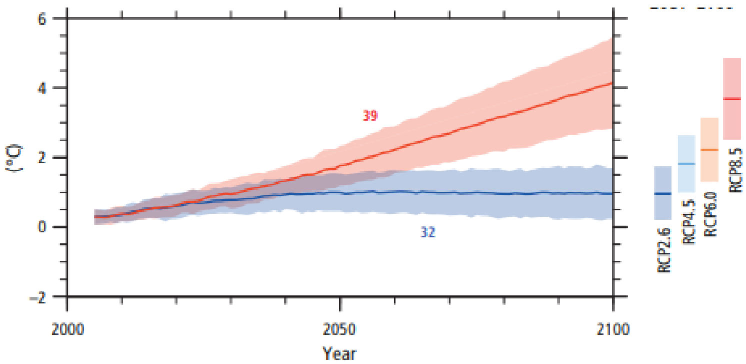


Figure 2: 2 Global average surface température change (relative to 1986–2005)

Changes in precipitation in a warming world will not be uniform. The high latitudes and the equatorial Pacific are likely to experience an increase in annual mean precipitation by the end of this century under the RCP8.5 scenario. In many mid-latitude and subtropical dry regions, mean precipitation will likely decrease, while in many mid-latitude wet regions, mean precipitation will likely increase under the RCP8.5 scenario (Figure 2.3)

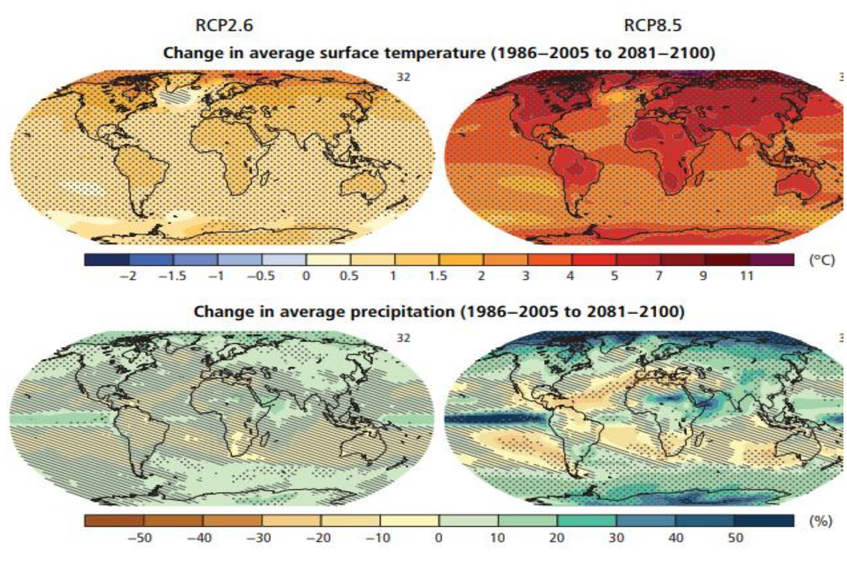


Figure 2: 3 change in annual mean surface temperature and change in annual mean precipitation, in percentages.

2.5 Irrigation Schemes in the Didessa River sub Basin

2.5.1 Previous Studies of the Area

Before beginning of any activity, review of earlier work is very important to get general understanding of the area and to minimize the time and cost that would have been spent for collecting related information. Accordingly, previous studies and data aimed for different purposes, the current study has been collected from different organizations. Most of the previous studies and more general information considered were as bellow.

2.6 Review of Effective Water Allocation Model

WEAP Model: Water Resources System Simulation modeling helps to understand the relationship between available water for demand under existing conditions and future development scenarios. In particular, the water resource modeling is used to identify areas of conflict caused by water scarcity. WEAP is one of the Water Evaluation and Planning System model and is originally developed by the Stockholm Environment Institute at Boston ((SEI), 2015) . It represents the system in terms of its various supply sources (e.g. rivers, streams, groundwater, and reservoirs); withdrawal, transmission and wastewater treatment facilities; ecosystem requirements, water demands and pollution generation. The data structure and level of detail may be easily modified to meet the requirements of a particular analysis, and to reflect the limits imposed by restricted data. The WEAP model applications generally include several steps. The study description sets up time frame, spatial boundary, system components and arrangement of the problem. The Current Accounts, which can be viewed as a calibration steps in the development of an application, provide the actual water demand, resources and supplies for the system. Scenarios built on the Current Accounts and allow one to investigate the impact of alternative assumptions or policies on future water availability and use. Finally, the scenarios are evaluated with regard to water sufficiency, benefits, compatibility with environmental targets, and sensitivity to uncertainty in key variables ((SEI), 2015). So for this study WEAP model is selected because of its inclusive, straightforward, easy-to-use, flexible data input, interfacing with Excel (import-and export) and Possibility to model the impact of climate change scenarios on reservoir. As a database, WEAP provides a system for maintaining water demand and supply information (Ahmed, 2015).

2.7 The WEAP Approach

Computer modeling in the field of water resources has a long history. Many sophisticated models have faltered by being mathematically obscure and overly ambitious in attempting to "optimize" solutions to real-life problems. Experience shows that the best approach is to build a straightforward and flexible tool to assist, but not substitute for, the user of the model. WEAP represents a new generation of water planning software that utilizes the powerful capability of today's personal computers to give water professionals everywhere access to appropriate tools.

The design of WEAP is guided by a number of methodological considerations: an integrated and comprehensive planning framework; use of scenario analyses in understanding the effects of different development choices; Demand-management capability; Environmental assessment capability; and Ease-of-use. These are discussed in turn below.

2.8 Demand Management Capability of weap

WEAP is unique in its capability of representing the effects of demand management on water systems. Water requirements may be derived from a detailed set of final uses, or "water services" in different economic sectors. For example, the agricultural sector could be broken down by crop types, irrigation districts and irrigation techniques. An urban sector could be organized by county, city, and water district. Industrial demand can be broken down by industrial subsector and further into process water and cooling water. This approach places development objectives--providing end-use goods and services--at the foundation of water analysis, and allows an evaluation of effects of improved technologies on these uses, as well as effects of changing

2.8.1 Urban Water Management by WEAP

One of the strengths of WEAP is that it is adaptable to whatever data is available to describe a water resources system. That is, it can use daily, weekly, monthly, or annual time-steps to characterize the system's water supplies and demands. This flexibility means that it can be applied across a range of spatial and temporal scales. Indeed, WEAP has been used throughout the world to analyze a diverse set of water management issues for small communities and large managed watersheds alike.

Historically, WEAP has been used primarily to assess the reliability of water deliveries and the sustainability of surface water and groundwater supplies under future development scenarios. This type of application of WEAP has focused on the water supply implications of proposed management and/or infrastructural changes, but has overlooked the impacts of these changes on the management of storm water and wastewater. Recent advancement of the model, however, has allowed for the holistic, comprehensive consideration of each of these facets of managing local water resources (Haileyesus, 2011).

3. Methodology and material

3.1 Description of study area

This thesis emphasize on the Arjo Didessa reservoir water management system which is located in Dembi wereda. Didesa sub-basin which is mainly located in East and West Welega zone, Illubabor zone, Jimma (special zone of Oromiya region) and some part in Kamashi zone of Benishangul-Gumuz.

3.1.1 Geographical Location

Geographically the sub-basin is located between $07^0$40'- $10^0$0'N and $35^0$32'-$37^0$15'E latitude and longitude respectively in western part of Ethiopia. The general elevation in the basin ranges between 653 meter a.m.s.l. and 3144 meter a.m.s.l. Physically, Didessa basin drains four zones (Jima, Illubabor, East Wollega, and West Wollega) of the National Regional State of Oromia as well as Benishangul Regional State.

Didessa River, which is the largest tributary of the Blue Nile (Abay) contributes roughly a quarter of the total flow of Blue Nile. The total catchment area drained by the river is estimated to be 34000 km^2 originating from the mountain ranges of Gomma in South Western Ethiopia. The main upper streams namely; Dembi river in the South flow eastwards for about 75kms until they are joined by the Eastern tributaries such as Wama, Indris and so on, then after, turning rather sharply to the north until it reaches the Blue Nile (Abay) River.

In the North East direction, the main tributary of Didessa River with the largest catchment area is Anger River. The mean annual rainfall in the study area is about 1745mm. The majority of the area is characterized by a humid tropical climate with heavy rainfall and most of the total annual rainfall is received during one rainy season called summer. The maximum and minimum temperature varies between 21.3 – 30.9^{0}C and 10.9 - 15.1^{0}C, respectively.

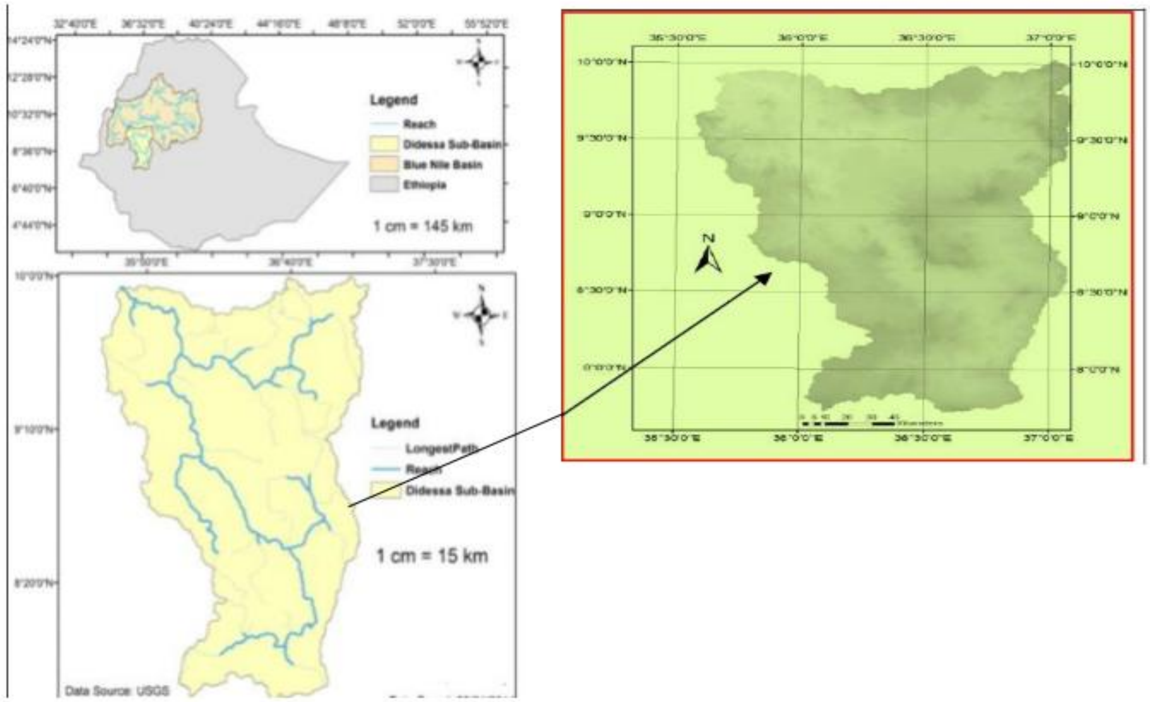


Figure 3: 1 Didessa Sub-basin Locations

Physio-graphically, Didessa sub basin can be categorized in to two broad units which are the high land plateau and the associated low lands. The high land plateaus mainly embrace the Jimma- Ilu Abba Bora high lands, the Guduru highlands of Horo Guduru Wellega while the associated low lands include the Didessa low lands. The study area under Didessa Sub basins Integrated Land Use Planning Project include Jimma, Ilu Abba Bora highlands, Horo Guduru Wellega highlands, and associated low lands of Didessa valleys s(source: oromia water work enterprise). From the assessment of land use/land cover, major land cover types identified include moderately cultivated, dense woodland, intensively cultivated land, wooded grassland, open woodland, natural forest cover, natural forest with coffee, coffee farm with shade trees, river forest, bamboo forest, plantation forest, settlement, shrub land and open grassland. Different land use types in different land cover have been identified in the sub basin. These include mixed cultivation, coffee production, livestock production, subsistence and commercial forest products utilization, non-timber products utilization, beekeeping, Wildlife management and utilization, infrastructure development, mining and investment activities on different activities.

Identification of these land use/ land cover types is important to indicate the conditions of the land potentials and constraints that could help integrated land use planning for the sustainable development of the communities living in and around the studied sub basins(SOURCE: OWWDSE).

3.1.2. Metrological data

According to Hurni (1986) classification, the Didessa river sub basin has five agro climatic zones. These are wet Dega, moist Dega, wet Weyna Dega, moist Weyna Dega and moist Kolla. It has got uni-modal rain fall distribution. The altitude range of the sub basin is 820 m a.s.l to 3200 m a.s.l. The mean annual precipitation of Didessa sub basin ranges from 1159.85 mm to 2113 mm. The average minimum and maximum temperature range of Didessa sub basin is 11.3 to 23.17co. The elevation range of Didessa sub basin is from 786 to 3202 m.a.s.l. (source; MWR)

3.1.3. Major land forms

The Arjo Didessa project area is made up of three main broad soil and landscape units based on the general physiographic character of the landforms. These are: Low land plains and plateau with some undulating to steep land forms including depressions and valley floors, Moderate to high relief hills, severely dissected side slopes and plateaux and high to mountainous relief hills and plains of seasonally wetland and waterlogged. The slope or gradient of the project area varies from 0 to >36%.

3.1.4 Geology

The upper part of Didessa sub basin is dominated by Jimma Volcanic and the central part with Wellega Basalt and the lower parts are dominated by undifferentiated lower complex, Wellega Basalt and Adigrat Sand Stone.

3.1.5 Rainfall

The annual rainfall distribution resulting from this cycle is shown most clearly in the two distinct rainy periods which are characteristic of the northern plains of the basin. The western part of the basin has mono-modal rainfall with the peak rainfall in July to August while the eastern part is dominated by bi-modal rainfall in autumn (short) and summer (long) rainfall peaks. The major peak located in the Didessa is in July to August and the minor peak is in October to December months. On the high plateau to the west of oromia, the rainfall distribution shows a continuous increase from the small rains to the summer peak rainfall. The distribution of rainfall over the highland areas is modified by orographic effects and is significantly related with altitude.

According to the following description, the annual and monthly rainfalls are characterized by high variability (Figure 3.2). Spatially, annual rainfall varies from 508.9mm to 1206.6mm in the highlands of west of Didessa, referring to upper part of the sub-basin (source ministry of water resource).

Figure 3: 2 sub catchment of didessa river sub basin

3.1.6 Temperature

The temperature varies considerably in the basin within altitude. The mean annual maximum temperature of the study area varies from 22.84^{O}C to 33.68^{O}C; while the mean minimum temperature varies from 6.54^{O}C to 17^{O}C. The mean annual temperature of the area estimated according to the data of the eight stations varies from 14.69^{O}C to 25.34^{O}C. This shows that a strong relationship between temperature and altitude as summarized in table at appendix 2 which shows mean temperatures in the growing season related to altitude.

3.2.1 Relative humidity

Relative humidity has been measured at different stations in or adjacent to the basin. There is relatively little variation over the basin with the mean annual relative humidity varying from in Jimma to at Arjo. Seasonal variation, expected would be higher in the lower rainfall areas.

3.2.2 Land Use and Soil Type

Land use is one of the main factors affecting surface flow, and evapo-transpiration in a watershed. The source of land use map of the study is the MERIS (Medium Resolution Imaging Spectrometer) based Glob-Cover 2009 land cover map is used after clipping it for my study area and modified to correspond with the WEAP predefined land uses classification. It contains a raster version of the Glob-Cover land cover map produced for the year 2009. The map is in geographic coordinate’s projection (WGS84 ellipsoid).

3.2.3 Soil Data

Different types of soil texture and physical-chemical properties are required for WEAP simulations. These data were obtained from various sources. The soil map obtained from Ministry of Water Resources of Ethiopian at Water Resources Information and Metadata Base Centre department. However, several properties like moisture bulk density, saturated hydraulic conductivity, percent clay content, percent silt content and percentage sand content of the soil which are required by WEAP model were not incorporated. As it is shown in (Fig. 2.5), the major soil types Humic Nitosols. Comparison of this generated soil database of the country with the previously available FAO soil database (MOWIE, 2013) shows that the soil database from the former has more detail classification than the FAO soil data base.

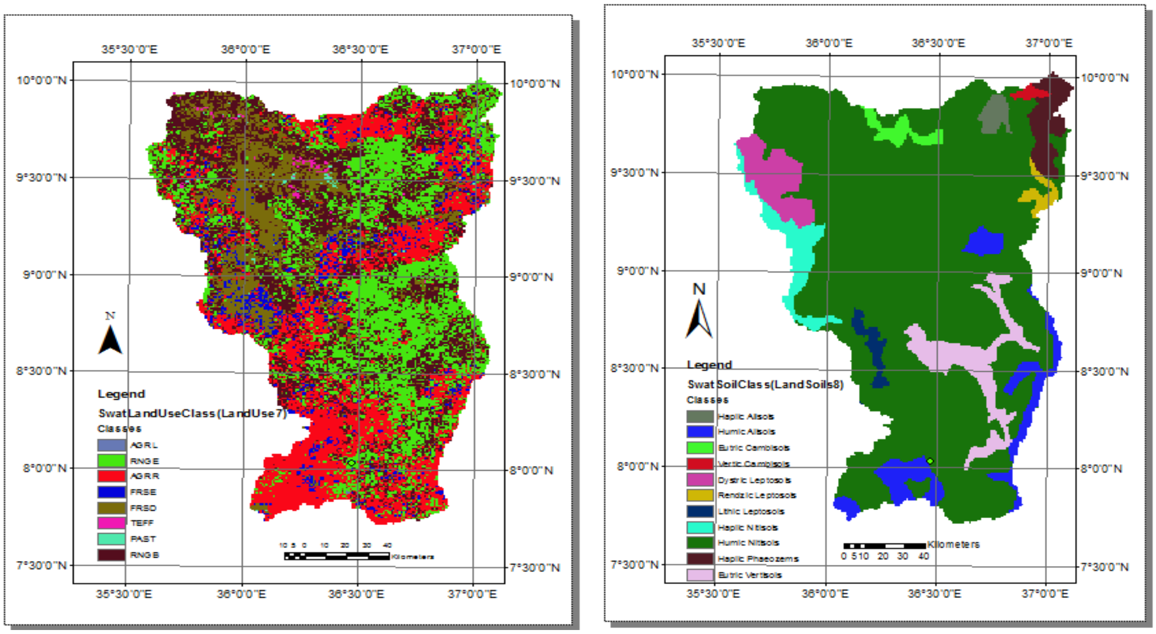


Figure 3: 3 Land Use Groups Used in the WEAP Model Source: Oromia Water Works Design and Supervision Enterprise (OWWDSE, 2014)

3.2.4. Percentage of Land cover type

Table 3: 1 Percentage of Land cover type

Land cover type	Arial coverage
Cultivated	45.6
wood land	34
Forest	10.7
Bamboo	3.7
grass land	2.8
state farm	2
perennial crop	0.6
Bush land	0.3
Urban	0.2

3.2.5 Kc (crop coefficient) Value

The crop coefficient, relative to the reference crop, is given here for each land class type. There is a special case involving Kc and double cropping. In cases where there are two different crops planted on the same land at different times of the year (double cropping), you can choose to model this with two separate branches on the demand tree, one for each crop. Double cropping could also be modeled with one branch, where the various crop and land use parameters would change over the year to reflect the two different crops. The important point to remember is that Kc should not be set to 0 unless you are double cropping. When Kc = 0, WEAP will ignore that land entirely, including no precipitation, evaporation or runoff. For fallow land, set Kc to a small but non-zero value, such as 0.05. I have taken the kc of the awash catchment assuming they have similar weather condition with Didessa catchment crops and it look like this:

Table 3: 2 kc value of the different land of use (source: ambo irrigation office)

Kc value	jan	feb	Mar	Apr	May	Jun	Jul	aug	sep	Oct	nov	Dec
Shrubs	0.65	0.66	0.77	0.77	0.78	0.78	0.78	0.78	0.78	0.78	0.77	0.7
Grassland	0.69	0.81	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.89	0.66	0.66
Rain fed	0	0	0	0	0.35	0.65	1	1.06	1.04	0.52	0	0
Irrigated	0.65	0.65	0.66	0.66	0.77	0.77	0.77	0.78	0.75	0.66	0.66	0.65

3.2.6. Catchment Runoff to Rivers

Catchment Runoff can be directed to a river by dragging the Catchment Runoff symbol from the legend in the Schematic view to anywhere along the river. If the Catchment Runoff is to be Head flow to the river, the symbol can be placed anywhere above the first node of the river, and the dialog box that appears will ask you if the Catchment Runoff is to represent Head flow (See River Head flow for additional details). Note that if you select a Catchment as a head flow source for a river, then under the Head flow variable tab for that river, it will be set/locked to "Inflow from Catchment". Catchments must contribute runoff to one and only river node, and optionally to one groundwater node.

3.3 Methodology

The method used in this thesis fulfillment include, the study of literature review, field level investigation of the study area (physical Features and Topography, Drainage, Climate and Rainfall, Geological Settings ,Seepage, Land Resources, Socio Economic Features(Population and Economic Activities)) and applying different methods and techniques to estimate the runoff in to the reservoir. The reservoir operation will be performed applying simulation techniques. Literature reviews are embodied in each and respective topics and sections for convenience of referencing purposes. Finally the reservoir

3.3.1 Watershed delineation

Prior to data collection the boundary of the study area was delineated. The Digital Elevation Model (DEM) following drainage boundaries of Didessa basin coverage was shown blow.

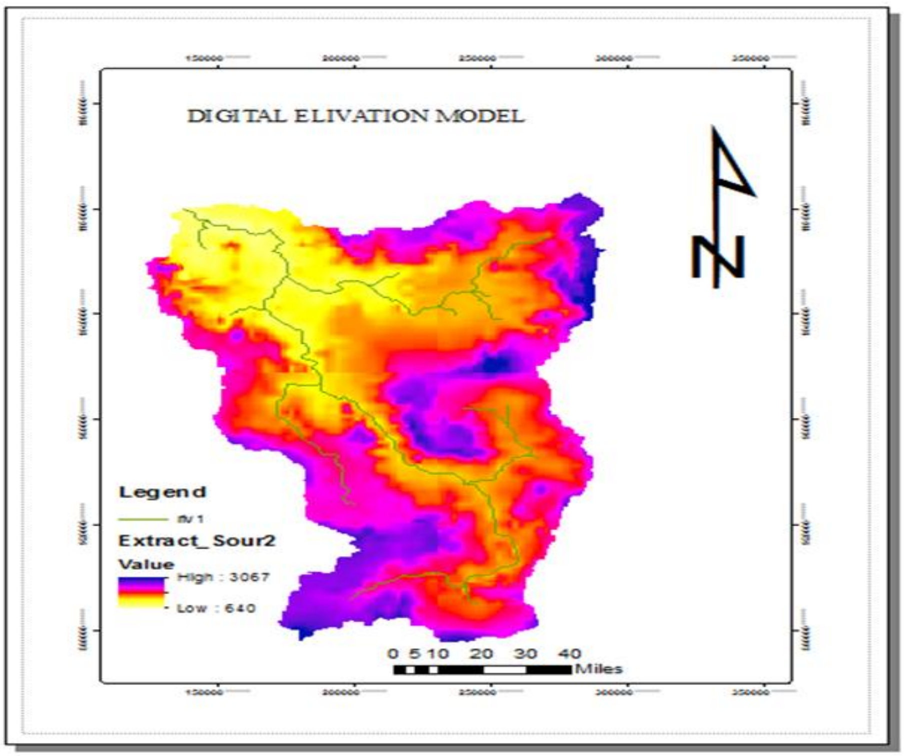


Figure 3: 4 the Digital *Elevation* Model (DEM)

3.3.2 Material 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 and Microsoft EXCEL to analyze WEAP outputs.

3.3.3 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 source of data required for the study.

3.4 Data Analysis

Before starting hydrological and Metrological data analysis; it is important to check whether the data are homogeneous, correct, sufficient and complete with no missing data, it is because erroneous data resulting from lack of appropriate recording, shifting of station location and processing are serious as they lead to inconsistency and ambiguous results that may contradict to the actual situation

3.4.1 Metrological data collection

The meteorological data will be collected from National Meteorological Agency (NMA). The Availability and quality of meteorological data such as rainfall, temperature, Sunshine hours, wind speed, and relative humidity are vital for any water resource study. & these data will pass through some tests such as:-

- Test for consistency of record
- The stream flow data which is taken from Ministry of water resource is checked and there is no outlier.
- Filling missing stream flow data

3.4.2 Hydrological data analysis

Due to human and intrinsic errors in data readings and complex relationship of hydrological Processes that cannot be expressed explicitly, exact prediction of hydrological variables are Impossible. As a result of this disadvantage, it is crucial that statistical analysis is conducted to missed data Allow a better understanding of the statistical trends and relationships existing within the data, That results in better model development. So we will take some measurements & calculation.

3.4.2.1 Filling of missing stream flow data

Measured flow data are vital to many problems in hydrologic analysis and design. Since there are costs related to data collection, it is imperative to have complete records at every station.

However the actual condition in most of the data records this is not satisfied for different reasons. For gauges that require periodic observation, the failure of the observer to make the necessary visit to the gauge may result in missing data. Vandalism of recording is another problem that results in incomplete data records, and instrument failure because of mechanical or electrical malfunctioning can result in missing data. Any such causes of instrument failure reduce the length and information content of the flow on record (Arnold, J. G, Moriasi, D. N, Gassman, P. W, Abbaspour, K. C, White, M. J, Srinivasan, R, et al., 2012). In order to make use of partially recorded data, missing values need to be filled in sequence. To fill the missing recorded stream flow gauging data various methods are available. The most common methods are the simple Arithmetic Mean Method and Normal-Ratio Method and these methods are used for filling of missing data in this study.

3.4.2.2 Filling missing flow data by Arithmetic mean method

The arithmetic mean of the flows values observed at the stations in a drainage basin is the simplest objective estimate of the average flow of river for a basin. This method is suitable for basins with a large number of flow gauging stations that are spaced uniformly or otherwise adequately sample the flows over the basin. Its adequacy may be tested by comparison with more sophisticated methods in given situations.

3.4.2.3 Filling the missed flow by Normal Ratio Method

The normal ratio method is preferred to be used where the mean annual precipitation of any of the adjacent stations exceed the station in question by more than 10%. Material Used The materials used for this project will be Arc view GIS tool to obtain hydrological and physical parameters and spatial information, Global Mapper to manipulate the DEM data in line with the shape files of the river basin, WEAP model for basin simulation and Microsoft EXCEL to do some manipulation.

3.4.2.4 Homogeneity Tests for rainfall Time series in XLSTAT

Use this tool to determine using one of four proposed tests (Pettit, Bush and, SNHT, or von Neumann), if we may consider a series is homogeneous over time, or if there is a time at which a change occurs. Homogeneity tests involve a large number of tests for which the null hypothesis is that a time series is homogenous between two given times. The variety of the tests comes from the fact that there are many possible alternative hypotheses: change in distribution, changes in average (one or more times) or presence of trend.

The tests presented in this tool correspond to the alternative hypothesis of a single shift. For all tests, XLSTAT provides p-values using Monte Carlo resampling. Exact calculations are either impossible or too costly in computing time.

3.5. Development of Rainfall- Runoff Model for Didessa sub basin

Fundamental to rainfall-runoff simulation is the determination of the amount of effective rainfall or the volume of direct runoff that a given rainfall event will produce on each portion of the watershed. Determination of this quantity is most difficult and is a major cause of error. Methods for obtaining this quantity are, for example, the SCS curve-number method. The SCS method is developed by the Soil Conservation Service (Wagner, 2006) for estimating direct runoff from storm rainfall on small un gaged watersheds. Because of its simplicity and relative accuracy, it is one of the most frequently utilized methods for runoff estimation. It employs rainfall and watershed data that are ordinarily available or easily obtainable. The model can be applied to large watersheds with multiple land uses. For instance (LaSeur, 1976)developed a model, using the SCS curve-number technique and the soil-moisture accounting procedure, for prediction of runoff from agricultural watersheds of areas up to 3400 Km2 (Singh, 1989). From the above discussions it is clear that the SCS method is quite applicable in Ethiopian condition where most of the watersheds (or part of the watersheds) is not gauged and the hydro meteorological data are generally scarce. Consequently, in this research, this method is used as a major tool to develop the rainfall-runoff model for Didessa sub Basin. The rainfall-runoff model for Didessa sub basin is made up of two modules each module representing the most important hydrological processes. Both modules are written in the *Micro soft-Excel* spread sheet and they are quite convenient and simple to use. The modules must be run successively as the output of the first module is the input for the second module. The first module is used to calculate the excess rainfall amount or runoff from a number of observed point rainfall readings spread over the sub catchments. One of the most important parameters which are needed to run these modules is classification of the Antecedent Moisture Condition (AMC) and the Curve Number (CN). These parameters are already determined for all sub catchments and put in the Excel spread sheet. The second module contains the unit hydrograph ordinates of the Sub catchments with its convolution programs. It also contains the 'normal' or the routed unit hydro graph ordinates of a sub catchment where necessary. The input data to this module are the excess rainfall Determined in first module.

3.5.1 Estimation of Areal rainfall using Thiess polygon method

Determination of the average amount of rain that falls a watershed during a given storm is fundamental requirement for many hydrologic studies. Many factors affect spatial variation of rain falling on the ground and generating runoff. Rain gage networks are designed to sample this distribution optimally. A method of estimating mean areal rainfall must be able to represent this distribution. Although there are several methods to estimate areal rainfall no method accurately represents this distribution. Singh and Chow dhury (1986) studied the various methods for calculating areal average precipitation, including the ones described here, and concluded that all the methods give comparable results, especially when the time period is long (Chow, 1988). A number of techniques for estimating mean Areal rainfall have been developed. Some of these techniques are simple, well-tried and as old as modem hydrology. (Singh,1989). The arithmetic-mean method is the simplest method for determining areal average rainfall. It involves averaging the rainfall depths record at a number of gages. This method is satisfactory if the individual gauges are uniformly distributed over the area and the individual gauge measurements do not vary greatly about the mean. The other methods include Isohytal, Thiessen and Reciprocal-distance-squared method (Chow, 1988). In this research, Thiessen polygon method is used for the purpose of estimating the areal rainfall on each sub-catchment. In this method polygons are constructed so that surrounding each gauge is a polygon representing the area for which the point rainfall data is taken to be representative. Each polygon side is constructed along the perpendicular bisector of lines joining each pair of adjacent gauges. The area weighting coefficients are then calculated as area of each polygon divided by total area of the catchment for which the areal rainfall is to be found. Each rainfall station, therefore, will have its own weighting coefficient. Obviously the sum of all weighting coefficients in each sub catchment should be unity. Once the observed point rainfall amounts for each station are known the weighting coefficients can be used to estimate the areal rainfall on each sub-catchment.

3.5.3 Excess rainfall determination by SCS method

The SCS method of estimating direct runoff (excess rainfall) from total rainfall is based on methods developed by the SCS hydrologists. The principal application of the method is in estimating quantities of excess rainfall in flood hydro graphs or in relation to flood peak rates. The hydrologic principles of the method are not new, but they are put to new uses. Because most SCS work is with ungagged watersheds the method was made usable with rainfall and watershed data that are ordinarily available or easily obtainable for such watersheds. In flood hydrology it is customary to deal separately with base flow and to combine all other types in to direct runoff, which consists of surface runoff, subsurface runoff and channel runoff in unknown proportions. The SCS method estimates direct runoff, but the proportions of surface runoff and subsurface flow are ignored, that can be better appraised by means of the runoff curve number(CN), which is another indicator of the probability of flow types: the larger the CN the more likely that the estimate is of surface runoff. The most generally available rainfall data in most part of the world are the amounts measured at non-recording rain gages, and it was for the use of such data or their equivalent the rainfall-runoff relation was developed. The data are totals for one or more storms occurring in a calendar day, and nothing is known about the time distributions. The relation therefore excludes time as an explicit variable; this means that rainfall intensity is ignored. If everything but storm duration or intensity is the same for two storms, the estimate of the runoff is the same for both storms. The SCS method can, therefore, be useful for Ethiopian watersheds in general where there is scarcity of hydro meteorological data.

3.6. 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 identification of the most important model parameters and changing the parameter set. Model parameters changed during calibration were classified into physical and process parameters. Physical parameters represent physically measurable properties of the watershed; while the process parameters are those not directly measurable. Model calibration can be manual, automatic and a combination of the two methods (Tigist, 2009). Manual calibration use trial and error techniques in parameter adjustment through a number of simulation runs. It is subjective to the modeler’s assessment and can be time consuming. Computer based automatic calibration involves the use of a numerical algorithm which finds the extreme of a given numerical objective function. Model performance is assessed statistically by comparing the model output and observed flow values. The statistical measures commonly used are the coefficient of determination (R2), Nash-Sutcliffe Efficiency (NSE) and the Root Mean Square Error (RMSE) (Tigist, 2009).

3.7 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.

3.8 Catchment Simulation Methods

There was a choice among five methods to simulate catchment processes such as evapo-transpiration, runoff, infiltration and irrigation demands. These methods include (1) the Rainfall Runoff (simplified coefficient method), (2) Irrigation Demands Only (Simplified Coefficient Approach), (3) the Soil Moisture Method, (4) the MABIA Method, and (5) the Plant Growth Method (PGM). The choice of method should depend on the level of complexity desired for representing the catchment processes and data availability. The Soil Moisture Method was used for this work because of its more complexes representing the catchment with two soil layers, as well as the potential for snow accumulation and in addition the method allows for the characterization of land use and soil type impacts to these processes. In the upper soil layer, it simulates evapo-transpiration, considering rainfall and irrigation on agricultural and non-agricultural land, runoff and shallow interflow (SEI, 2015). Base flow routing to the river and soil moisture changes are simulated in the lower soil layer (Figure 3.5). 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,

$$Rd_j \frac{dz_{1,j}}{dt} = P_e(t) - PET(t)k_{c,j}(t)\left(\frac{5z_{1,j} - 2z_{1,j}^2}{3}\right) - P_e(t)z_{1,j}^{RRF_j} - f_j k_{s,j} z_{1,j}^2 - (1 - f_j)k_{s,j} z_{1,j}^2$$

Here z1,j = [1,0] is the relative storage given as a fraction of the total effective storage of the root zone, Rdj (mm) for land cover fraction, j. Pe is the effective precipitation. PET is the Penman- Montieth reference crop potential evapo transpiration where kc,j is the crop/plant coefficient for each fractional land cover. The third term (Pe (t) z1,j RRFj) represents surface runoff, where RRFj 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,

$$RT(t) = \sum_{j=1}^{N} Aj\left(Pe(t) Z_{1.j}^{\;RRFj} + FjKs.jZ_{1.j}^{\;2}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Base low emanating from the second bucket is computed as:

$$S_{\max} = \frac{dz}{dt} = \left(\sum_{j=1}^{N} (1 - fj) k_{s.j} z_{1.j^2}\right) - k_2 z^2{}_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

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

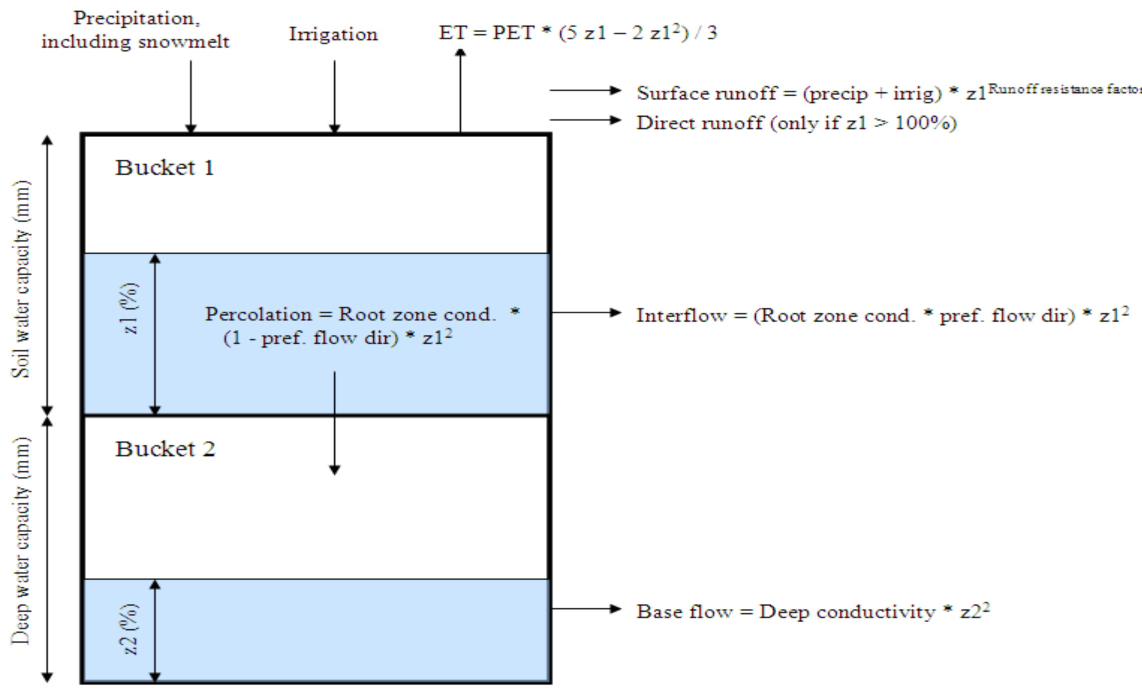


Figure 3: 5 Concepts of soil moisture and equations (source: WEAP User Manual)

3.8.1 Root Zone Water Capacity

Root zone water capacity is one of the parameter used in water evaluation and allocation planning system to calibrate the simulated rainfall runoff and observed stream flow. The effective water holding capacity of the top layer of soil, represented in mm which ranges is greater or equal to zero.

3.8.2 Deep Water Capacity

Effective water holding capacity of lower is deep soil layer (bottom "bucket"), represented in mm. This is given as a single value for the catchment and does not vary by land class type. This is ignored if the demand site has a return flow link to a groundwater node.

3.8.3 Deep Conductivity

Conductivity rate (length/time) of the deep layer (bottom "bucket") at full saturation (when relative storage z2 = 1.0), which controls transmission of base flow. This is given as a single value for the catchment and does not vary by land class type. Base flow will increase as this parameter increases. This is ignored if the demand site has a return flow link to a groundwater node.

3.8.4 Runoff Resistance Factor

Runoff Resistance Factor used to control surface runoff response. Related to factors such as, leaf area index and land slope runoff will tend to decrease with higher values (range 0.1 to 10). This parameter can vary among the land class types.

3.8.5 Root Zone Conductivity

Root zone (top "bucket") conductivity rate at full saturation (when relative storage z1 = 1.0), which will be partitioned, according to Preferred Flow Direction, between interflow and flow to the lower soil layer. This rate can vary among the land class types.

3.8.6 Preferred Flow Direction

Preferred flow direction 1.0 = 100% horizontal, 0 = 100% vertical flow. Preferred Flow Direction used to partition the flow out of the root zone layer (top "bucket") between interflow and flow to the lower soil layer (bottom "bucket") or groundwater. This value can vary among the land class types.

The general parameters for in weap tool analysis are listed as bellow.

Table 3: 3 Calibration paramètres in possible range (source :WEAP guide book)

Instance	variable p(parameter)	Range	Unit
	Soil Water capacity	> = 0	mm
	Deep Water Capacity	> = 0	mm
	Runoff Resistance Factor	>= 1000	mm
CATCHMENT	conductivity	20	mm/month
	Deep conductivity	> = 0.1	mm/month
	Preferred flow direction		
	InitialZ1	> = 1	%
	InitialZ2	0 - 100	%

3.9. Reservoir storage zone calculation

In general, the main purpose of the reservoir is to provide a source of water for demand sites during dry periods. WEAP model can simulate a reservoir; by taking in account the reservoir's operating rules, downstream requirement priorities, net evaporation on the reservoir, and hydropower generation. The operation of a reservoir is decided according to pre-defined operating rules. Such operation rules are approximation of reality and divide the reservoirs into water level-related Zones. Generally Reservoir storage is divided into four zones or pools. These include, from top to bottom, the flood-control zone, conservation zone, buffer zone and inactive zone. The conservation and buffer pools together constitute the reservoir's active storage. WEAP ensure that the flood-control zone is always kept vacant, i.e., the volume of water in the reservoir cannot exceed the top of the conservation pool. Fig 3.6 shows zoning of reservoir storage:

1) Flood-control zone (Sf) that can hold water temporarily thereafter release storage to reduce potential downstream flood damage,

2) Conservation zone (Sc) which is available storage zone for downstream demands
Including water supplies, irrigation and navigation, etc.,

3) Buffer zone (Sb) that can be used to control and regulate water demands during dry periods and

4) Inactive zone (Si) which is dead storage mainly required for sediment collection. WEAP allows the reservoir to freely release water from the conservation pool to fully meet the downstream demand requirements. Once the storage level drops into the buffer pool, the release will be restricted according to the buffer coefficient, to conserve the reservoir's decreasing supplies. Water in the inactive pool is not available for allocation although under extreme conditions evaporation may draw the reservoir into the inactive pool.

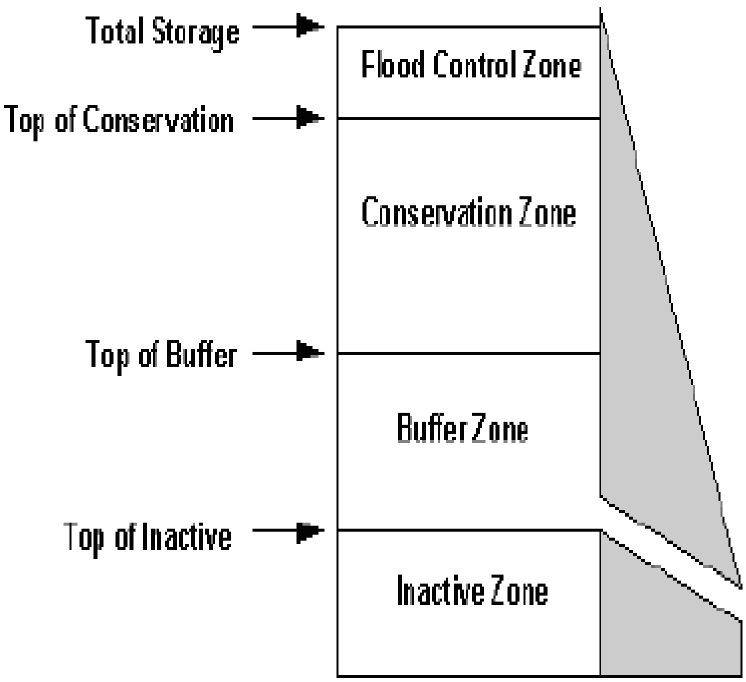


Figure 3: 6 Reservoir storage zones (source: (Azman, Impact of Climate Change on Water Resources Availability in the Komati River Basin Using WEAP21 Model., 2007))

The amount available to be released from the reservoir is the full amount in the conservation and flood control zones and a fraction of the amount in the buffer zone (the buffer coefficient fraction). Each of these zones is given in terms of volume. The water in the inactive zone is not available for release.

St = Sf + Sc + (bc * Sb) ………………………………………………………………………...3.3

Where St is total available water that can be released from the reservoir, Sf is storage of flood control, Sc is storage of conservation, bc is the buffer coefficient and Sb storage of buffer.

All of the water in the flood control and conservation zones is available for release, and equals the amount above Top of Buffer (ToB), *Flood Control and Conservation Zone Storage Res = Storage for Operation Res – Top of Buffer Res* Or zero if the level is below Top of Buffer. *Flood Control and Conservation Zone Storage Res = 0* Buffer zone storage equals the total volume of the buffer zone if the level is above Top of Buffer, *Buffer Zone Storage Res = Top of Buffer Zone Res – Top of Inactive Zone Res* Or the amount above Top of Inactive if the level is below Top of

Buffer, *Buffer Zone Storage Res = Storage for Operation Res – Top of Inactive Zone Res* Or zero if the level is below Top of Inactive. *Buffer Zone Storage Res = 0*

WEAP uses the Buffer Coefficient to slow releases when the storage level falls into the buffer zone. When this occurs, the monthly release cannot exceed the volume of water in the buffer zone multiplied by this coefficient. In other words, the buffer coefficient is the fraction of the water in the buffer zone available each month for release. Thus, a coefficient close to 1.0 will cause demands to be met more fully while rapidly emptying the buffer zone, while a coefficient close to 0 will leave demands unmet while preserving the storage in the buffer zone. Essentially, the top of buffer should represent the volume at which releases are to be cut back, and the buffer coefficient determines the amount of the cut back.

Note: The buffer coefficient determines how much of the water that is in the buffer zone at the beginning of a time step is available for release. However, this doesn't restrict WEAP from releasing some or all of water that flows into the reservoir during the time step. Even if the buffer coefficient is 0, WEAP can still release any water that flows into the reservoir in that time step if needed to meet downstream demands in this case, the storage level will not decrease, but it may not increase either.

3.9.1Water demand calculation

The calculation process, as described in the WEAP User Guide, is based on mass balance of water for every node and link is subject to demand priorities, supply preferences. Calculation starts from the first month of the Current Account year to the last month of the last scenario. For non-storage nodes, such as points on a river, the currently month’s calculation is independent from the previous month’s calculation. For storage nodes, such as reservoirs, soil moisture, or aquifer storage, the storage for the current month depends upon the previous month’s value. Whatever water enters the system during a month, it will either be stored in a reservoir, aquifer, or catchment soils, or leave the system by demand site consumption or evapotranspiration.

The identified sites were included in the model as individual demands rather than group demand in configuration on the schematics, however it might lower the flexibility in modeling how each irrigation site may make demands on the surface water network according to its particular cropping pattern.

Using the demand priorities and supply preferences, WEAP determines the allocation order to follow when allocating water demand. Demand sites with higher priorities are processed first by the WEAP Allocation Algorithm. These priorities are useful in representing a system of water rights and also important during a water shortage (SEI, 2005). Supply Preferences indicate the preferred supply source where there is more than one source to a demand site. The allocation order represents the actual calculation order used by WEAP for allocating water. Table 3.2 shows how the priority was assigned to each compartments of demand category.

Table 3: 4 Assigned priority levels for the upper Arjo Didessa reservoir

Demand type	Priority level
Domestic use	1
Livestock use	2
Local irrigational use	4
Governmental irrigational use	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:

*Annual Demand Total activity level *Water Use Rate*……………………………………………………3.4

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:

Total Activity Level * Activity *Level* ……………………………………………………………..3.5

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:

3.10 SCENARIO DEFINITION AND IMPLEMENTATION

Scenarios are used to compare various "what if" cases and provide a structured method of thinking about possible future water resource development and management options, opportunities and risks, and how these might interact. The results are useful for consensus building and decision making. Within the context of this research, a scenario is defined as "a contemplated state of the Eastern Nile Basin induced either through targeted human intervention (e.g. combinations of development and management interventions) or through externalities (e.g. climate change, economic policies etc.)".

3.10.1 Priorities for Water Allocation

Three user-defined priority systems are used to determine allocations from supplies to demand sites and catchments (for irrigation), for in stream flow requirements, livestock, domestic use and for filling reservoirs and generating for downstream schematic irrigation use

Competing demand sites and catchments, reservoir filling and schematic irrigation, and flow requirements are allocated water according to their demand priorities. The demand priority is attached to the demand site, catchment, reservoir (priority for filling or hydropower), or flow requirement, and can be changed by right clicking on it and selecting General Info. Priorities can range from 1 to 99, with 1 being the highest priority and 99 the lowest. Reservoir filling priorities default to 99, meaning that they will fill only if water remains after satisfying all other higher priority demands. Many demand sites can share the same priority. These priorities are useful in representing a system of water rights, and are also important during a water shortage, in which case higher priorities are satisfied as fully as possible before lower priorities are considered. If priorities are the same, shortages will be equally shared. If a demand site or catchment is connected to more than one supply source, you may rank its choices for supply with supply preferences. The supply preferences are attached to transmission links, and can be changed by right clicking on a link in the Schematic View and selecting General Info, or Edit Data, Supply Preference. If a demand site has no preference, set Supply Preference to 1 on its entire transmission links. You may change the preferences over time or from one scenario to another. For example, a demand site might prefer to pump groundwater in the winter and withdraw water from the river in the summer. In this case, you would use the Monthly Time-Series Wizard to separately specify the preferences for these two transmission links (from groundwater and from the river) in each month.

Using the demand priorities and supply preferences, WEAP determines the allocation order to follow when allocating the water. The allocation order represents the actual calculation order used by WEAP for allocating water. All transmission links and in stream flow requirements with the same allocation order are handled at the same time. For example, flows through transmission links with allocation order 1 are computed, while temporarily holding the flows in other transmission links (with higher allocation order numbers) at zero flow. Then, after order 1 flows have been determined, compute flows in links with allocation order 2, while temporarily setting to zero flows in links ordered 3 and higher.

In general, if a source is connected to many demand sites with the different demand priority, WEAP attempts to allocate these flows regarding of the supply preferences on the links. For example, demand site DS1 is connected to a river as first preference while demand site DS2, DS3 and ds4 is also connected to the river as the order of their performance. In this way, domestic water users have a high chance to receive water from the river in the case of a water shortage. Note: In those cases, a supply preference of is used for all demand sites.

You may switch among viewing demand priorities, supply preferences or allocation orders on the schematic: from the Main Menu, select Schematic, Change Priority View. If WEAP is not allocating water as you would expect, change the priority view on the Schematic to "Allocation Order" to make sure that it is allocating in the order you intend.

4. DATA PROCESSING AND WEAP MODEL SETUP

4.1 Data Analysis

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

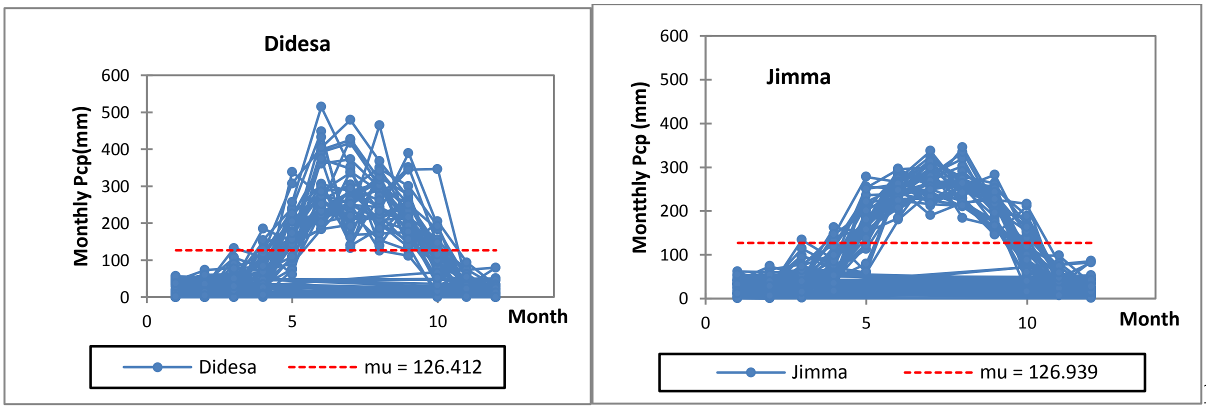
4.1.1Homogeneity test

Alexanderson's SNHT test for Homogeneity is applied for testing of monthly rainfall. The SNHT test (Standard Normal Homogeneity Test) was developed by (Hamed, 2008) to detect a change in a series of rainfall data. The test is applied to a series of ratios that compare the observations of a measuring station with the average of several stations. The ratios are then standardized. Monthly Sum of rainfall is used to analyses presence homogeneity and the results are evaluated in XLSTAT software. We followed the same procedure as trend test and found that data are homogeneous (see table below) for the rainfall data presented in **appendix part**.

Table 4: 1 Alexandersson's SNHT Homogeneity test for selected stations of didessa cachement.

	Kendall's tau(τ_o)	p-value (Two-tailed)	alpha
JIMMA	7.698	0.146	0.05
BEDELE	2.5	0.93	0.05
NEKEMTE	4.8	0.5	0.05
DIDESA	3.6	0.72	0.05
GIMBI	3.3	0.8	0.05
NEJO	2.81	0.89	0.05
ARJO	2.2	0.96	0.05
SHAMBU	4.1	0.63	0.05

Monthly Sum of rainfall is used to analyses presence homogeneity and the results are accepted as evaluated in XLSTAT software and the data are homogeneous. p-values are greater than alpha (0.05), hence data of all stations are consistent



1

Figure 4: 1 Homogeneity test for selected stations of didessa cachements.

4.1.2 Consistency test

Sometimes a significant change may occur in and around a particular rain gauge stations. Such change occurring in a particular year will start affecting the rain gauge data, being reported from a particular station. In order to detect such inconsistency and to correct and adjust the reported rainfall values, a technique called double mass curve method is generally adopted. In this method a group of 5 to 10 neighboring stations are chosen in the vicinity of doubtful station. The mean daily rainfall values are serially arranged in reverse chronological order To determine relative consistency, one compares the observations from a certain station with the mean of observations from several nearby stations. This mean is called the 'base' or 'pattern'. It is difficult to say how many stations the pattern should comprise. The more the stations is the smaller the chance that inconsistent data from a particular one will influence the validity of the average of the pattern. In conventional double-mass analysis, this checking requires removing from the pattern the data from a certain station and comparing them with the remaining data. If these data are consistent with the general totals in the area, they are re-incorporated into the pattern. Data of each station are arranged in descending order. The cumulative sums, station to be tasted and base station; are plotted against each other and a line (or lines) of best fit are drawn in excel work sheet. According to the double mass curve test, all the stations were consistent. For illustration the double mass curve test for some selected stations are presented below.

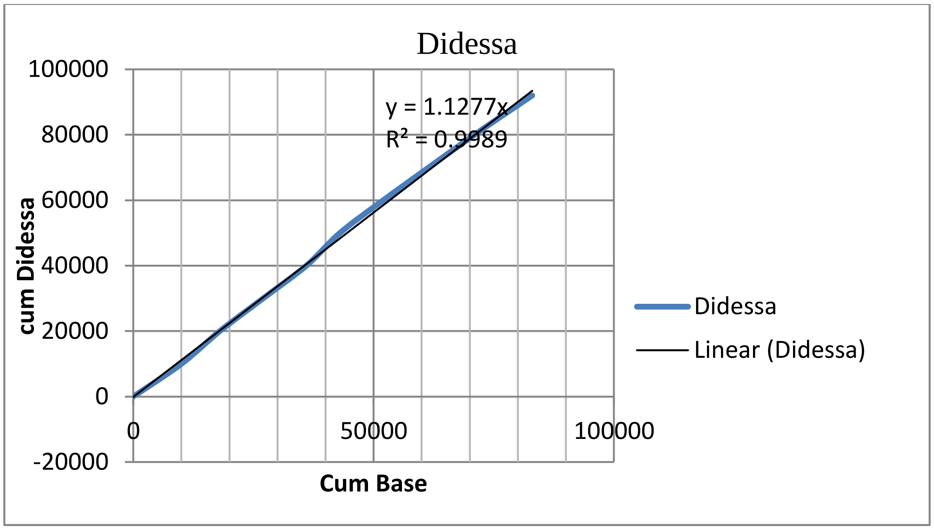


Figure 4:2 the double mass curve test for Didessa

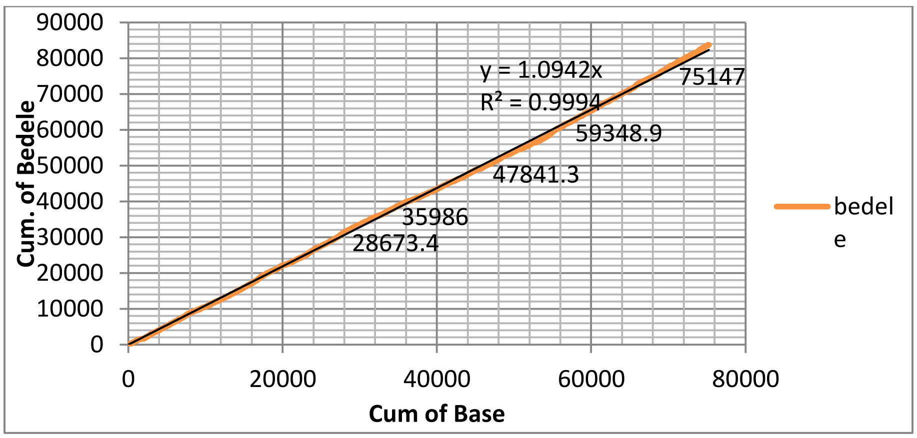


Figure 4:3 the double mass curve test for beddelle

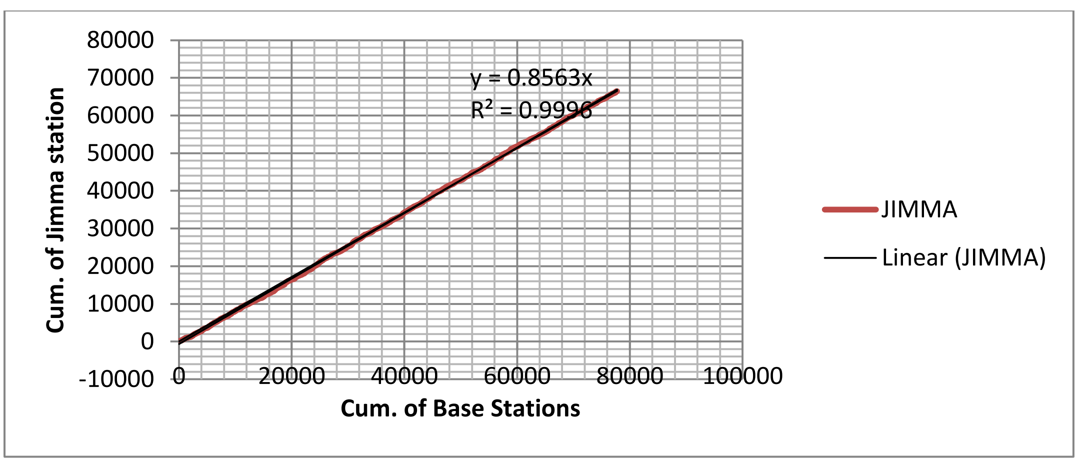


Figure 4:4 the double mass curve test for Jimma

4.1.3 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, so as 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. List of Selected weather monitoring Stations and Available data sets for rainfall and climatic variables are available as below table.

Table 4: 2 List of Selected weather monitoring Stations and Available data sets

StationName	Zone	Station Elevation	Latitude	Longitude	Data coverage	% of missing Rainfall	% of missing Temp.(^oC)
			Decimal Deg.	Decimal Deg.			
Bedele	Illubabor	2011	8.5	36.3	1980-2015	17	24.9
Arjo	Misrak Wellega	2565	8.8	36.5	1989-2015	27	33.1
Shambu	Misrak Wellega	2460	9.6	37.1	1980-2015	14	41.0
Nekemte	Misrak Wellega	2080	9.1	36.5	1980-2014	7	11.5
Gimbi	Mirab Wellega	1970	9.2	35.8	1980-2015	18	41.4
Nedjo	Mirab Wellega	1800	9.5	35.5	1980-2015	20	21.8
Jimma	Jimma	1718	7.7	36.8	1980-2015	5	4.6
Agaro	Jimma	1666	7.9	36.6	1995-2014	55	20
Dedessa	Misrak Wellega	1310	9.4	36.1	1980-2015	18	38.1

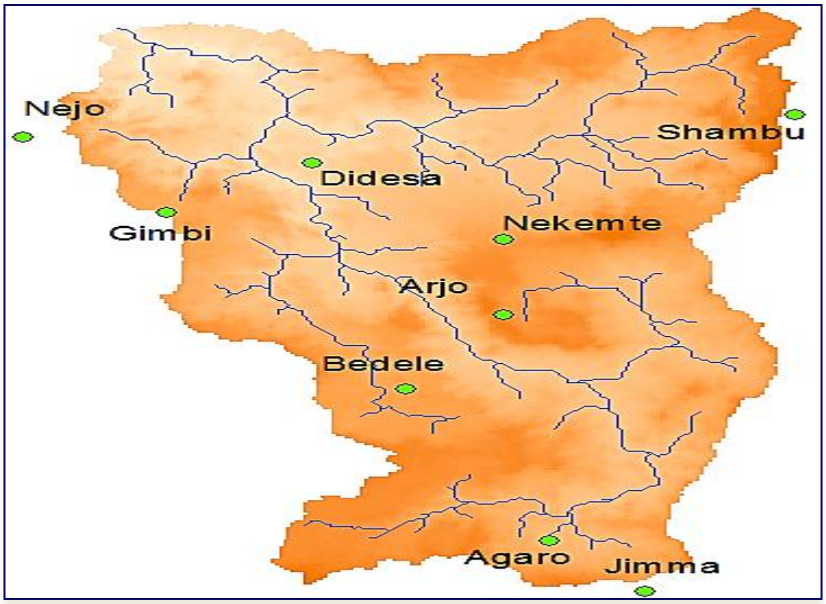


Figure 4:5 Map of weather gauging location.

Mean monthly rainfall profile illustrates local seasonal rainfall variation as well as spatial differences within the basin. Relevant Statistics of the selected key stations base series rainfall values within this region are given in table 4.2. The corresponding profiles are graphically illustrated in figure 4.6 and 4.7monthly profile indicates the occurrence and relative strength of the dry, wet and intermediate season of monthly rainfall in the different location of the catchments area. The rainfall patterns of the study area reflect the Bi-Modal regime with wetland dry seasons.

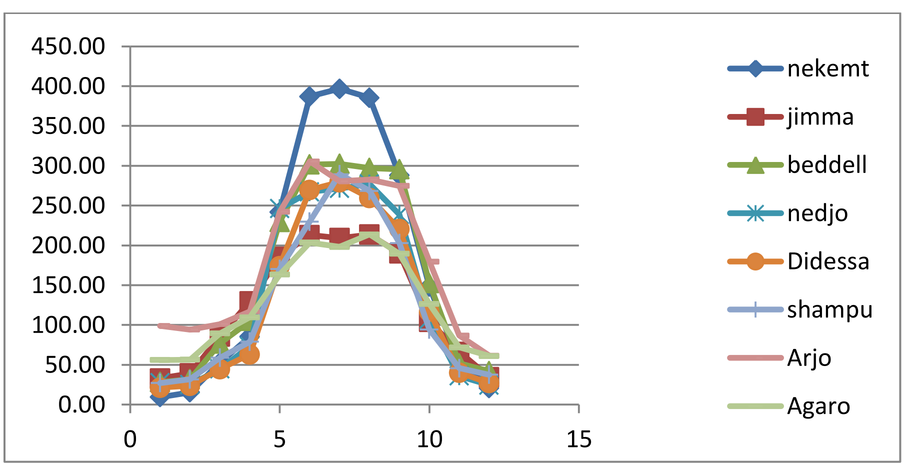


Figure 4: 6 Comparaison of Seasenal Rainfall Variation in the major sub-station Area

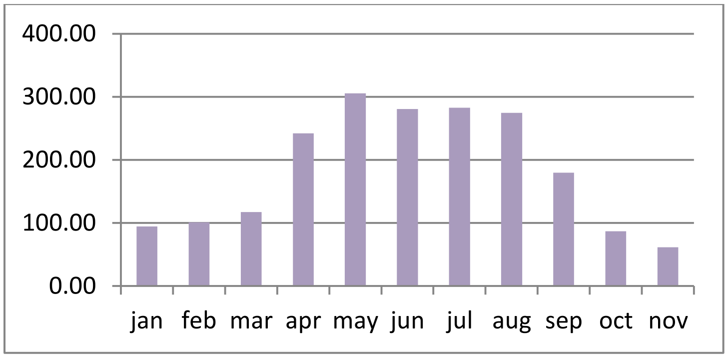


Figure 4:7 Seasonal Rainfall Variations for the Study Area

4.1.4 Stream flow data trend analysis

The following figure indicates that mainly two major things on stream flow data due to land use and land cover change on the upper Didessa sub basin. The above all seen seasonal rainfall Variation feature on the major stream flow gauging were an overestimated and under estimated stream flow data. The major causes of this estimation are seen as below. First let's see the overestimated one like the 2004 flooding accuracy indicators problem the other was due to rainy season in July and August months. The second was the under estimation. This is due to land use and land cover change which result in more percolation if conservation structures were developed and the data measuring problems at the gauging stations.

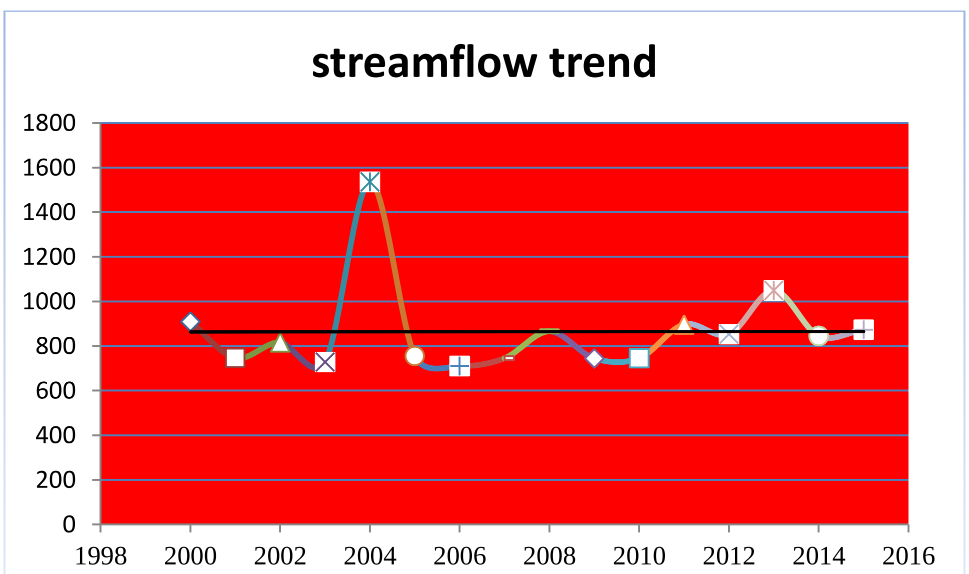


Figure 4:8 Annual Stream Flow data trend indicator of Didessa River (CM)

4.2. 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 result view allows 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 label assigned for each demand site a priority level ranging from 1 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.

4.2.1 Configuration of WEAP model

In the schematic part of WEAP the boundary of watershed delineated, rivers, demand sites and reservoirs are specified. GIS maps of rivers and reservoir 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. The Arjo Didessa reservoir is schematized in this approach. The total inflows to Arjo Didessa reservoir which dembi river enter as head water. In addition to these the inflows from un gauged catchments to the reservoir is also configured as a river system with head water flow.

Demand areas from the surface water in the study area were integrated into four groups for setting up of the WEAP model. The demand sites which included in the schematics are:

- ➢ Arjo Didessa irrigation which abstract water from Didessa River as the water source.
- ➢ Informal irrigation use which abstract water from Didessa River as the water sourcce

- Livestock use which abstract water from Didessa River as the water source.
- Domestic use which abstract water from Didessa River as the water source.

The schematic of the WEAP model of the study area for the existing condition was shown below.

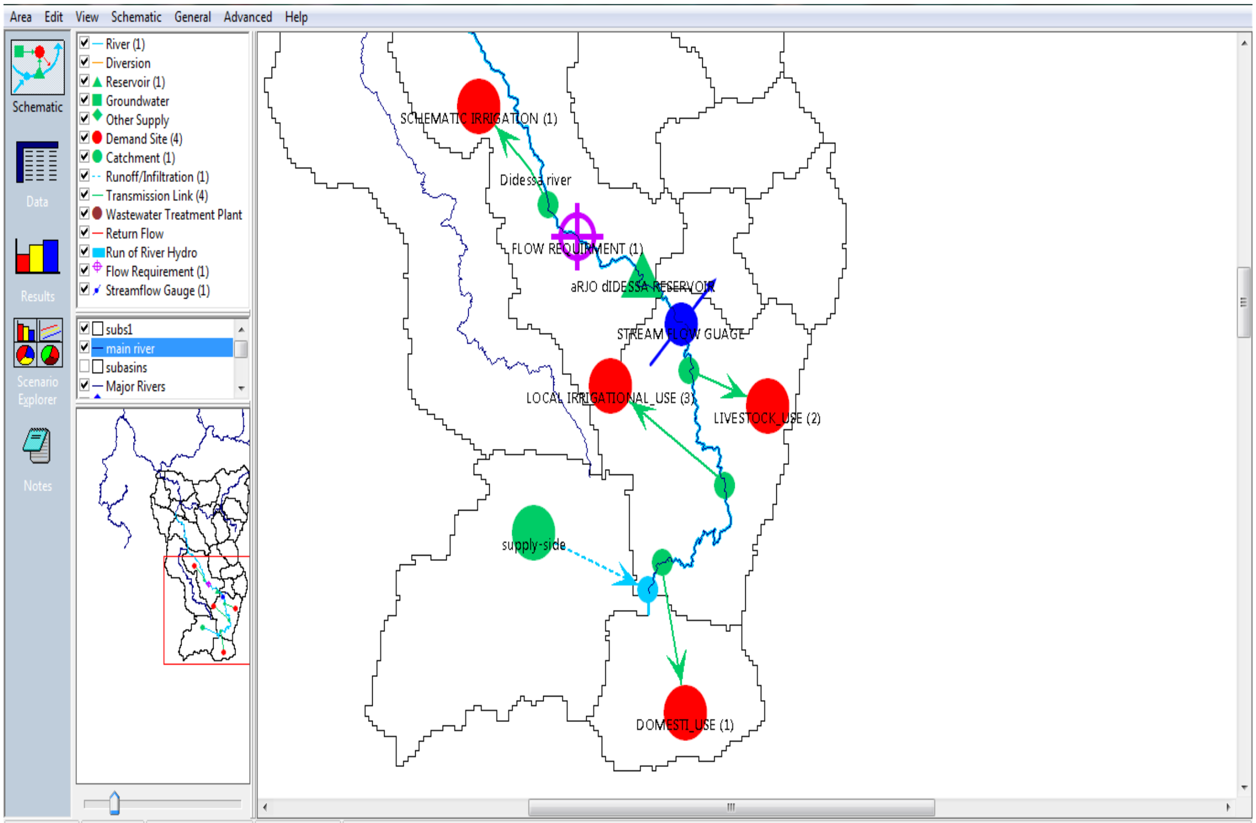


Figure 4:9 Schematic part of the WEAP model for upper Didessa sub basin

4.2.2 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, temperature, humidity and wind speed), open water evaporation and water demands for existing users (Irrigation schemes etc.) in addition these land use and average Kc value were used (see Appendix 1 & 2). Others input data to WEAP from demand side are as follows.

Table 4: 3 Population of domestic and Livestock

S/No	Demand	Population		Livestock				
		Rural	Urban	Cattle	Equines	Goat	Poultry	Sheep
1	Didesa	40,865	15,059	150,094	50,210	10,785	47,586	56,683
2	Jimma	93,317	13,020	120,986	60,247	11,785	55,687	60,607
3	Gomma	93,317	13,020	50,094	45,875	12,875	37,568	36,331
4	Limmu	87,803	27,410	56,648	45,342	14,857	20,685	50,038
5	Limmu Seka	118,970	87,803	47,511	33,221	12,751	21,003	4,015
6	Limmu Kosa	171,019	11,141	100,156	3,844	12,345	28,565	35,243
7	Sigmo	70,230	1,952	110,564	51,220	12,275	49,597	58,981
8	Settema	82,337	23,181	57,088	30,212	11,785	35,413	15,671
9	Nunu Kumba	43,591	17,003	97,953	47,531	5,879	48,751	36,681
10	Wama Boneya	69,056	18,033	67,084	48,330	30,584	34,562	39,761
11	Mana	92,541	15,059	87,563	33,675	34,251	45,892	46,865

Table 4: 4 Annual water demand rate of domestic and Livestock Population (sourc :WHO)

1. Annual water demand rate

Population	Annual Water use rate (m^3/person)
Rural	9.125
Urban	26.28
Cattle	9.13
Equines	7.3
Goat	1.46
Poultry	0.05
Sheep	1.46

Table 4: 5 Irrigation water demand (M^3/year) (source : FAO)

2. Irrigation water demand

Crop type	Area coverage in ha	m^3/ha
Potatoes	659	4148
Coffee	2280	3810
Chat	506	4824
Maize	861	3935
Onion	760.05	5641
Sugar cane	80000.00	4424

Total monthly crop water requirement

Table 4: 6 *monthly Irrigation water requirements on Arjo Didessa River (mm) (source: Ambo water resource agronomic sector).*

S/N	Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	precipitation deficit												
1.1	Potatoes	122.2	22.6	0	0	0	0	0	0	0	33	104	133
1.2	Onion	165.2	23.1	0	0	0	0	0	0	0	38	135	184
1.3	coffee	134.7	84.2	0	0	0	0	0	0	0	43	89.5	131
1.4	chat	108	0	0	0	0	0	0	0	0	46	106	121
1.5	Maize	94.5	0	0	0	0	0	0	0	0	64	114	121
1.6	Sugar cane	35.3	24.2	80.7	67.4	56.4	23.8	6.4	17.8	45	22.2	23.3	19.9

5. Result and Discussion

5.1. Model calibration

The results of the incremental calibration for the Didessa at Arjo are summarized in Figure 5-1, Figure 5-2 and table 5-1. Overall there is good agreement between simulated and observed Monthly flows. The seasonal variation shows a fairly good agreement between high flows and low flows from figure 5: 2 but the rise of the hydrograph appears to be a bit delayed and the corresponding fall. WEAP includes a linkage to a parameter estimation tool (PEST) that allows the user to automate the process of comparing WEAP outputs to historical observations and modifying model parameters to improve its accuracy. I use excel to calibrate one or more variables in WEAP model, which can be particularly useful when using the Soil Moisture method of catchment hydrology and I get the result as bellow.

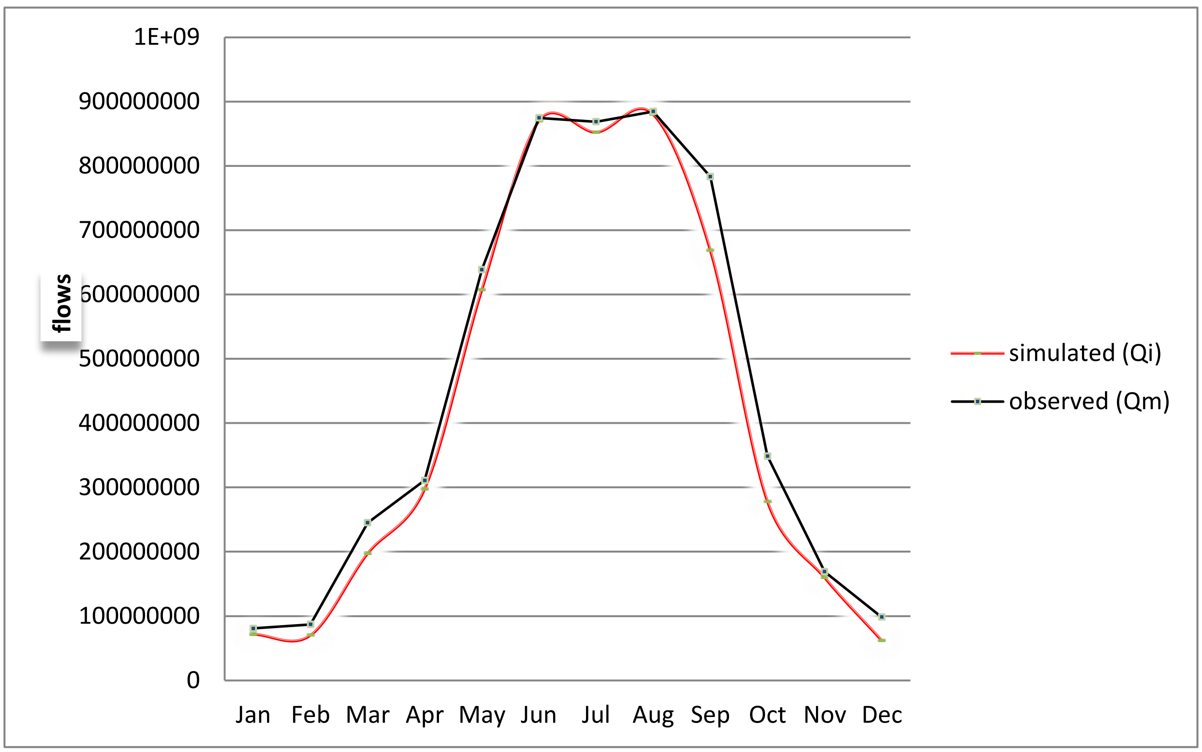


Figure 5: 1Observed and simulâted monthly average flows for Didessa at Arjo reservoir

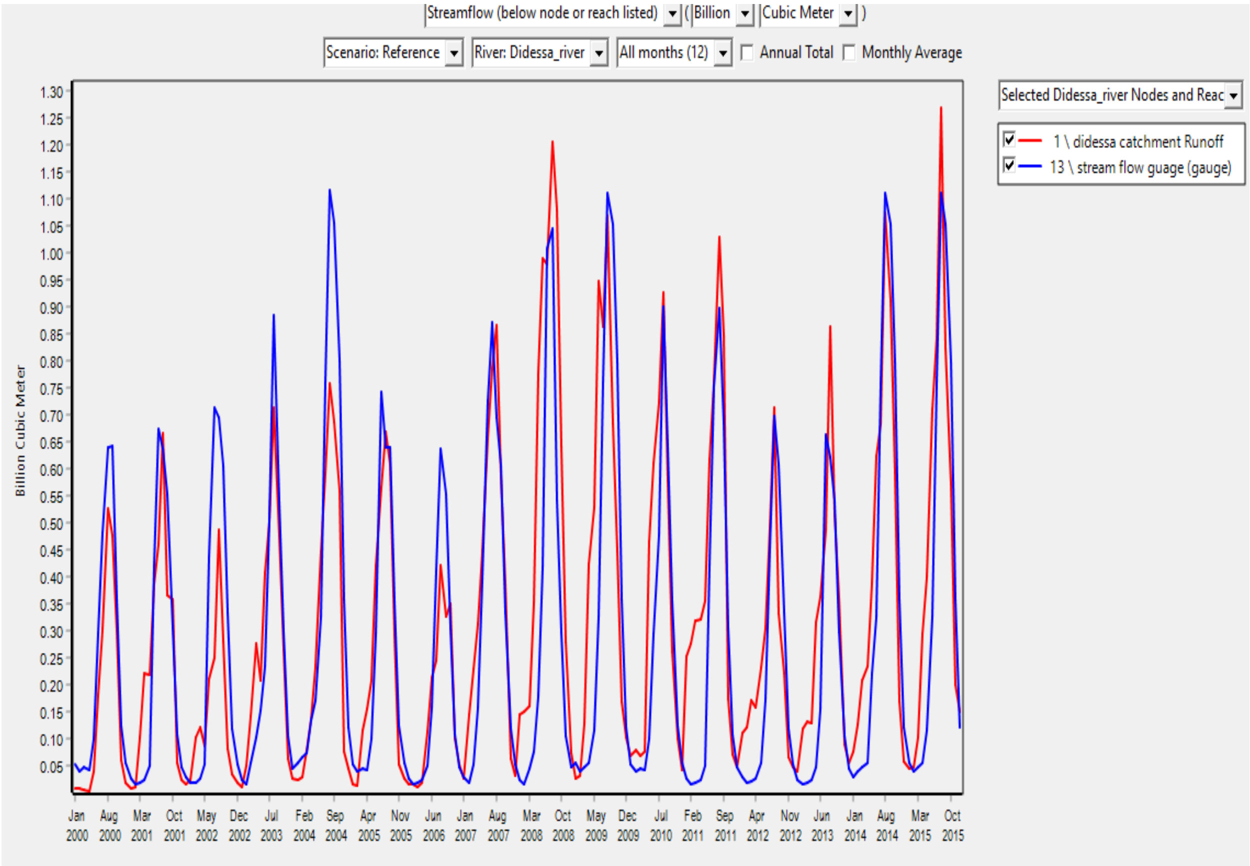


Figure 5: 2Observed and simulâted monthly flows for Didessa at Arjo reservoir

5.2. Model performance evaluation

NSE: The Nash-Sutcliffe Efficiency (Nash and Sutcliffe 1970) is a dimensionless, normalized statistical value and expresses the noise to information ratio (equation 1). It shows how well the plot of observed versus simulated data fits the 1:1 line. Its usage is recommended from ASCE (1993).

$$NSE = 1 - \frac{\sum_{i=1}^{n}(Qi^{m} - Qi^{s})^{2}}{\sum_{i=1}^{n}(Qi^{m} - Q^{m})^{2}} - - - - - - - - - - - - (5.1)$$

Where,

Qi^{m}= observed discharge at time step i

Qi^{s} = Simulated discharge at time step i

Q^{m}= mean of observed discharge

The range of NSE goes from -1 to 1. NSE < 1 indicates that the model's prediction is worse than the mean observed discharge and NSE = 1 signifies an optimal t of observed and simulated values. For values between 0 and 1 the performance is generally seen as acceptable (Nash, 1970)

*Table 5: 1*The Nash-Sut cliffe Efficience acceptable performance for calibration for (2000-2010)
Efficience acceptable performance for calibration for (2000-2010)

Month	simulated flow(Q_i)	Observed flow (Q_m)	$Q_m av$	(Qm-Qi)2	$(Q_is-Q_mav)^2$
Jan	71401877	80846139	449133628	3.781E+14	1.3564E+17
Feb	69979383	86892844	449133628	7.243E+14	1.3122E+17
Mar	197100729	2.45E+08	449133628	6.071E+15	4.1663E+16
Apr	297626896	3.11E+08	449133628	8.721E+15	1.9077E+16
May	606911128	6.39E+08	449133628	1.738E+16	3.595E+16
Jun	869766671	8.74E+08	449133628	8.969E+15	1.8091E+17
Jul	852020046	8.69E+08	449133628	2.147E+16	1.7591E+17
Aug	879769296	8.85E+08	449133628	2.714E+16	1.8955E+17
Sep	668172609	7.83E+08	449133628	4.621E+16	1.1155E+17
Oct	277803461	3.49E+08	449133628	2.925E+16	1.0064E+16
Nov	159724078	1.69E+08	449133628	3.523E+15	7.8432E+16
Dec	61914047	98542755	449133628	1.342E+15	1.2291E+17
sum				1.712E+17	1.2329E+18

$(Qm-Qi)^2/(Q_is-Q_mav)2$ = 0.86

For values of NSE is 0.86 which is between 0 and 1 the performance is generally seen as acceptable.

5.3. Validation

The validation results for the period (2000-2015) for the Didessa at Arjo are summarized in Figure 5.3 and Figure 5-4 below. Overall, the simulated flows for the validation period compare well with the observed flows but there is some variation which is evident in the seasonal plot and the standardized residuals plot.

- Observed and simulated monthly flows at Didessa at Arjo for the validation period (2010-2015)

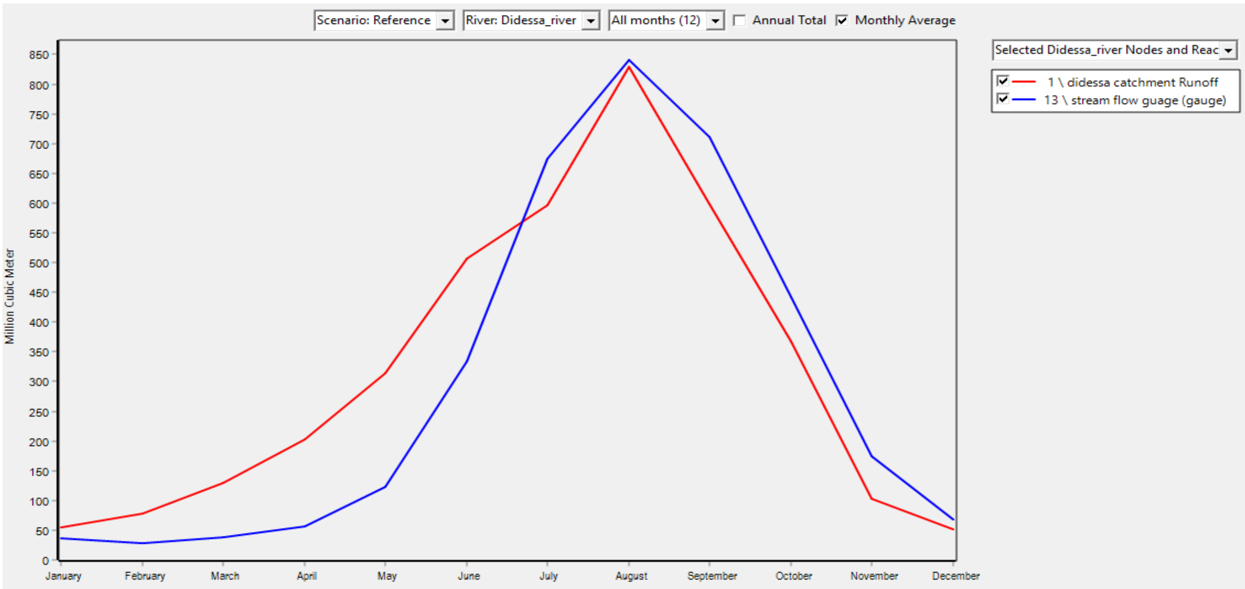


Figure 5: 3 correlation between the average monthly simulated and observed flows

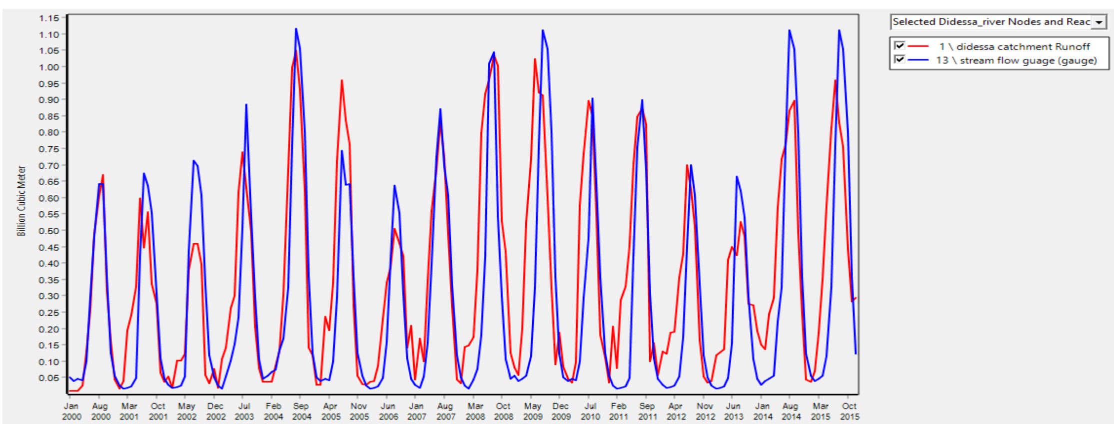


Figure 5: 4 corrélation between the monthly simulated and observed flows Shows the correlation between the monthly simulated and observed flows data for the validation period. (2010-2015)

Table 5: 2 The Nash-Sut cliffe Efficience acceptable performance for validation for (2010-2015)

Month	simulated flow (Qi)	observed flow (Qm)	Qmav	(Qi-Qm)2	(Qis-Qmav)2
Jan	69025946.4	80846138.88	449133628.1	1.39717E+14	1.44482E+17
Feb	74407858.9	86892843.96	449133628.1	1.55875E+14	1.40419E+17
Mar	93208894.3	98542755.36	449133628.1	2.84501E+13	1.26682E+17
Apr	129805153	169076124.4	449133628.1	1.54221E+15	1.01971E+17
May	149544490	245018863.4	449133628.1	9.11536E+15	8.97537E+16
Jun	193677796	311013532.4	449133628.1	1.37677E+16	6.52577E+16
Jul	198434428	348816527.3	449133628.1	2.26148E+16	6.28501E+16
Aug	307362371	638738048.5	449133628.1	1.0981E+17	2.00991E+16
Sep	502887359	783127977.8	449133628.1	7.85348E+16	2.88946E+15
Oct	560520046	868553908.6	449133628.1	9.48849E+16	1.24069E+16
Nov	601139484	874472484.6	449133628.1	7.47109E+16	2.31058E+16
Dec	689606534	884504331.4	449133628.1	3.79852E+16	5.78272E+16
Sum				4.4329E+17	8.47744E+17

NB For values of NSE is 0.5 which is between 0 and 1 the performance is generally seen as acceptable.

5.4. Scenarios and Results of WEAP Model Analysis

The scenarios result were structured and explained in terms of the following layout under climate change and irrigation expansion scenarios. The results will be explained with regard to:

- Reservoir Capacity to service need
- Evaporation from the reservoir due to climate change
- Irrigational and other water demand

5.4.1 Climate change scenarios

5.4.1.1 Basin temperature change scenario

The lowland areas are the most affected, as these areas are largely dry and exposed to flooding during extreme precipitation in the highlands. Future temperature projections of the IPCC mid-range scenario show that the mean annual temperature will increase in the range of 0.9 to 1.1C^0 by 2030, in the range of 1.7 to 2.1ºC by 2050, and in the range of 2.7 to 3.4ºC by 2080 in Ethiopia compared to the 1961 to 1990 (Emerta, 2013). As shown in figure 5.6 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 reservoir surface temperature. The average watershed temperature increases from 18.32C (baseline value) to 25.42 C in 2015-2030, and 20 to 27.6 C in 2031-2050 time period.

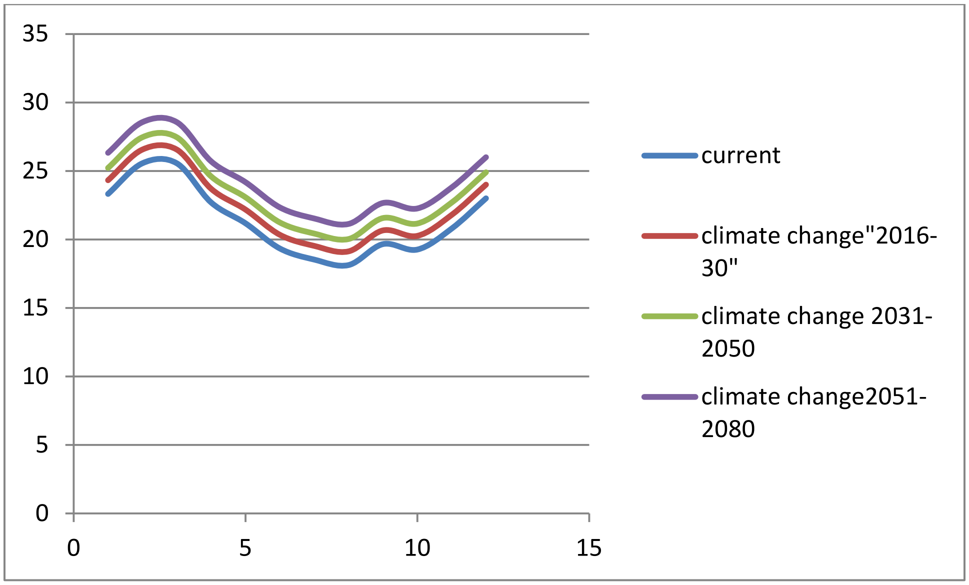


Figure 5: 5Mean Monthly upper Didessa temperature *in* deferent *scenario*

The average monthly basin temperatures are expected to increase more significantly in May. For the 2016 - 2030 time periods, the increase was 1.1C in relation to the baseline temperatures. For the 2031 - 2050 timeframe, the increase is even higher, at 2.1C in comparison to the 2000 -2015 temperatures. For the 2051 - 2080 timeframe, the increase is even higher, at 3.4C in comparison to the 2000 -2015 temperatures.

Table 5: 3 Mean Monthly upper Didessa temperature *in* deferent *scenario (c^0)*

MONTHLY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
current scenario temp	24.09	25.8	25.6	25	23.3	21.1	19.9	19.5	20.83	22.2	23	23.5
2016-2030 scenario temp	25.09	26.8	26.6	26	24.3	22.1	20.9	20.5	21.83	23.2	24	24.5
2031-2050 scenario temp	26.19	27.9	27.7	27.1	25.4	23.2	22	21.6	22.93	24.3	25.1	25.6
2051-2080scenario temp	27.49	29.2	29	28.4	26.7	24.5	23.3	22.9	24.23	25.6	26.4	26.9

The increase in temperature decreases in precipitation which has multiple effects on water availability for irrigation and other farming uses. The average change in rainfall is projected to be in the 4.5mm percent, 8.4mm percent, and 13.8mm percent over 20, 30, and 50 years, respectively.

Table 5: 4 Mean Monthly upper Didessa precipitation *in* deferent *scenario (mm)*

MOTH	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
current scenario temp	14.1	16.53	38.64	59.6	172	282.16	291.286	266.44	222.79	112.835	34.449	22.17
2016-2030 scenario prcp	13.4	15.79	36.9	56.9	164	269.46	278.178	254.45	212.764	107.757	32.8988	21.17235
2031-2050 scenario prcp	13.2	15.46	36.13	55.7	161	263.82	272.352	249.121	208.309	105.501	32.2098	20.72895
2051-2080 scenario prcp	12.5	14.71	34.39	53	153	251.12	259.245	237.132	198.283	100.423	30.6596	19.7313

5.4.1.2 Effect of climate change scenario on Basin Runoff

The runoff over the catchment shown in the figure 5.7 blow which look like fluctuating pattern but a little variation in the baseline year (2000-2015) after then a great variation for the future time period. The average runoff of all over the upper Didessa catchment for the baseline period was 720MMC. For the future runoff of the watershed are 710MMC and 740MMC for the time period of 2016to 2030 and 2031to 2050 years respectively. In total there is an increase of runoff on the watershed in the coming two consequent year when it is related to the current year but it is decreasing in (2031 - 2050) years when it is compared with the (2016 - 2030) period.

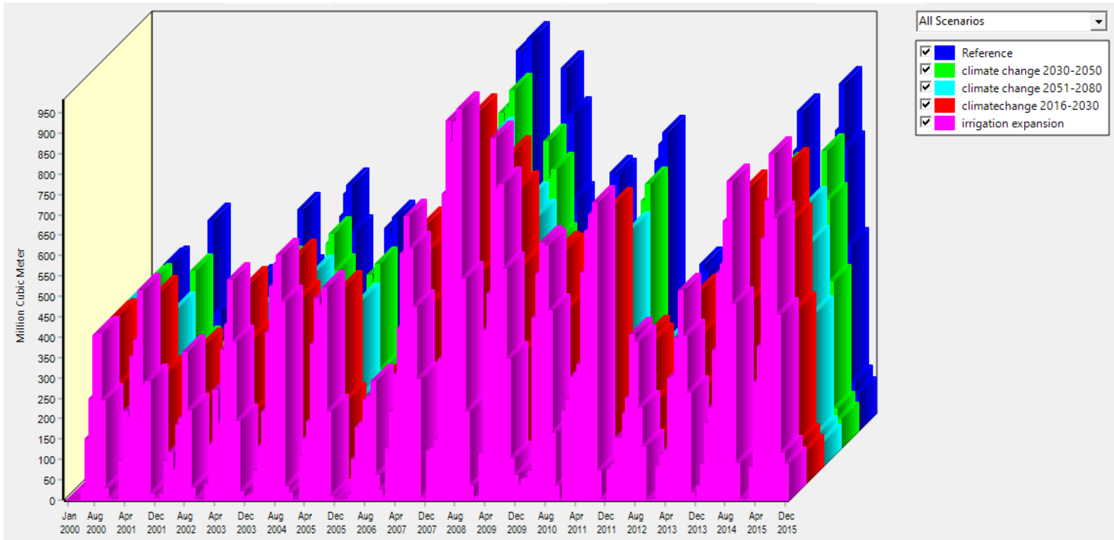


Figure 5: 6 Basin annually runoff variables in deferent time period

5.4.1.3 Evaporation from the reservoir

This section describes the baseline scenario, giving emphasis to the driving forces of evaporation. The results of modeled reservoir evaporation in the present day scenario revealed that the reservoir has a variable trend. As it can be seen from Fig 5.8 the level in some months shows a rising while in some other a declining tendency. The maximum and minimum net evaporation rate were recorded for the month Jan and July with respectively a value of 30.9 Mm3 and 22.4Mm3 annually. Similarly The Arjo Didessa reservoir monthly evaporation for future time period is shown in the same figure 5.8 and table 5.5 blow, relative to the current baseline period. Compared to the baseline evaporation, the average annual evaporation in the period 2016-2030 will be (21%) higher, and in the period of 2031-2050, (13.9 %) higher evaporation in the present-day scenario of 23.5Mm3. When looking 2031-2050 and 2051-2080 periods the simulation of annual evaporation is 319.08Mm3. Generally the reservoir evaporation more in March, to May months of the year this indicates that, the increase in temperature will also increases the average reservoir evaporation under the climate change and irrigation expansion scenario in more or less.

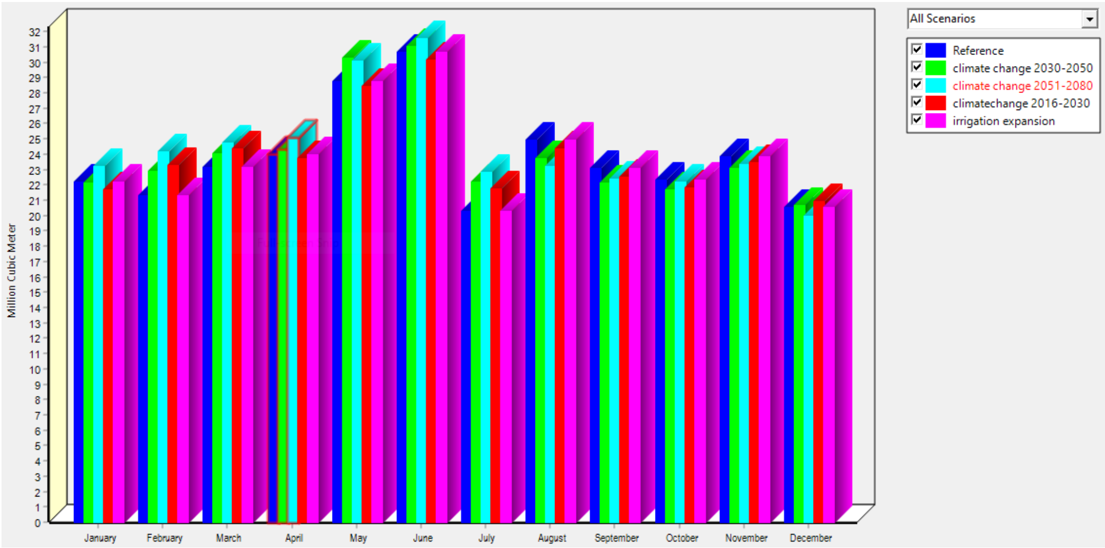


Figure 5: 7 Net monthly evaporation of Didessa reservoir (Mm3)

Table 5: 5 Net monthly evaporation of Didessa reservoir (Mm3)

Monthly	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Reference	22.2	21.3	23.1	24	28.7	30.6	20	24.9	23.1	22.4	23.9	20.6
Climate change (2030-2050)	22.1	22.9	24	24.3	30.3	31	22	23.7	22.3	21.7	23.1	20.7
climate change (2051-2080)	23.2	24.2	24.8	25.1	30.1	31.5	23	23.3	22.4	22.2	23.4	20
Climate change (2016-2030)	21.7	23.3	24.4	23.7	28.4	30.2	22	24.4	22.5	21.8	23.5	21
irrigation expansion	22.3	21.4	23.2	24.1	28.8	30.8	20	25	22.4	22.3	24.1	20.7

5.4.1.5 Reservoir inflows and outflows

Upper Didessa catchment is the major inflows for Arjo Didessa reservoir since the other rivers are the tributary at the same time the areas downstream of the Arjo Didessa reservoirs are highly depends on the reservoir water release. The inflow of the reservoir has a fluctuating characteristic with the maximum at august and minimum at February while the total annual volume of inflow from upstream and the outflow volume to downstream of the reservoir were ,is as you see below. In Jan, Feb, Mar, Apr, May, Oct, Nov and Dec there is no rainfall as the result the inflows less than the outflows and the reservoir volume decreased in those months but in Jun, July, Aug, and Sept the inflows greater than the out flows so the reservoir volume become increased. The table 5.6 blow shows the monthly inflows and out flows of the Didessa reservoir in the baseline year.

Table 5: 6 Monthly Inflow and outflow of Didessa reservoir (m3)

Monthly	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Inflow	50	50	200	210	500	800	713	711	559	170	101	50
Outflow	200	200	200	210	200	500	577	644	550	270	219	200

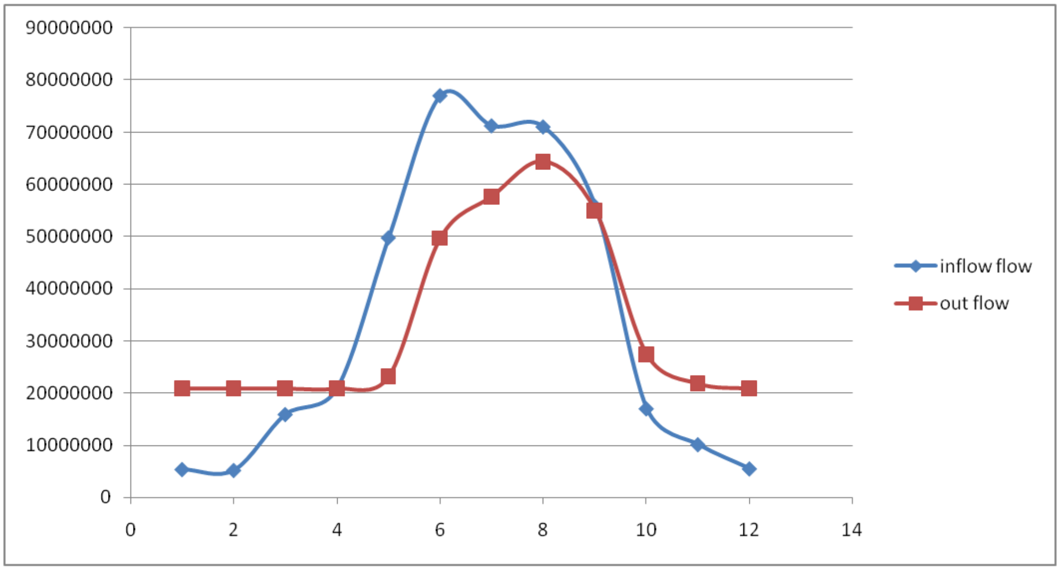


Figure 5:8 Monthey In flow and out flow of Didessa réservoir (m^3)

The above figure shows that the inflow and outflow of Arjo Didessa reservoir in which the maximum inflow and outflow are at different position. Maximum inflow was in August, but for outflow it was in September, this is because of concentration time a time which takes the runoff from

remote place of the catchment to rich at outlet of the watershed. As the result of this the Maximum outflow of the reservoir was during august.

5.2.1.4 Réservoir Storage capacity

The results of reservoir storage capacity simulated show under climate change scenarios that some of the months are full, in the rainy months of August, September, and October but not in the other month. The minimum storage value was in June while the maximum reservoir storage was in the month of September. The annual average Arjo Didessa reservoir capacity under baseline year was 1.64Bm3, while,1.650Bm3, 1.63Bm3 and 1.68Bm3in the coming 2016-2030, 2031-2050 and 2051-2080 respectively within demand priority given to the reservoirs in the WEAP model Figure 5.8 shows the storages capacity of Arjo Didessa reservoirs operation.

Here the above result shows that the decrements of the storage capacity of the reservoir between top of inactive and top of conservation zone due to temperature and rainfall increment on the catchment. The Arjo Didessa reservoir cannot store beyond the maximum storage elevation of 1356.1 m sl. But due to monthly average fluctuation of storage the reservoir still store minimum water in some months. To make sure the reservoir operation in the future the following assumptions should be applicable: the dam height should be increased with minimum operational level gate height, the under sluice or bottom outlet should be in operational in order to scouring the silt deposited and upstream watershed should be conserved in order to minimize the silt deposition in the reservoir.

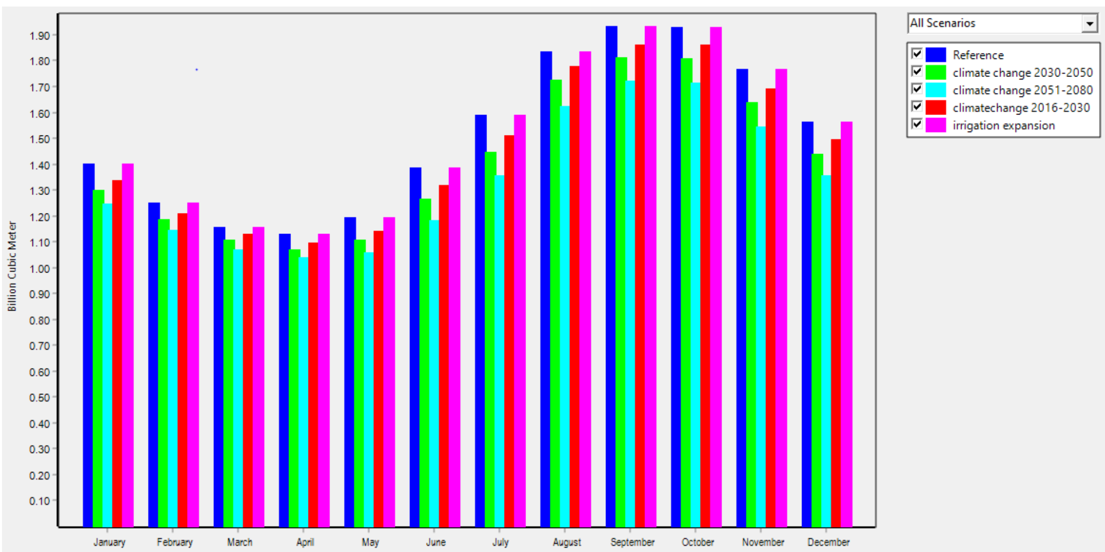


Figure 5: 8 The Storage capacity of Arjo Didessa réservoirs

5.5.2. Total water required at different scenario

5.5.2.1. Current scenario

A key scenarios describing possible future irrigation situation in the Upper Didessa sub 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 (Awulachew, Loiskandl, & Alamirew, 2007). From this assumption, the Didessa reservoir dam in the basin has been simulated for irrigation water supply in downstream Irrigation Schemes. Design capacity of the Reservoir has an average annual volume of 706.6MCM. Before climate change and irrigation expansion the area of Arjo is 56000ha. The Scenario shows the utilization of the full irrigation potential with the Didessa reservoir capacity for different uses. The model result gives the monthly average water demand and annual summation demand for downstream Irrigation Scheme. The total net amount of water required to meet the irrigation demands of all the sites from current scenario (2000 – 2015) was as bellow

Table 5: 7 Curent scenario water balance

Reference(annual)	Supply Delivered(m^3)	Supply Requirement(m^3)	unmet(m^3)
Domestic use	14022203.62	14022203.62	0
Livestock use	2289365.15	2289365.15	0
Local irrigational use	26284.34567	28647.528	0
Governmental irrigation use	189205458.4	189205458.4	0

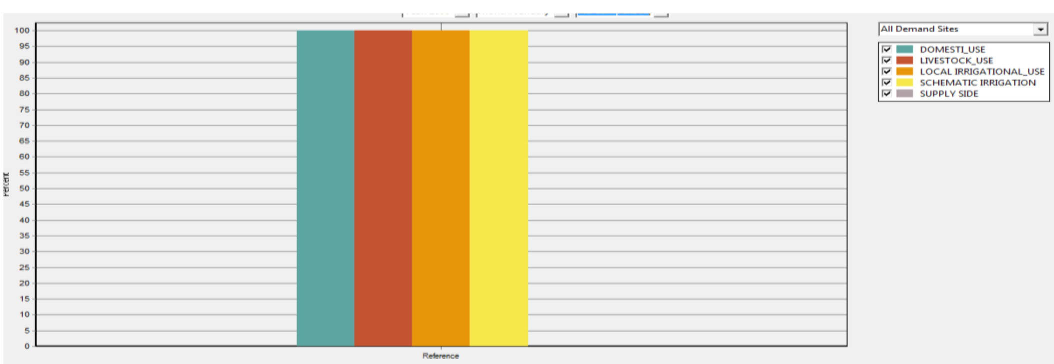


Figure 5: 9 Reliability Coverage in percentage in curent scenario

5.5.2.3. Climate change scenario (2016-2030)

The runoff over the catchment is fluctuating pattern but a little variation in the baseline year (2000-2015) after then a great variation for the future time period due to climate change. In total there is a decrease of runoff on the watershed in the coming two consequent years when it is related to the current year however it is enough to satisfy water required by users.

Table 5: 8 *Climate change scenario (2016-2030)*

scenario (2016-2030)	Supply Delivered(m^3)	Supply Requirement(m^3)	unmet(Mm^3)
Domestic use	13778334.13	14022203.62	0.244
Livestock use	2098775.675	2289365.15	0.191
Local irrigation use	26284.34567	28647.528	0.00236
government irrigation	189205458.4	189205458.4	0.00

5.5.2.3. Climate change scenario (2031-2050)

Even though there is change in water runoff volume due to climate change there is no risk of water required in the (2031 - 2050) and 2051-2080 years when it is compared with the (2016 - 2030) period. This means still there is enough water for different users.

Table 5: 9 Climate change scenario (2031-2050)

scenario(2031-2050)	Supply Delivered(m^3)	Supply Requirement(m^3)	unmet(Mm^3)
DOMESTI_USE	13778334.13	14022203.62	0.244
LIVESTOCK_USE	2098775.675	2289365.15	0.19
LOCAL IRRIGATIONAL_USE	26284.34567	28647.528	0.00236
SCHEMATIC IRRIGATION	189205458.4	189205458.4	0.00

Table 5:10 Climate change scenario (2051-2080)

climate change (2051-2080) scenario	supply delivered(m30	supply requirement(M3)	unmet(m3)
Domestic use	12998334.13	14022203.62	0.2243869
Livestock use	2098775.675	2289365.15	0.19
Local irrigation use	26284.34567	28647.528	0.002363
government irrigation	189205458.4	189205458.4	0.00

5.5.2.4. Irrigation expansion scenarios

Irrigation expansion scenarios describing possible future irrigation situation in the Upper Didessa sub Basin have prioritize the development of irrigation areas to their full potential. Working from this assumption, the Didessa reservoir dam in the basin have been selected for simulation of irrigation water supply in downstream Irrigation Schemes. The future climate change and irrigation expansion coverage was 56000ha while forecast potential downstream of Didessa, giving a total irrigable potential of 80000ha (from Arjo Didessa document). The total net amount of water required to meet the irrigation demands of all the sites is as bellow.

Table 5:11 *Irrigation expansion scenarios*

Irrigation expansion scenarios	Supply Delivered(m^3)	Supply Requirement(m^3)	unmet(m^3)
Domestic use	14022203.62	14022203.62	0.00
Livestock use	1848518.525	2289365.15	0.00
Local irrigation use	23177.81967	28647.528	0.0286
government irrigation	265225508.7	265225508.7	0.00

Sugar cane need complete full year irrigation.

Table 5: 12 *Monthly Sugar cane irrigation water allocated for current and irrigation expansion scenario*

Scenario/Monty	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Current irrigation area	15.7	10.8	36.1	30.2	25.3	10.6	2.90	7.90	20.1	9.9	10.4	8.90
Irrigation expansion scenarios	22.3	15.3	50.6	42.3	35.3	14.9	4.02	11.2	28.2	13.9	14.6	12.5

5.2.2.4 Reliability

The percent of the time steps in which a demand site's demand was fully satisfied.

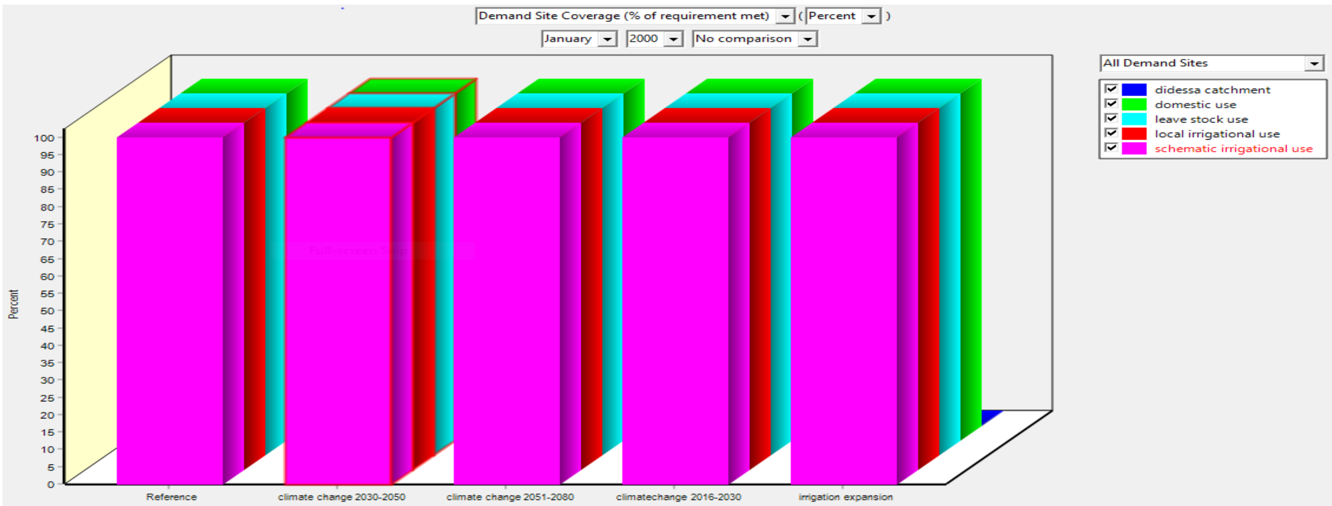


Figure 5: 10 water coverage reliability for all scenarios.

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This thesis analyzed the effects of climate change and irrigation expansion scenarios on Arjo Didessa reservoir water evaluation using WEAP model. The effect of climate change on the reservoir and the downstream irrigation development which depend on the water release of Arjo Didessa reservoir for its demand supply for the current and future development by considering the return flow in operation and other development are insignificant. First the meteorological missed data due to misreading and failed of the gauging instruments were filled by multi-regression method. The filled data consistencies were then checked by double mass curve at Ghimb, Beddelle, nedjo, Jimma, Didessa, Arjo and Nekemt gauging stations. The WEAP model also calibrated and validated using simulated and observed stream flow data. The performance evaluation of the model confirmed that the statistical measure parameters were very good and the model can be used to simulate future stream flow with the climate change and irrigation expansion effect in the basin. For the climate change scenario, the volume of reservoir evaporation in the (2016-2030) period was increased by 13.1%, 2031-2050 periods was increased by by 21.3%, and 2051-2080 period was increased by 23.4% when comparing with the current scenario. While compared with the baseline period, the first 15 years the reservoir evaporation will increase. The Arjo Didessa Reservoir water has nearly full supplement yet there is not much unmet demand in all irrigation areas in the coming different future time period. This implies the current reservoir flow is enough with irrigation expansion in the future even though there is flow decrement due to climate change. At the end the Water Evaluation and Planning System (WEAP) Model has been found to be useful as an Integrated Water Resources Management tool for balancing water supply and demand for current and future scenarios in a priority ways of allocation.

6.2. Recommendations

Several recommendations have been derived from the results obtained and its analysis. They can be as the follow:

- As WEAP simulation result the stream flow volume measurement of Didessa River decrease at different scenario due to the domestic water use, irrigational expansion use and livestock use from up stream.

- The second is due to the industrial development and lack of use management high amount of CO_2 gas emitted to atmosphere which contributes for the climate change in Didessa catchment by maximizing evaporation and reduces the amount of flow in Didessa River.

  Therefore these two problems have to minimize by planting trees to reduce evaporation and developing watershed conservation in order to maximize high runoff generation.

  These conservational measure structures on upper Didessa sub 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.

- Even though nearly enough flow until 2050 there is little bit unmet from 2050- 2080 climate change scenario and during irrigational expansion scenario. Therefore it is better find Additional Ground water flow to reservoir flow requirement or constructing reservoir or water harvesting structure for supplying the future unmet demand amount beside of the currently existing reservoir supply.

REFERENCES

(AMCOW, 2011) and Water Sanitation Program (WSP) Country Status Overviews (CSOs) for the WASH sector,. (2011) *which has international recognition and has been applied to assess water supply and sanitation coverage in Ethiopia in 2009/2010 (WSP, 2011).* Addis ababa: WSP wash sector.

(Samuelson, P. A. (1958). *Decision Making Technologies in Water Resources Management.*

(SEI), S. E. ((2015).). *WEAP: Water Evaluation and Planning System-User Guide.* Boston, USA.: Stockholm Environment Institute (SEI), (2015Stockholm Environment Institute, .

Abayneh. (2011). *Evaluation of Climate Change Impact on Extreme Hydrological Event .* Addis ababa.

Abayneh, A. (2011). *Evaluation of Climate Change Impact on Extreme Evaluation of Climate Change Impact on Extreme Hydrological Event Addis Ababa University.* Addis Ababa: Abayneh, A., (2011) Evaluation of Climate Change Impact on Extreme E Addis Ababa University.

Abebe, D. J. (2011). *Abebe, D., Jaap, E., Seimon, L., and Taye, A., (2011). Irrigation practice and policy in the low lands of the Horn Africa contribution to FAO Expert Meeting 24-25 November 2011, Nairobi.* Nairobi.

Agizew, N. a. (2015). *Climate Modeling of the Impact of Climate Change on Sugarcane and Cotton for Project on 'a Climate Resilient Production of Cotton and Sugar in Ethiopia.* AddisAbaba: Agizew, N. and Geremew, S. 2015. Climate Modeling of the Impact of Climate Change on Sugarcane and Cotton for Project o Ethipian development Research Institute,.

al., S. e. (2014). *Bottleneck Analysis Tool for the WASH sector (WASHBAT) .* addis ababa: UNICEF's sector (WASHBAT) l.

Awulachew, S. B, McCartney, M, Steenhuis, T. S, & Ahmed, A. A. (n.d.). (2008). A Review of Hydrology, Sediment and Water Resource Use in the Blue Nile Basin. *IWMI Working Paper 131 . Colombo, Sri Lanka: International Water Management Institute*.

Awulachew, S. B., Loiskandl, W. A., & Alamirew, T. (2007). *Water Resources and Irrigation Development in Ethiopia.* . Ethiopia: Adis ababa.

Azman, B. (2007). *Impact of Climate Change on Water Resources Availability in the Komati River Basin Using WEAP21 Model.* delft,Nezerland: UNESCO-IHE Institute for Water Education.

Azman, B. (2007). *Impact of Climate Change on Water Resources Availability in the Komati River Basin Using WEAP21 Model.* UNESCO-IHE Institute for Water Education, Delft, .

Azman, B. (2007). *Azman, B. (2007) Impact of Climate Change on Water Resources Availability in the Komati River Bas.*

BA, S. (2011). Flow Regime and Land Cover Changes In the Didessa Sub-Basin of the Blue Nile River,South-Western Ethiopia. *Master E, Uppsala University, Sweden*.

Chow. (1988). *(Estimation of Areal rainfall using Thiess polygon method).*

Emerta, A. (2013). *climate change, growth, and poverty in Ethiopia.* AddisAbaba : The Roberts. Strauss center.

Emerta, A. (2013). *climate change, growth, and poverty in Ethiopia.* . ethiopia: Emerta, A. (201The Roberts. Strauss center, working paper No.3.

Endalkachew, G. (2012). *Climate Change Impact on Surface Water Sources of Addis Abab case study Legedadi-Dire-Gefersa Catchments and Reservoirsa.* Addis Ababa institute of Technology.

Habtom, M. (2009). *Evaluation of climate change impact on upper blue Nile Basin Reservoir.* Arba Minch: Arba Minch University.

Haileyesus, B. (2011). *Evaluation of Climate Change impacts on hydrology on selected Catchments of Abbay Basin. Addis Ababa* . Addis Ababa. : Addis Ababa University.

Hamed, K. H. (2008). Trend detection in hydrologic data: The Mann–Kendall trend test under the scaling hypothesis. . *Journal of Hydrology Volume 349, Issues 3–4, 1 February 2008 , 350–363.*, pp350-360.

IPCC. (2000). *Driving force of climate change.* Newyork: A Special Report of IPCC Working Group III Summary for Policymakers. ISBN:.

IPCC. (2007). *climate change as aresult of human activity.* Addisababa: ethiopia.

IPCC. (2007). *Technical paper VI Climate change and Water.*

IPCC. (2007a). *technecal peparIVclimate change and water.* ,New york: Cambridge university press.

IPCC. (2014). *Summary for Policymakers integrated view of climate change* . IPCC (2014) Summary for Policyma as the final part of the IPCC's Fifth Assessment Report (AR5).

LaSeur, W. a. (1976). *developed a model, using the SCS curve-number technique and the soil-moisture accounting procedure.*

Linsley, R. K., M. A. Kohler and J. L. H. Paulhus. (1982). Hydrology for Engineers, 3rd Edition. McGraw-Hill, New York.

Linsley, R. K., M. A. Kohler and J. L. H. Paulhus. (1982). Hydrology for Engineers, 3rd Edition . *McGraw-Hill, New York*, 508 p.

Mamo, T. M. (2014). Morphometric Analysis of Didessa River Catchment in Blue Nile Basin, Western Ethiopia. *Science, Technology and Arts Research Journal* , 3(3): 191-197.

MOWIE, F. a. (2013). *Developping a wateraudit for AwashBasin.* AddisAbaba ethiopia: GCP/INT/072/ITA.

Nash, J. E. (1970). River flow forecasting through conceptual models part I. *A discussion of principles. Journal of Hydrology*, 10,pp282-290.

Reuben, N. (2007). *Application of the WEAP Model in Integrated Water Resources Management of the Nyando River Basin,.* Kenya: Jomo Kenyatta University.

Snyder. (1938). Synthetic unit graphs. *Trans Americans Geophysics*, Un. 19.

Tigist, T. (2009). *Water Resource Utilization and Its Related Effects Lake Abiyata and the Surrounding.* . Addis Ababa Ethiopia.: Addis Ababa University,.

Wagner, T. (2006). parameter estimation and regionalization for contineous rainfall-runoff models including uncertainity. *journal of hydrology320*, pp132-154.

.

APPENDIX-1 Hydrological Data

Station name: Arjo Didessa

Element: Monthly total stream flow (m3/s)

year/month	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
1980	80.9	86.7	109.0	192.5	155.9	154.0	140.8	166.3	167.3	105.8	77.1	65.3
1981	64.4	57.1	115.4	89.8	176.6	144.8	173.7	183.8	159.8	86.8	108.3	70.2
1982	83.1	78.4	78.3	115.0	158.6	174.4	142.0	211.3	191.8	121.9	136.6	82.4
1983	77.5	6.3	98.3	37.7	184.0	342.0	210.3	207.2	200.1	146.9	92.6	60.0
1984	75.6	65.2	73.3	89.5	163.2	169.7	203.3	167.9	158.1	85.9	96.1	78.0
1985	69.8	58.0	85.2	121.6	152.1	171.5	186.9	168.4	154.0	93.6	80.3	70.7
1986	63.5	77.1	88.5	98.1	110.7	183.9	185.5	150.1	142.8	100.0	65.0	75.5
1987	67.6	84.0	127.4	88.1	141.4	188.6	207.3	176.9	136.7	130.0	74.4	80.6
1988	85.8	86.6	80.5	84.8	167.1	172.9	158.5	201.6	204.7	147.8	63.7	62.1
1989	68.8	68.0	121.0	120.2	122.9	167.5	187.6	179.0	167.5	108.3	73.3	129.7
1990	66.6	68.5	107.8	88.2	134.6	223.6	191.2	213.1	183.7	79.0	88.3	66.8
1991	88.8	79.3	89.7	129.7	127.1	169.2	201.5	206.0	149.2	90.2	66.0	85.3
1992	75.0	77.7	92.0	125.5	144.9	196.1	191.9	225.8	163.1	150.9	91.1	72.1
1993	78.2	80.4	102.6	154.0	173.5	193.3	176.4	214.2	149.0	146.5	63.1	58.4
1994	64.4	63.5	95.9	118.5	172.0	187.1	198.6	165.6	155.0	69.5	69.5	62.9
1995	65.8	65.7	94.9	127.5	141.9	169.4	170.8	197.3	166.1	89.7	68.5	94.4
1996	80.0	69.3	133.4	130.5	163.5	167.0	196.1	139.4	177.0	86.3	90.9	70.8
1997	87.3	21.6	56.7	126.4	264.5	351.3	201.3	238.8	206.7	310.7	207.1	80.0
1998	70.6	21.5	117.5	66.6	116.5	277.4	270.9	331.4	208.5	212.0	75.8	0.0
1999	3.8	6.8	34.1	98.4	212.0	185.4	197.6	144.2	191.3	209.6	16.3	17.9
2000	0.0	1.0	118.5	99.7	266.9	297.3	184.4	187.2	273.9	293.1	30.7	32.3
2001	14.3	30.7	103.0	126.0	154.5	207.2	231.1	221.9	211.6	147.1	17.4	0.0
2002	6.6	0.0	85.7	49.4	93.2	280.6	278.2	267.0	156.3	56.0	4.6	101.8
2003	19.1	72.0	127.5	216.4	72.6	201.1	265.4	215.7	111.5	78.4	8.7	17.9
2004	23.5	2.4	55.8	148.2	153.1	205.1	187.1	220.3	257.5	134.1	33.9	39.8
2005	16.4	0.0	20.5	88.9	86.6	273.2	195.8	181.6	277.9	83.2	34.3	57.3
2006	21.2	37.3	138.8	94.7	140.2	262.4	286.6	227.5	174.0	181.7	55.5	39.5
2007	33.0	45.2	96.8	64.4	197.6	166.8	263.7	270.1	243.7	67.8	30.3	0.6
2008	19.6	9.9	19.4	154.3	224.1	262.7	233.5	252.3	77.5	142.4	39.9	30.0
2009	32.4	13.8	73.7	131.7	103.0	163.8	144.1	177.4	268.9	99.6	20.5	23.5
2010	2.0	99.3	42.7	89.1	181.8	243.0	181.7	171.2	202.2	106.6	95.5	78.6
2011	84.6	64.8	83.2	118.2	165.6	202.8	161.6	277.0	259.4	81.2	107.5	79.5
2012	60.9	56.6	90.0	108.9	143.2	188.4	223.6	248.4	216.3	53.1	54.2	89.9
2013	22.4	72.4	97.5	94.3	176.6	307.0	239.6	352.0	231.5	273.6	62.6	1.0
2014	29.2	59.3	111.9	114.9	295.8	149.9	188.9	427.6	268.0	124.8	53.5	5.0
2015	61.3	66.1	48.3	106.3	290.7	166.4	190.1	384.9	333.9	116.4	109.0	89.5

Estimated of Arjo Didessa Reservoir Evaporation (mm)

APPENDIX-2 Meteorological Data

Station name: Arjo Didessa

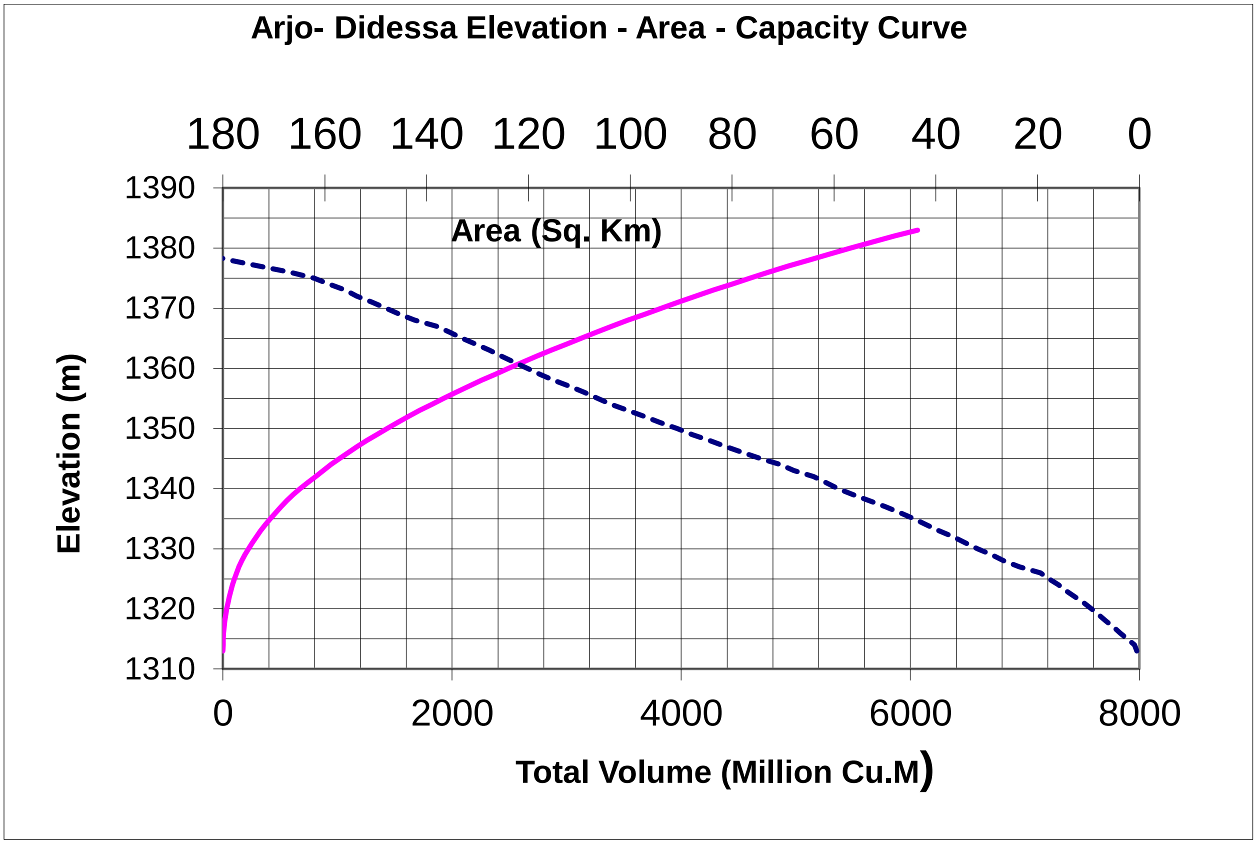
Element: Monthly total rainfall (mm)

year/month	Jan	feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	0.0	23.7	39.3	87.7	229.1	175.9	198.5	210.3	199.2	38.9	39.0	47.3
1981	50.8	43.3	37.1	18.4	244.1	206.9	226.3	211.6	213.5	85.7	83.4	63.6
1982	73.5	62.2	85.0	113.6	118.6	204.8	165.4	192.8	121.3	141.1	91.0	62.6
1983	61.3	57.3	68.7	65.5	151.7	327.1	675.2	400.8	186.4	107.4	31.5	1.5
1984	0.0	3.1	8.9	19.5	221.0	306.2	286.8	308.5	150.4	0.0	8.2	13.6
1985	1.0	0.0	47.3	89.3	218.9	361.2	373.0	296.4	168.2	145.5	26.8	22.7
1986	0.0	5.4	11.8	73.1	90.0	184.2	339.4	259.0	220.2	94.3	5.1	0.5
1987	3.5	3.0	25.0	28.5	141.2	399.0	425.6	295.6	214.8	97.2	54.4	0.5
1988	0.6	11.4	31.9	0.0	275.3	339.9	372.5	442.4	380.1	241.0	8.0	0.0
1989	0.0	0.0	159.6	38.1	242.9	312.4	336.9	289.4	304.8	120.0	22.0	72.4
1990	4.2	11.8	44.2	4.0	111.7	279.6	401.8	227.2	141.2	47.1	19.2	0.0
1991	6.6	17.4	33.2	90.8	114.1	224.6	345.8	303.6	149.4	10.3	0.5	9.7
1992	3.6	51.9	94.2	100.2	80.8	196.6	152.9	206.7	169.9	183.2	64.9	6.0
1993	0.0	7.9	26.3	95.0	122.3	223.6	306.6	263.8	170.1	132.4	15.3	0.0
1994	0.1	0.0	1.2	73.4	193.9	236.4	236.4	280.7	91.4	50.6	16.5	0.3
1995	0.0	0.0	33.6	19.3	80.9	112.6	272.9	244.2	176.0	89.4	9.7	4.5
1996	21.4	4.2	78.9	60.0	239.0	310.7	380.3	369.7	370.0	31.4	9.9	56.6
1997	13.0	0.0	13.3	154.1	183.8	203.2	277.4	282.5	147.4	176.4	60.2	0.0
1998	0.0	0.0	13.2	12.3	281.0	398.1	195.6	370.6	253.7	190.7	29.0	0.4
1999	17.6	0.2	0.0	47.9	177.8	305.8	141.4	273.8	351.1	141.0	16.8	11.3
2000	0.0	0.0	0.4	154.2	240.8	448.2	132.4	347.3	300.3	191.9	21.1	0.0
2001	0.0	10.9	27.1	30.8	142.9	184.0	196.3	223.7	253.9	127.8	39.8	31.2
2002	6.0	14.5	30.0	31.1	76.7	233.0	252.1	125.5	111.8	16.5	0.2	7.8
2003	0.0	35.1	50.0	0.0	73.1	392.9	417.2	302.3	192.8	67.0	36.0	5.5
2004	0.0	5.2	5.5	34.8	105.7	251.7	427.8	317.5	139.5	147.1	36.2	1.2
2005	6.0	0.4	107.3	18.8	110.0	373.3	347.8	173.4	251.8	123.7	76.9	46.3
2006	47.0	52.1	10.2	82.1	153.5	193.8	294.0	261.4	344.6	346.3	37.0	29.5
2007	0.0	15.4	23.2	68.4	156.7	432.4	168.5	172.0	208.4	87.4	62.7	46.5
2008	11.1	0.0	5.0	118.5	307.3	404.7	479.5	367.6	268.4	78.3	54.7	3.0
2009	0.0	13.9	25.5	129.4	61.4	299.7	192.4	324.3	276.3	95.3	5.6	23.2
2010	1.7	0.4	0.0	18.1	256.7	514.9	351.9	139.0	254.1	100.8	3.0	1.1
2011	29.4	0.0	19.1	25.7	173.5	374.7	138.9	185.7	282.2	65.5	10.0	0.0
2012	46.9	43.5	72.1	69.2	167.6	187.4	214.3	283.4	211.5	87.2	72.3	68.9
2013	53.7	56.9	73.3	55.8	225.5	209.9	201.4	209.6	191.1	97.7	93.3	59.9
2014	47.4	44.1	87.5	116.9	204.3	217.9	336.7	232.8	389.8	192.4	1.8	0.0
2015	0.0	0.0	2.3	0.0	206.0	130.3	224.4	196.7	164.9	113.6	78.1	100.6

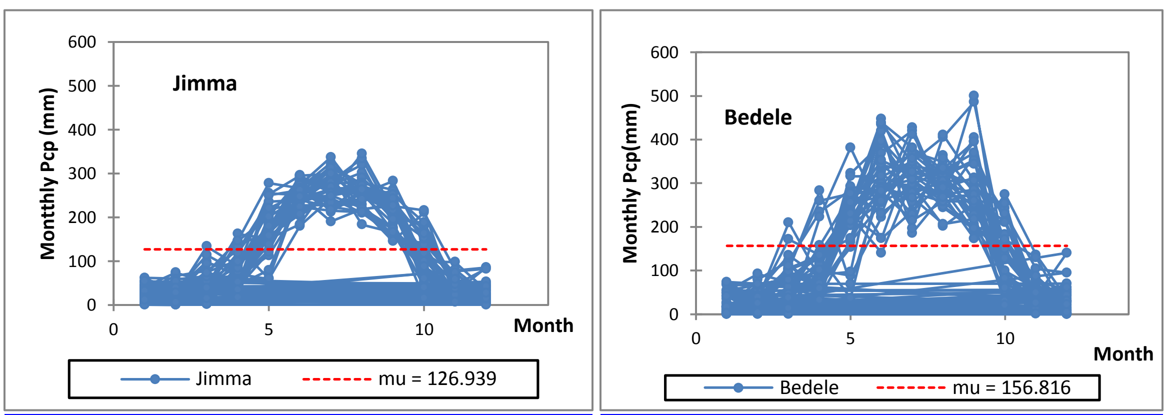
Element: Monthly total temperature(c^0)

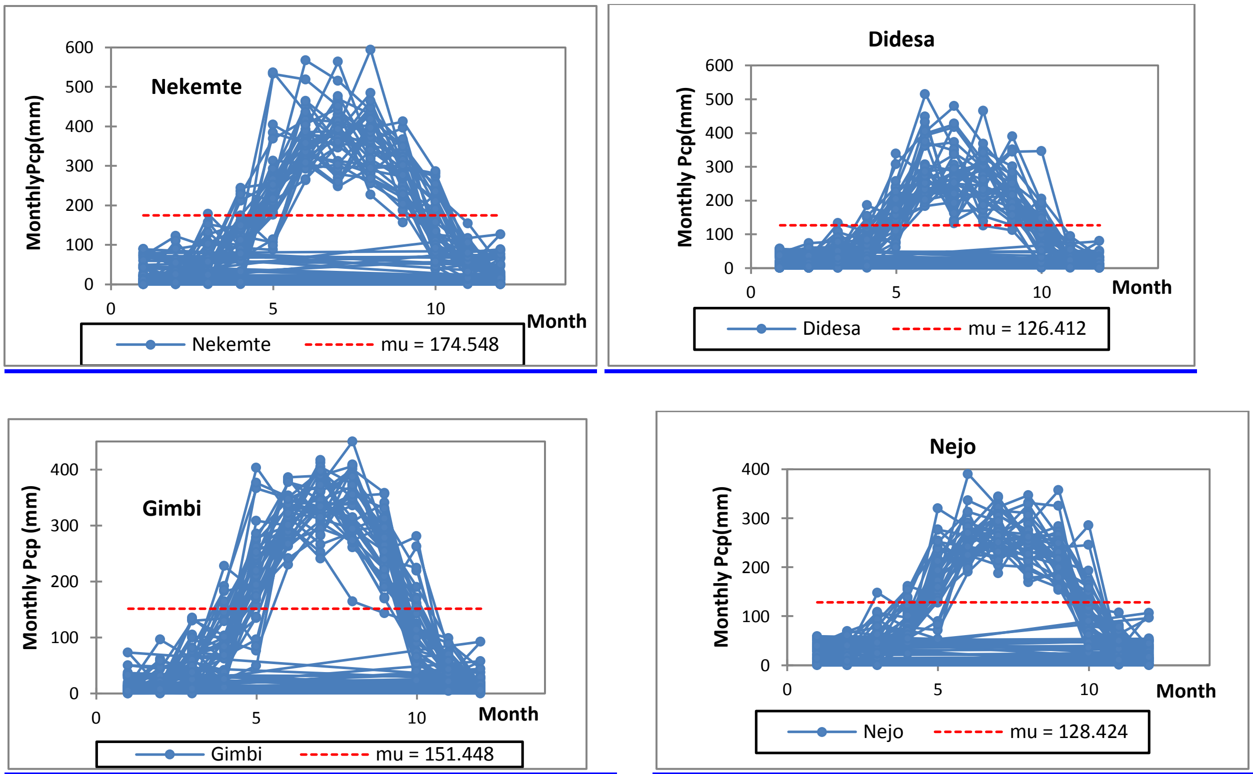
year/month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	22.31	22.82	23.47	22.2	19.5	18.27	17.15	17.83	18.27	19.58	20.07	20.99
1981	22.5	22.95	22.6	22.59	20.38	18.93	17.17	17.12	17.93	20.07	20.75	21.75
1982	21.55	22.55	22.63	22.53	20.23	18.9	17.15	17.2	18.7	19.49	20.13	21.13
1983	21.4	23.3	24.14	22.84	21.14	19.14	17.87	17.11	18.18	19.32	20.2	20.96
1984	22	22.52	23.85	24.05	20.96	18.12	17.42	18.61	18.5	21.35	20.95	21.45
1985	22.99	22.22	22.21	23.39	21.73	19.4	19.48	18.28	17.65	19.19	20.06	21.17
1986	22.57	22.78	23.25	21.89	23.05	18.23	18.07	18.35	18.85	19.76	22	21.67
1987	21.95	23.52	21.68	23.14	20.83	19.18	19.04	18.45	19.66	20.33	21	21.43
1988	21.96	22.52	24.13	23.84	21.71	19.12	16.8	17.66	18.43	19.94	21.23	22.33
1989	22.2	20.94	21.98	20.63	20.26	18.46	17.15	17.47	18.72	19.55	20.33	19.9
1990	21.05	21	22.48	22.69	21.19	18.55	17.37	18.13	18.45	20.26	20.79	21.72
1991	22.19	23.56	22.27	21.63	20.38	16.84	16.93	17.26	19.04	20.1	20.64	20.4
1992	20.34	21.54	23.29	22.14	20.6	18.3	16.53	16.37	18.93	19	18.85	20.18
1993	20.28	21.01	22.46	20.28	20.3	18.3	17.23	17.43	18.2	19.28	21.01	22.22
1994	22.48	22.86	23.58	23.34	20.47	18.65	17	17.07	18.93	21.06	20.85	21.86
1995	22.34	23.84	24.61	22.75	21.24	20.18	17.64	17.94	19.51	20.79	20.9	21.05
1996	21.61	24.03	22.98	22.3	20.36	17.94	18.04	19.46	20.4	18.2	21.04	21.11
1997	21.89	24.38	24.37	21.54	20.13	19.52	18.02	18.85	20.97	20.42	20.46	21.33
1998	22.39	23.71	24.26	25.39	20.2	19.94	17.75	18.17	19.93	19.8	20.08	21.62
1999	22.5	25.6	25	24.56	21.26	19.95	17.65	18.14	19.3	19.17	21.17	21.93
2000	23.32	25.56	25.56	22.7	21.18	19.34	18.53	18.13	19.66	19.26	20.79	23
2001	22.7	24.53	22.62	23.15	21.86	18.83	17.89	18.18	20.54	20.59	21.38	22.36
2002	21.5	24.7	24.25	24.23	22.92	19.87	19.48	18.48	19.72	20.72	22.01	21.68
2003	22.96	25	23.93	23.67	25.68	18.68	17.49	17.52	18.87	22.02	22.02	22.52
2004	23.4	24.21	24.81	23.42	22.41	18.5	17.92	18.57	19.18	20.69	20.96	22.55
2005	23.47	26.1	24.38	24.18	22.54	19.57	18.23	18.89	19.2	20.47	21.25	22.52
2006	23.82	24.87	23.83	24.51	21.95	19.8	18.03	17.71	19.09	21.39	21	21.47
2007	22.97	23.74	24.84	23.04	21.97	20.05	18.41	18.52	19.27	22.26	22.82	23.03
2008	23.89	24.56	25.73	23.45	20.83	20.62	18.66	18.64	20.38	19.53	23.11	22.79
2009	23.2	24.47	25.43	25.66	25.01	24.16	21.39	19.19	20.55	21.53	22.18	22.61
2010	23.08	24.97	25.47	25.89	22	21	19.34	18.33	18.97	21.06	22.06	22.03
2011	22.66	25.28	24.88	25.77	23.21	21.17	20.28	18.79	19.61	22.23	21.83	22.47
2012	23.07	25.16	25.03	24.24	22.08	19.72	23.02	19.02	20.07	22.24	22.49	22.69
2013	24.79	24.81	25.58	21.58	18.42	16.46	18.09	18.04	20.48	21.11	21.4	22.43
2014	22.77	24.09	23.84	22.02	20.74	20.56	18.36	18.68	21.86	22.15	23	23.34
2015	22.77	24.09	23.84	22.02	20.74	20.56	18.36	18.68	21.86	22.15	23	23.34

Arjo- Didessa Elevation - Area - Capacity Curve



Graphical representation of homogeneity test of monthly flow data





Graphical representation of homogeneity test of monthly flow data