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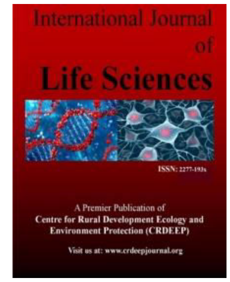

Full Length Research Paper

Arjo Didessa Reservoir Water Evaluation and Application System, Ethiopia

Ebisa Abiram
Lecturer, Ambo University, Ethiopia.

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Corresponding Author:
Ebisa Abiram

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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. Currently Arjo Didessa earthen dam is the reservoir found in the Upper Didessa River being utilized for Irrigation uses and other purpose from the same source. For this reason it needs evaluation and planning of the Didessa river water at different scenario. To address water resources fairly to all users requires technical issues and specialized tools 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 model to assess the consequences of climate change and irrigation expansion on current and future water use scenario. Records of hydrology and meteorological data have been statistically tested and arranged as an input data source to fit the model. 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 was increased by the time.

Introduction

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.

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. Water is influenced by human activities and 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).

The main aim of this thesis is to evaluate adequacy Arjo Didessa reservoir water balancing demands and supplement in current and future scenario, to predict future water demands and allocation based on different development scenarios and to analyses water required for irrigation, drinking and livestock at deferent scenario to ensure the sustainable development in Didessa watershed

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 issurplus 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.

Materials and methods

Description of study area

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

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.s.l. and 3144meter a.s.l.

Methods

The method used in this thesis fulfillment include, the study of literature review, collecting relevant information or data of the study area, discusses the types and source of data required for the study, applying different methods and techniques to estimate the runoff in to the reservoir. The reservoir operation will be performed applying simulation techniques.

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.

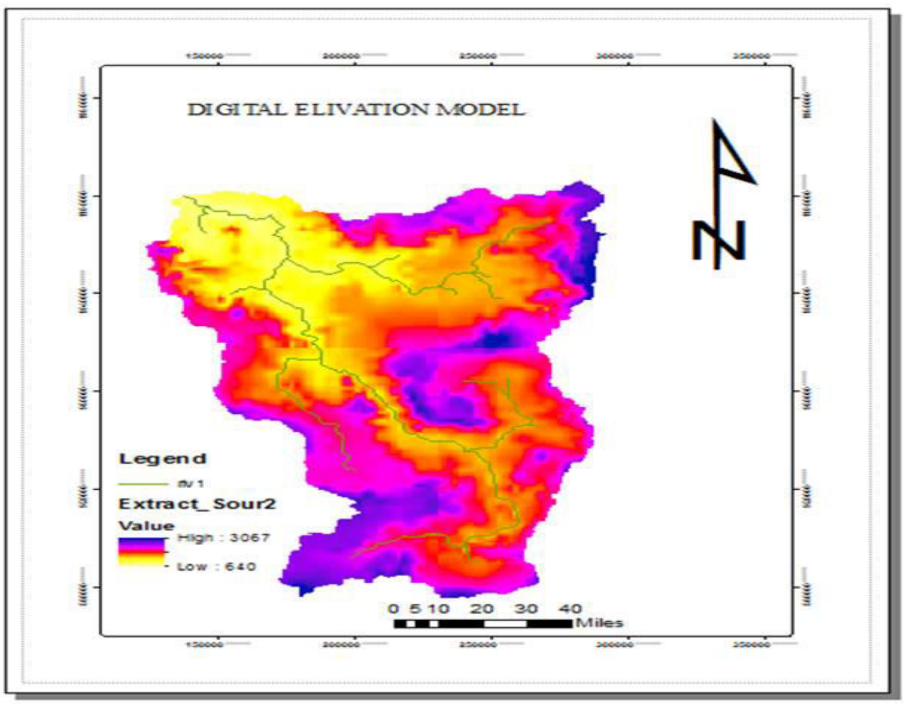

Fig 1. The Digital *Elevation* Model (DEM)

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.

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

Result and Discussion

The results of the incremental calibration for the Didessa at Arjo are summarized in Figure and table below implies 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 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 below.

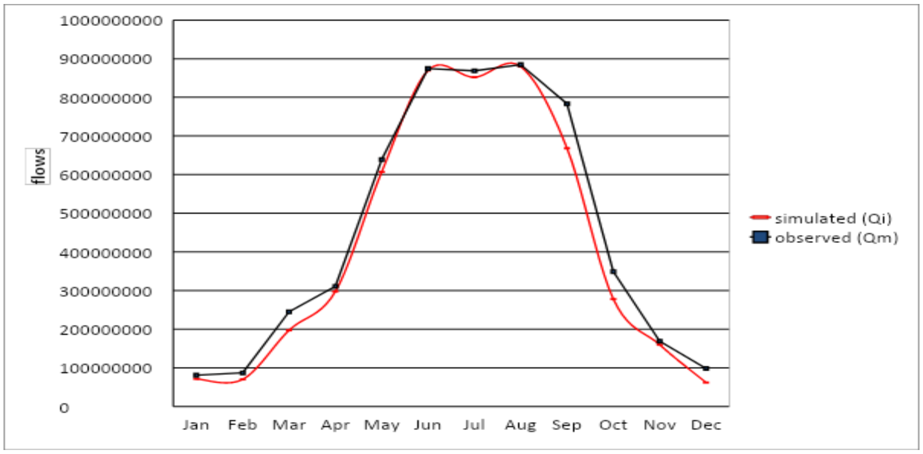

Fig 2. Observed and simulâted monthly average flows for Didessa at Arjo reservoir

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 = (Qim-Qis)2i=1nQim-Qm2----------(5.1)

Where,

Qim= observed discharge at time step i

Qis= Simulated discharge at time step i

Qm= 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)

$$NSE = (Qm-Qi)^2/(Q_is-Q_mav)2 = \underline{0.86}$$

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

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).

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

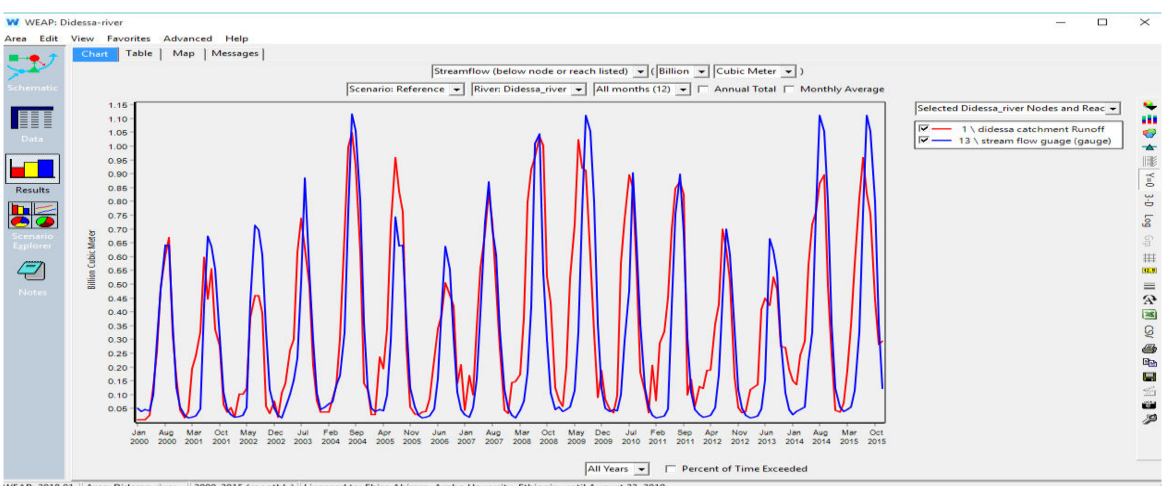

Fig 3. Observed and simulated monthly flows for Didessa at Arjo reservoir

Discussion

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 Didessareservoir 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 bell.

Table 1. Current 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

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 2. 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

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 3. Climate change scenario (2031-2050)

Scenario(2031-2050)	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	0.19
Local irrigational_use	26284.34567	28647.528	0.00236
Schematic irrigation	189205458.4	189205458.4	0.00

Table 4. 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

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. 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

Conclusion

This research analysed the effects of climate change and irrigation expansion scenarios based on current and future development by considering the return flow in operation and other development are insignificant on Arjo Didessa reservoir water evaluation using WEAP model. 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 eight gauging stations. The 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 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.

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.

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 Modelling of the Impact of Climate Change on Sugarcane and Cotton for Project on 'a Climate Resilient Production of Cotton and Sugar in Ethiopia.*Addis Ababa: 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.* Addis Ababa : The Roberts. Strauss centre.

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

Endalkachew, G. (2012). *Climate Change Impact on Surface Water Sources of Addis Ababa case study Legedadi-Dire-Gefersa Catchments and Reservoirs a.* 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 a result of human activity.* Addis ababa: Ethiopia.

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

MOWIE, F. a. (2013).*Developing a water audit for Awash Basin* .Addis Ababa 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 continuous rainfall-runoff models including uncertainty. *Journal of hydrology320*, pp132-154.