Water Allocation System Analysis with Future Development and Climate Change Scenarios in Genale Dawa River Basin, Ethiopia

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ABSTRACT

The ever-increasing population, urbanization, and climate changes increase water demand in all sectors. The current study analyzed the water allocation systems with the effects of future development and climate change in six scenarios. The study used Water Evaluation and Planning System Model (WEAP) as a water allocation tool. Rainfall and temperature data from meteorological stations and biased corrected CORDEX Africa RCM 8.5 climatic data and planned water uses for domestic, livestock, and irrigation sectors were taken as input data. The WEAP model was well calibrated and validated using observed stream flow from four selected river gauging stations. The Nash-Sutcliffe Coefficient (NSE) ranges from 0.69 to 0.94, and the coefficient of determination (R^2) ranges from 0.76 - 0.96 during calibration and validation, confirming the model's performance to mimic the reality in the basin. The basin's water demand and supply delivery were analyzed with climate change, future development, and their combination scenarios in the short-term (2019-2030) and long-term (2031-2050). The current overall water demand of primary water uses (domestic/Industrial, livestock, and irrigation) in the basin was computed as 231 mcm as a reference scenario without any unmet demand. The overall water demand in the basin increases to 263 mcm, 548 mcm, and 556 mcm with 0 %, 2.5 %, and 3.3 % unmet demand for short-term climate change, future development, and combination scenarios, respectively. In the three scenarios, water demand for long-term conditions was also computed as 308 mcm, 567 mcm, and 1046 mcm with 0 %, 5.2 %, and 6.9 % unmet demand, respectively. The analysis further indicated irrigation efficiency improvement up to 70 % will reduce overall water demand to 494 mcm and 801 mcm with 0 % and 1 % unmet for short-term future development and combination scenarios, respectively. Finally, the analysis compared the maximum water demand in the current study (1.05 bcm) with the surface water potential of the basin (8.04 bcm), and it showed that only 13 % of the potential could utilize with the planned future development and climate change effect. Therefore, improving the water use characteristics of the basin with of water storage facilities development is highly recommended.

Key Words: climate change, future development, Water demand, water allocation, Genale-Dawa, Ethiopia

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1. INTRODUCTION

Population growth and urbanization are occurring in the developing world at an ever-increasing rate. These processes increase the demand for water in agriculture, power generation, industry, and urban water supply. Water is not only influenced by human activities but also by natural factors, such as climate change. Climate change affects specific hydrological cycle components, especially precipitation, and temperature, which alters water resources' spatial and temporal availability and demands. It can change flow magnitude, variability, and timing of the flow (Habtom, M., 2009; Kinfe, H., 1999). Climate variations can also affect the use of agricultural land associated with irrigation demand systems (Thornton P. et al., 2009). As water resources within the rural river basins exploit their limits, problems with pollution and resource degradation arise (Aklilu A, and Alebachew A., 2009). Additional limits are imposed on water abstraction to mitigate all the damage to water resources and their environment (Abdullahi, H., 2015). Hence, the impact of climate change and future developments on water resources is the most crucial research agenda worldwide today (IPCC, 2007).

Climate change affects the demand and availability of water for crop production and livestock. In Ethiopia, the Agriculture sector is vulnerable to climate change because of its greater reliance on climate-sensitive rain-fed production systems and the lower resilient capacity of small-scale producers (Thornton et al. 2006). The Genale Dawa Basin is a highland–lowland system with a risk of natural resource degradation, particularly water, and land (Bastian van den Bout, 2015), due to a rapid increase in the demand for water and high climate variability. Since many people in the Genale-Dawa Basin depended vastly on subsistence farming and pastoral livelihood, they faced frequent drought and abruptly declining rainfall. More than 91% of the population in the basin lives in rural areas, where accessibility of basic needs hardly any, and Climate change expects to worse the variability of rainfall and increase in temperature, which leads to frequent drought and flood episode's.

Conversely, the basin has high potential water resources (Berhanu B. et al., 2014). All the above conditions demand water allocation study in the basin that considers climate change and development activities as scenarios. However, no significant works related to such issues in the basin existed. Therefore, the study focuses on different aspects of water allocation that are paramount and contribute to the national efforts on integrated water resources management.

Due to changing water supplies and increased water demands, tools and methods for water allocation have become an important area of study. The water resources allocation is facing significant challenges due to increased variation in water availability caused by climate change and an increasing water demand resulting from future developments in the river basins (Dan. Y, 2017). Therefore, this study assessed the impact of climate change and future development expansion on available water resources (Jin F. et al., 2007) using a decision support system known as the Water Evaluation and Planning (WEAP) Model (Reuben, N., 2007). WEAP is a systematic framework developed for evaluating climate change and other drivers that water managers commonly challenge (Reuben, N., 2007). Indeed, the WEAP model is one of the valuable tools for integrated water resources management. It can use as a database, forecasting, and policy analysis tool (SEI, 2012), depending on the focus of the study. Thus, the WEAP selects to assess the impacts of climate change and the future development of water resources in the Basin (Yates D et al., 2005).

2. MATERIALS AND METHODS

2.1. Description of Study Area

The Genale-Dawa river basin occupies parts of the three Regional States: Oromiya and Somali, and a small section of the Southern Nations, Nationalities, and Peoples' Region (SNNPR). The geographical coordinates are; 3°30' N to 7°20' N; and 37°05' E to 43°20' E;

the total area of the basin is about 172 889 km^2 (Lahmeyer International and Yeshi - Ber Consult, 2006; Tilahun A, 2015).

Genale-Dawa basin is found within the southernmost part of Ethiopia and is characterized by great geographical diversity with high and rugged mountains, flat-topped plateaus, deep gorges, and plains (Figure 1).

The basin can define four relief types: Highlands and plateaus surrounded by ranges of escarpments, volcanoes, steep sloping, gently sloping lowlands adjacent to the foot of the cliffs, and floodplain basins. Mount Tulu Dimtu (4,377m a.s.l) is the highest mountain on the northern side of the basin. The altitude decreases from north to south and west to east to attain an elevation of 176m a.s.l at both Genale and Dawa Rivers junction (Lahmeyer International and Yeshi - Ber Consult, 2006; Tilahun A, 2015).

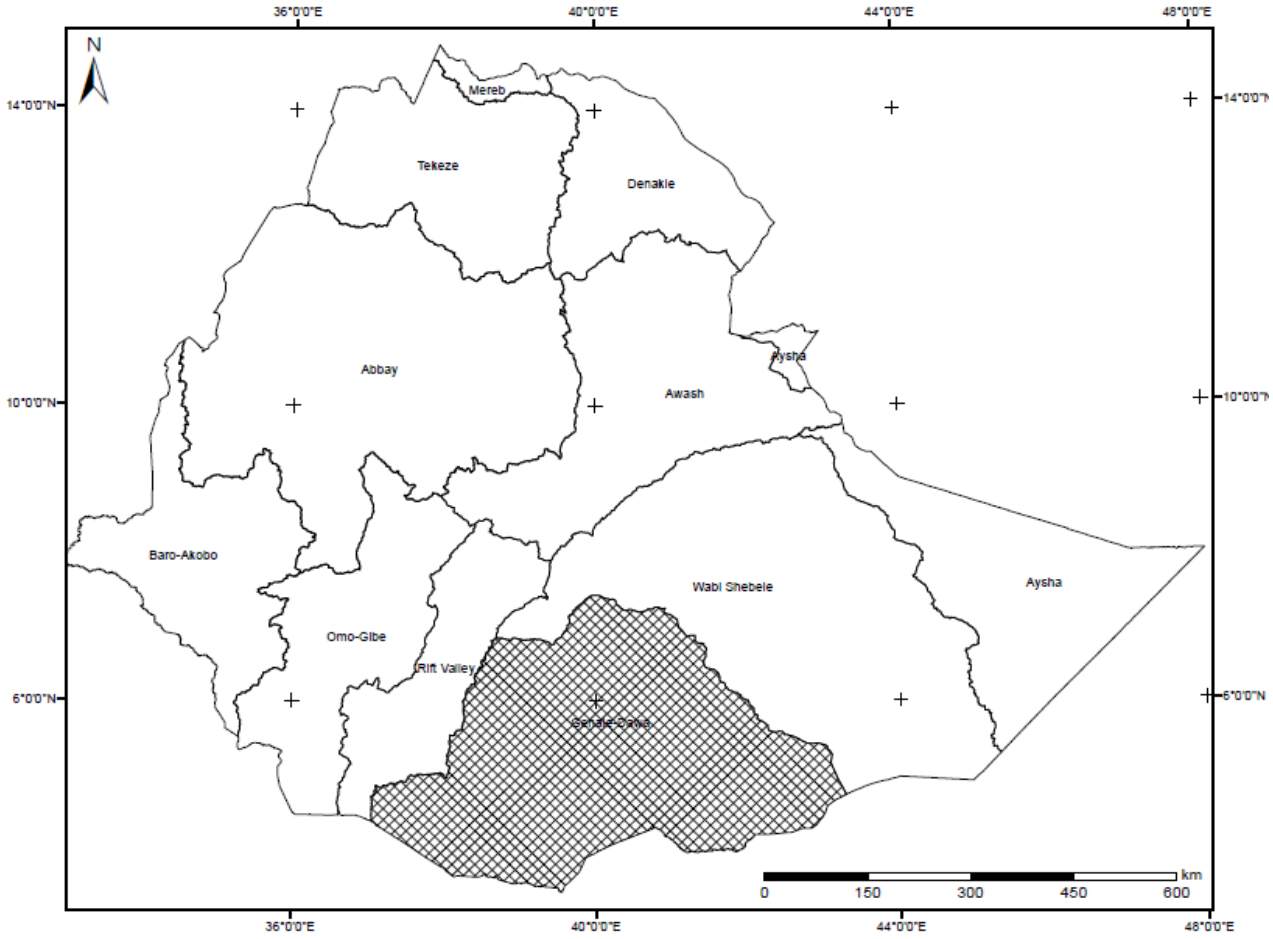


Figure 1: Location of the study area

2.2. Meteorology data

Several meteorological stations have been installed by the National Meteorological Agency (NMA) of Ethiopia (Figure 2). Even though sufficient numbers of meteorological stations have been established throughout the project area, information regarding the detailed climatic conditions of the area is very limited because of malfunctioning gauging stations, recorders not timely measuring the data, etc.,

Rainfall

The easterly and southeasterly weather system produces two rainy seasons in the Genale-Dawa basin. Therefore, the basin receives the first rains during spring (March to May) and second rains during autumn (Oct-Dec) (Lahmeyer-International & Yeshi-Ber Consult, 2006; Tilahun A, 2015). The Thirty-two years (1987-2018) monthly time-series rainfall data for seventeen rain gauge stations (Figure 2) is the primary input for the WEAP hydrological model.

Temperature

The monthly time-series temperature data for seventeen stations is input for the model. The temperature varies considerably in the basin within altitude. The mean annual maximum temperature of the study area ranges from 22.9^{0}C to 35.1^{0}C, while the minimum temperature varies from 6.5^{0}c to 21.8^{0}C.

2.3. Land Use and land cover

The 30m resolution Land use data was accessed from the water and land resources center (WLRC, 2017). Each land covers unit is tremendously influenced by the properties of landforms, soils, and climate (Figure 2).

2.4. Soil map and soil properties

The soils in the study area are the main products of Cambisols, Leptosols, Luvisols, Calcisols, Nitisols, Arenosols, Vertisols, Fluvisols, and Regosols (Figure 2). Many

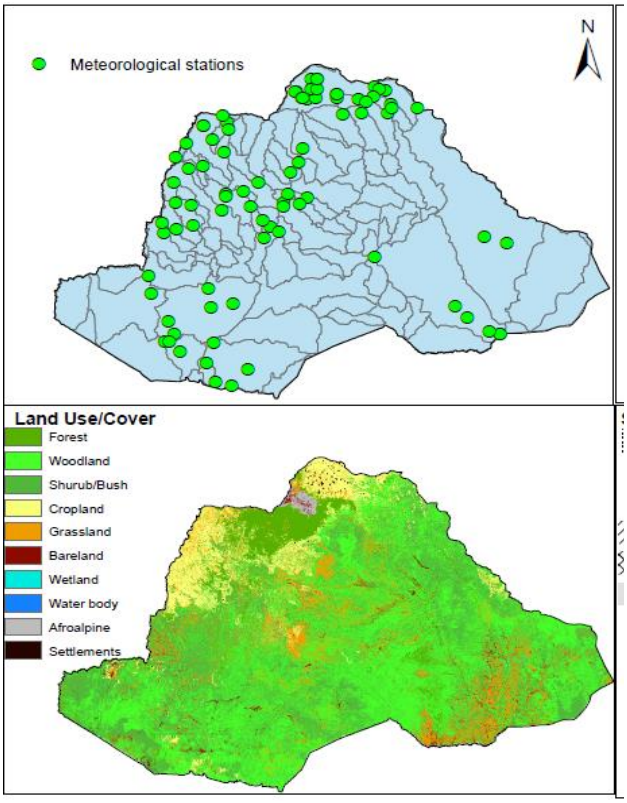


Figure 2: Spatial distributions of input data in Genale dawn Basin

2.6. WEAP model set up

In the schematic part of WEAP, the watershed's boundary did delineate rivers, demand sites, and reservoirs specified. GIS maps of waterways and reservoirs determine the streams' exact location in WEAP (Figure 3). Importantly, these features are stored within the model and local sites of evaporation losses. Demand areas linking the surface water in the study area integrate into thirteen groups for setting up the WEAP model. The model configures at the wereda level; there are around 38 weredas in the basin, considering each wereda. Their population census fed to the model with their corresponding growth rate at a particular year, a recent projection from CSA (2017). The schematics, the irrigation water requirement, and livestock demand compute on the water abstraction sources and the demand sites included in the schematics.

Physicochemical properties for the Genale-Dawa river basin were obtained from the Water Land Resource Center (WLRC, 2015), with a scale of 250m.

2.5. Hydrological data

Hydrological gauging stations are maintained by the Hydrology Department of the Ministry of water and energy (MoWIE), which processes and files data. In the Genale-Dawa River basin, about 21 hydrological gauging stations record the flow in the River, showing the primary spatial distribution of stream flow gauging stations in the basin. Out of all the time-series stream flow data (1990-2008) from four gauging stations; Dawa @Melka Guba, Genale u/s @Chenemesa, Weyib Nr. Bore Dimtu and Genale D/s @Halowey (Figure 2) used for calibration and validation.

2.7. Water Demand Calculation

Average Daily Demand (ADD):- The average daily demand takes with universal water access standard and effort to include domestic, commercial, institutional, and industrial needs. The Average daily demand becomes the base to drive the Maximum daily demand (MDD) to have rooms to accommodate some future changing effects. The Annual Water Use Rate (AWUR) is the major input of WEAP model inputs. It computes based on the specific guidelines from the Ministry of Water, Irrigation, and Energy. Therefore, the Maximum Demand per person per year is 82.1 cubic meters per year.

2.8. Model Calibration and Validation

Calibration is an iterative exercise to establish the most suitable parameter in modeling studies (Reuben, 2007). It is essential to calibrate the model against real-world data.

Therefore, the method includes comparing model results with observed stream flow data obtained from the field, finding places where the model and field differ, assessing the reasons for any inconsistencies, and making the necessary changes to calibrate the model (Walski, T. 1983). Model physical and process parameters changed during calibration. Moreover, after calibration, the results check with statistical measures, including Nash-Sutcliffe Efficiency (NSE) and coefficient of determination (R2). Similarly, the model validates by applying the calibrated model using a different data set without changing the parameter values. Observed and simulated hydrograph values again compared as in the previous calibration procedure. The model's prediction is valid if the resultant fit is acceptable.

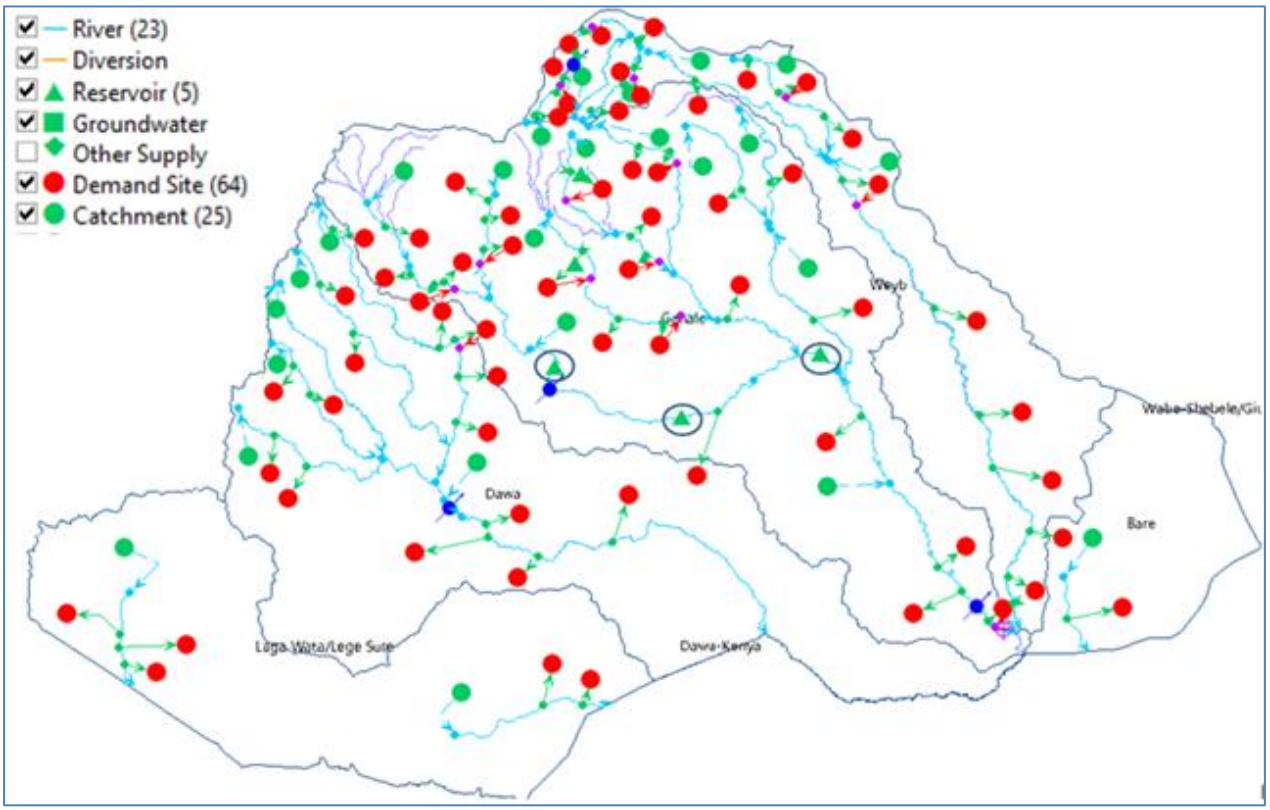


Figure 3: Schematic part of WEAP model for Genale Dawa River Basin

3. RESULTS AND DISCUSSION

3.1. Calibration and validation

The statistical summary for the calibration period (1990- 2000), the Nash-Sutcliffe Coefficient (NSE), ranges from 0.90 to 0.94, and the coefficient of determination (R^2) ranges from 0.92 -0.96 (Table 1), indicating an excellent agreement between modeled and observed flows for each control station. The graphical presentation also describes these evaluations (Figure 4). The same stream flow gauges with different periods were used to validate the stability and accuracy of the model setup and parameter values. Validation worked from 2001-2008, showing comprehensive temporal coverage and model performance major. The statistical summary for the validation period, the Nash-Sutcliffe Coefficient (NSE) ranges from 0.69 to 0.9 (Table 1), and the coefficient of determination (R2) ranges from 0.76- 0.90, indicating a perfect agreement between modeled and observed flows with the different time (Figure 5).

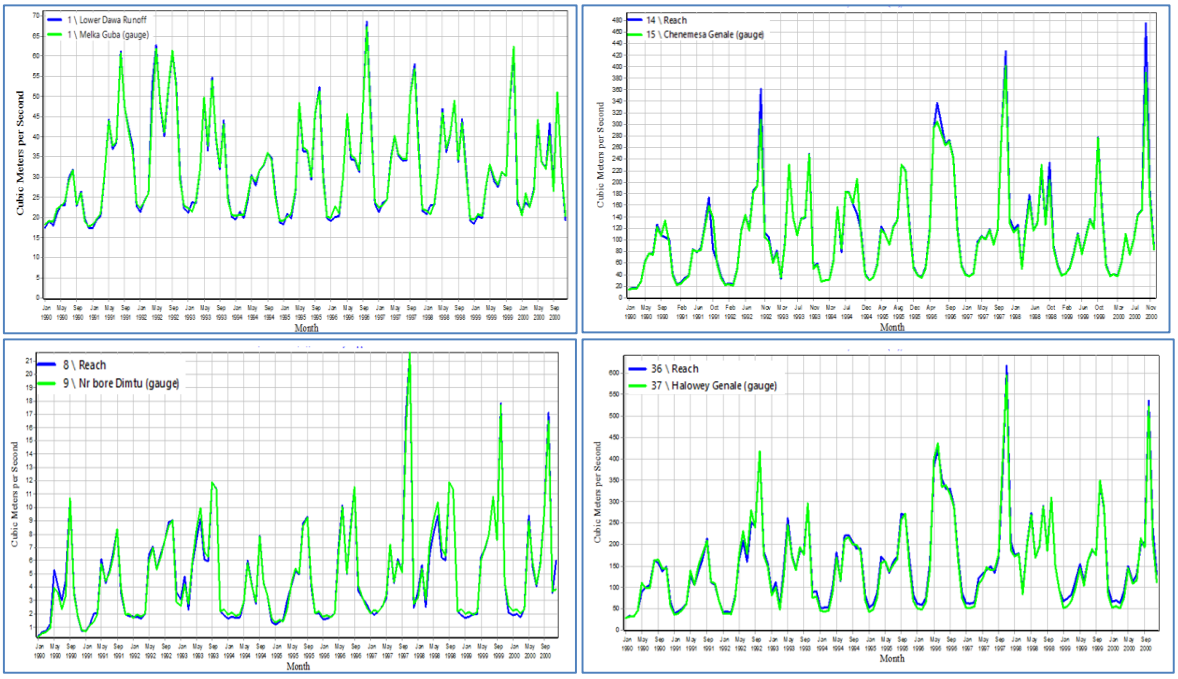


Figure 4: Model performance measure graphical representation during calibration

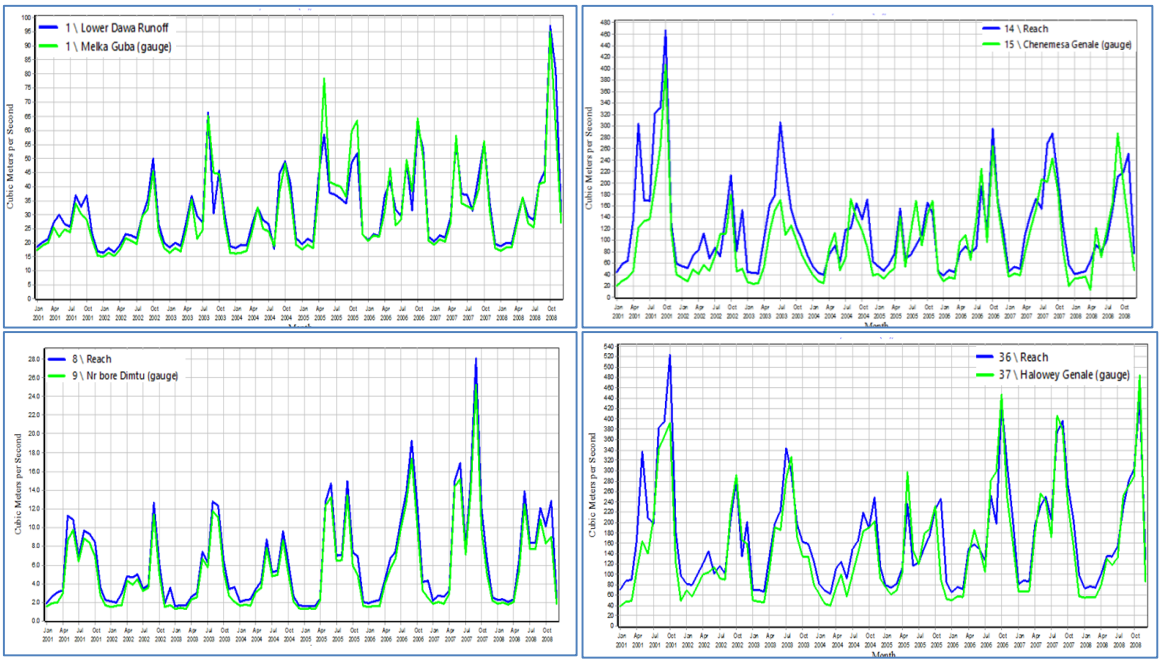


Figure 5: Model performance measures graphical representation during validation

***Table1**: Statistical summaries of the performance measure of simulated stream flow*

No.	Gauged River	Gauge Station Name	Calibration (1990 – 2000)		validation (2001 – 2008)	
			NSE	R2	NSE	R2
1	Dawa	Melka Guba	0.90	0.98	0.81	0.95
2	Genale u/s	Chenemesa	0.94	0.97	0.69	0.87
4	Upper Weyib	Nr.Bore Dimtu	0.94	0.96	0.90	0.92
3	Genale D/s	Halowey	0.90	0.98	0.88	0.94

3.2. Scenario Analysis

The study developed three scenarios based on various economic, demographic, hydrological, and technological changes to set one or more policy alternatives for future development. Each of the three plans will have analyzed in two terms: short-term, which runs from 2019-2030, for future, 2031-2050.

- Scenario 1: Future Development scenario
- Scenario 2: Climate Change Scenario
- Scenario 3: Combination Scenario

3.2.1. Reference Scenario /baseline/

The reference scenario considers the current hydrological and demand conditions of the basin. The reference model for the past 28 years (1990-2018) evaluates the basin's current hydrological system and serves as the current supply delivery. Similarly, the current year (2018), human and livestock population, and irrigated land coverage in recent years were the base to compute the water demand. The priority assigned to domestic and livestock needs and irrigation purposes. Finally, the model simulated the total current water use in the basin as 230.67 mcm/yr without any unmet demand (Table 2).

3.2.2. Scenario I: Development Scenario

The development scenario simulation concerns the country's development plan into two-time scales: short-term plan (2019 -2030) and long-term plan (2030 -2050). The future scenarios describe possible developments in line with the new Water Resources Management Strategy. The strategy targets to develop the full irrigation potential of the basin while considering the ever-increasing number of human and animal resources.

Short-term (2019 - 2030)

In this scenario, the future development for 2030 was analyzed. Accordingly, the irrigated land expects to increase by 15311ha, with the basin's human and livestock populations of the basin 6.85million and 6.3 million, respectively, in the year 2030. The domestic, livestock and irrigation water requirements were computed as 150 mcm, 104 mcm, and 294mcm, respectively. Bain total water requirement in short-term development is 548 mcm. However, supply delivery covered a total of 541 mcm, which led to 2.5% unmet demand (Table 3). Since the unmet demand is manageable with irrigation efficiency only, the development scenario considers different irrigation efficiency to support the short-term development plan with policy direction.

The irrigation demands of all the sites in the short-term scenario, 294 mcm, were computed with an irrigation efficiency of 45%, considering the average irrigation efficiency of furrow irrigation in Ethiopia. If irrigation efficiency increases by 10%, the irrigation water demand is reduced to 241mcm, and the supply delivered is 237mcm, which reduces the overall unmet demand to 1.3%. Further, if the irrigation efficiency improved to 70%, the irrigation water demand will reduce to 189mcm and avoid any unmet demand on the system (Table 3). Although the hydropower sector does not consume significant water except for the evaporation of the reservoir, the completion and operation of one of the three proposed dams also consider in this short-term development scenario, and 1600GwHr/yr energy produced with 90% water demand coverage in the reservoir.

Long-term Scenario I (2031 - 2050)

In this scenario, the planned activities for 2031-2050 were consider and analyzed. The national plan covered 25711 ha of irrigated land in the basin, and the projection of human and livestock population indicates 11.2 million and 7.8 million, respectively. In this scenario, annual water demand were computed as 245 mcm, 128 mcm, and 494 mcm for domestic, livestock, and irrigation water use and a total of 747 mcm (Table 4); however, with current water management, the supply delivery system did not cover all water demand and indicated about 5.2 % unmet demand. Even though irrigation efficiency increased to 70 %, the unmet demand is never avoid. It needs additional development strategies, like water storage facilities. The simulation with the master plan proposed three multipurpose reservoirs (GD-3, GD-5, and GD-6) covering all unmet demands for planned development. It clearly shows the need for water storage systems.

***Table 2**: Current water demand for the three major sectors in the Genale-Dawa basin*

Period	Total Population (Million)	Total Irrigated land (Hectare)	Water Requirements (MCM/Year)
Domestic	5.11		83.93
Livestock water Demand	5.6		61.32
Irrigation Water Demand		4,271	85.42
		Total	230.67

***Table 3:** Water demand, supply delivery, and unmet in Short-term and long-term Scenarios*

	Water Demand (mmc)		Supply Delivered (mmc)		Unmet (%)	
	Short	Long	short	Long	short	Long
Domestic	150.0	245.3	150.0	245.3	0.0	0.0
Livestock	103.5	128.1	103.5	128.1	0.0	0.0
Irrigation with efficiency (η=45%)	294.1	493.9	287.0	468.4	2.4	5.2
Irrigation with efficiency (η=55%)	240.6	404.1	237.4	387.4	1.3	4.1
Irrigation with efficiency (η=70%)	189.1	317.5	189.0	308.5	0.0	2.8

3.2.3. Scenario II Climate change scenario:

Bias-corrected CORDEX Africa RCM 8.5 climatic data used to analyze basin climate-change scenarios. Overall, the long-term average surface temperature was observed in the basin and increase. The basin temperature increased from 21.63^{0}C (baseline value) in 1980-2014 to 24.66^{0}C in 2019-2030 and to 25.32^{0}C from 2030-2050. Of course, basin rainfall showed fluctuating pattern without a defined change trend throughout the analysis period. In this scenario, the impacts of climate changes on the basin water allocation consider.

The climate change scenarios simulate the change of rainfall and temperature input data with the baseline demand units. Of course, their water demands changed since their water use rate changed with climate change in all sectors. Accordingly, the total water demand in the basin increased from 231 mcm (baseline) to 263 mcm (2019-2030) and 308 mcm (Table 5). However, basin water supply systems deliver it without any unmet demand.

***Table 5**: Future water demand for the three major sectors with climate Change Scenario*

Period	Population (Million)	Irrigated land (Hectare)	Water Demand (2019-2030) (mcm/yr)	Water Demand (2031-2050) (mcm/yr)
Domestic	5.11		95.69	112.01
Livestock water Demand	5.6		69.91	81.84
Irrigation Water Demand		4,271	97.39	114.00
		Total	262.99	307.85

3.2.4. Scenario III Combination Scenario

This scenario considered the combined effects of climate change and future development. The two periods of future climate change and future growth are also analyzed separately.

Scenario III Short-term (2019-2030)

Based on the simulation results, the total water demand for the basin in the short term was 556 mcm. However, the supply delivery covered a total of 544mcm, which led to 3.3 % unmet demand with 45 % irrigation efficiency. If irrigation efficiency increases by 10%, the irrigation water demand reduces to 286 mcm, and the supply delivered provide 279 mcm, which reduces the overall unmet demand to 2.3 %. Further, if the irrigation efficiency improves to 70 %, the irrigation water demand

would reduce to 224 mcm with only one percent-unmet demand (Table 6).

Scenario III Long-term (2031-2050)

In this scenario, the total basin water demand is 1056 mcm, with 686 mcm irrigation water with 45 % irrigation efficiency. However, supply delivery covered 639 mcm of irrigation water, which led to 6.9 % unmet demand. If the irrigation efficiency increases by 10 %, the irrigation water demand reduced to 562 mcm, and the supply delivered provided 529mcm, which reduced the overall unmet demand to 5.8 %. Further, if the irrigation efficiency improves to 70%, the irrigation water demand would be reduced to 441mcm and unmet demands of 4.6% (Table 6). Although the combined result of future development and climate change increased the basin's overall water demand, it never exceeded its surface water potential of 8.04bcm (Lahmeyer International and Yeshi -Ber Consult, 2006). If we compare this combined scenario with the previous single scenarios, the merging effect increases the percentage of unmet demand. The unmet portion in the current analysis and the gap between the potential resources and the current analysis demand clearly shows the seasonal variability of the resource's availability and water demand. Most of the water is available in the basin's rainy season, but the water is required in the dry season for irrigated agriculture. Therefore, the developments of water storage systems become essential to satisfy the basin's water demand.

***Table 6**: Water demand, supply delivery, and unmet in short-term and Long-term Scenario III*

	Water Demand (mmc)		Supply Delivered (mmc)		Unmet (%)	
	Short	Long	short	Long	short	Long
Domestic	128.27	245.50	128.27	245.50	0.0	0.0
Livestock	78.65	113.99	78.65	113.99	0.0	0.0
Irrigation with efficiency (η=45%)	349.12	686.27	337.44	639.11	3.3	6.9
Irrigation with efficiency (η=55%)	285.64	561.49	279.15	528.71	2.3	5.8
Irrigation with efficiency (η=70%)	224.43	441.17	222.26	420.96	1.0	4.6

4. CONCLUSION

This study used the WEAP model setup to explore the effects of multiple scenarios. The model examined the impact of future growth and climate change on water availability and supply delivered, which depends on the water released from river connections in the basin and observed meteorological. CORDEX Africa RCM 8.5 uses as the source of historical and future climatic data input, respectively. The WEAP model calibrates and validates using observed streamflow data from four selected gauge stations. The overall statistical measure confirmed the model's performance with the Nash-Sutcliffe Coefficient (NSE) range from 0.90 to 0.94, and the coefficient of determination (R^2) ranges from 0.92-0.96 during calibration. Likewise, Nash-Sutcliffe Coefficient (NSE) ranges from 0.69 to 0.9, and the coefficient of determination (R^2) ranges from 0.76 - 0.90 for the validation period. Once the model performance confirms, the water allocation for the basin analyzes with multiple scenarios. The current water demands of all sectors and the historical hydrological system served as the baseline scenario. Without any unmet demand, it gave a total water demand of 231 mcm/yr for the three major water use sectors. The simulation of the two future development scenarios, short-term (2019-2030) and long-term (2031-2050), gave a total water demand of the three sectors of 548 mcm and 567 mcm with 2.4 % and 5.2 % unmet demand, respectively. However, the unmet demand in these scenarios does possibly manage with irrigation efficiency improvement. Although the two periods (2030 and 2050) climate-change scenarios increased the overall basin water demand to 263 mcm and 308 mcm, respectively, the system showed no unmet demand.

The analysis further considered the combined effect of future development and climate changes with two-time periods as like hood scenarios. With these scenarios, the overall water demand increased to 556 mcm and 1046 mcm with 3.3 % and 6.9 % unmet demand for short-term and long-term, respectively. Of course, the technological improvements, which improve the overall irrigation efficiency of the basin to 70 %, will reduce these unmet demands to 1 % and 4.6% for short-term and long-term conditions, respectively.

Finally, the current research compares the maximum water demand (1.05 bcm) with the surface water potential of the basin (8.04 bcm). It demonstrated that only 13 % of the potential resources could utilize under future development and climate change effect. However, the current hydrological systems of the basin did not fully cover the analyzed demands since there is a seasonal variation between the supply and demand. Therefore, it is highly recommended to have water storage facilities to utilize the potential surface water resources of the basin.

5. REFERENCES

Abdullahi, H. (2015): Modeling Water Resource System for Effective Water Allocation of Juba Basin in Southern Somalia, Mekelle University Institute of Water and Environment

Aklilu A, Alebachew A. (2009): Assessment of climate change-induced hazards impacts responses in the southern lowlands of Ethiopia. Forum for Social Studies, Addis Ababa, Ethiopia

Bastian van den Bout (2015): The influence of land use change on soil erosion in the Genale catchment, Southern Ethiopia, MSc Thesis on Earth Surface and Water, Faculty of Geoscience, Department of Physical Geography Utrecht University

Berhanu B.,Seleshi Y. and Melesse A. M. (2014): Surface Water and Groundwater Resources of Ethiopia: Potentials and Challenges of Water Resources Development, In: Melesse A, Abtew W, Setegn S. (eds)Nile River Basin, Springer, Cham, DOI 10.1007/978-3-319-02720-3_6

CSA (2017): Central Statistical Agency projection, Addis Ababa, Ethiopia

Dan. Y (2017) Water Allocation under Future Climate Change and Socio-Economic Development: Case of Pearl River Basin

Habtom, M. (2009): Evaluation of Climate Change Impact on Upper Blue Nile Basin Reservoir, AMU

IPCC (2007): Contribution of WG-II, Fourth Assessment Report of IPCC

Jin F. Wang & Guo D. Cheng & Yi G. Gao & Ai H. Long & Zhong M. Xu & Xin Li & Hongyan Chen & Tom Barker (2007): Optimal Water Resource Allocation in Arid and Semi-Arid Areas Johannesburg Journal of Water Resources Planning and Management

Kinfe, H.(1999): Impact of climate change on water resource of Awash basin, Clim Res, V.12:91-96,

Lahmeyer Intern.& Yeshi-Ber Consult, (2006): Genale-Dawa River Basin Integrated Resources Development master, Plan Study, Phase 2 report, Ministry of Water Resources, Ethiopia

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

SEI (Stockholm Environment Institute) (2012): WEAP (Water Evaluation and Planning System): Gridline and Tutorial of the WEAP model

Thornton, P., Jones, P. Alagarswamy, G. & Andersen, J. (2009): Spatial variation of crop yield response to climate change in East Africa, Global Environmental Change, 19: 54-65

Tilahun A (2015): Assessing Surface Water Potential and Demand in Genale Dawa River Basin Addis Ababa Institute of Technology, Ethiopia

WLRC (Water and Land Resource Centre) (2015): Resource Availability Assessment Methodology for Land and Water Related Interventions in the WabiShebele and Genale-Dawa Basins, Volume I: Synthesis Report, WP1, Addis Ababa Ethiopia

Yates D, Sieber J, Purkey D, Huber-Lee A, Galbraith H (2005): WEAP21: a demand, priority, and preference driven water planning model: part 2, aiding freshwater ecosystem service evaluation

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